Status Review Report:

Alewife (*Alosa pseudoharengus*)

and Blueback Herring (*Alosa aestivalis*)

2019

National Marine Fisheries Service

National Oceanic and Atmospheric Administration

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Executive Summary

On August 5, 2011, the Natural Resources Defense Council (NRDC) petitioned NMFS to list alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) under the Endangered Species Act (ESA) as threatened throughout all or a significant portion of their ranges. In the alternative, the petitioner requested that NMFS designate Distinct Population Segments (DPSs) of alewife and blueback herring as specified in the petition (Central New England, Long Island Sound, Chesapeake Bay, and Carolina for alewives and Central New England, Long Island Sound, and Chesapeake Bay for blueback herring). Under the ESA, if a petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. 1533(b)(3)(A)). In response to the petition, NMFS published a positive 90-day finding on November 2, 2011, concluding that listing these species under the ESA may be warranted and initiated a status review (76 FR 67652).

On August 12, 2013, NMFS determined that listing alewife and blueback herring as threatened or endangered under the Endangered Species Act (ESA) (16 U.S.C. 1531 *et seq.*) was not warranted (78 FR 48943). However, NMFS also noted that there were significant data deficiencies and committed to revisiting the status of both species in 3 to 5 years, a period after which ongoing scientific studies, including a river herring stock assessment update by the Atlantic States Marine Fisheries Commission (ASMFC), would be completed.

The Natural Resources Defense Council and Earthjustice (the Plaintiffs) filed suit against NMFS on February 10, 2015, in the U.S. District Court in Washington, D.C, challenging the decision not to list blueback herring as threatened or endangered. The Plaintiffs also challenged the determination that the Mid-Atlantic stock complex of blueback herring is not a distinct population segment (DPS). On March 25, 2017, the court vacated the blueback herring listing determination and remanded the listing determination to NMFS (*Natural Resources Defense Council, Inc., et al.* v. *Samuel D. Rauch, National Marine Fisheries Services, 1:15-cv-00198 (D.D.C)).* As part of a negotiated agreement with the Plaintiffs, NMFS committed to publish a revised listing determination for blueback herring.

NMFS announced the initiation of an alewife and blueback herring status review in the Federal Register on August 15, 2017 (82 FR 38672, August 15, 2017). At that time, NMFS also opened a 60-day solicitation period for new scientific and commercial data on alewife and blueback herring to ensure that the status review was informed by the best available scientific and commercial information. A status review team (SRT) was tasked to conduct this review.

To conduct this Status Review, the SRT considered a variety of scientific information from the literature, unpublished documents, and direct communications with researchers working on alewife and blueback herring, as well as technical information submitted in the petition and by the petitioners and others in response to the 90 day finding and 60- day solicitation for new scientific and commercial data. The SRT compiled the best available information on the species and conducted a qualitative risk assessment through evaluation of the demographic risks, threats, and overall extinction risk facing the species or distinct population segment (DPS).

Based on a review of the best available information, the SRT identified the following four distinct population segments of alewife:

- Aw-Canada DPS the range includes Garnish River, Newfoundland to Saint John River, New Brunswick;
- Aw-Northern New England DPS- the range includes St. Croix River, ME to Merrimack River, NH;
- Aw-Southern New England DPS- the range includes Parker River, MA to Carll's River, NY; and
- Aw-Mid Atlantic DPS- the range includes Hudson River, NY to Alligator River, NC.

The SRT identified the following three distinct population segments of blueback herring:

- Bb-Canada- Northern New England DPS- the range includes Margaree River, Nova Scotia to Kennebec River, ME;
- Bb-Mid Atlantic DPS- the range includes Connecticut River, CT to Neuse River, NC; and
- Bb-Southern Atlantic DPS- the range includes Cape Fear River, NC.

Guided by the results from the demographics risk analysis as well as threats assessment, the SRT members used their informed professional judgment to make an overall extinction risk determination for each species, now and in the foreseeable future. The SRT used a "likelihood analysis" to evaluate the overall risk of extinction. Each SRT member had 10 likelihood points to distribute among the following overall extinction risk categories: *low* risk, *moderate* risk, or *high* risk (see section 6.1.4 Overall Level of Extinction Risk Analysis).

Alewife

The mean scores based on the SRT members' individual scores indicate that the level of extinction risk to the alewife rangewide is *low*, with 75 percent of the SRT members' likelihood points allocated to the *low* risk category. The SRT allocated 22 percent of their likelihood points to the *moderate* extinction risk category. The SRT allocated 3 percent of their likelihood points to the *high* extinction risk category. SRT members attributed the *high* extinction risk points to concerns associated with the species' complex anadromous fish life history, uncertainty in climate change and vulnerability, incidental catch, potential habitat modification (e.g. increased coastal development and water use), and concern about the adequacy of current and future regulatory mechanisms, including fisheries rangewide.

Overall the SRT acknowledged that alewife are at historical low levels, but noted that improved fisheries management efforts in recent years have reduced fishing mortality rates in alewife stocks and that hundreds of habitat improvement projects have been completed in the past 20 years. Many relatively robust populations of alewife exist, and genetic data show connectivity among populations (genetic continuum along the coastline) despite regional groupings.

SRT members also applied the same likelihood point method to each alewife DPS. The mean overall risk scores for alewife in the Aw-Canada DPS correspond to a 77 percent likelihood of a *low* risk and 23 percent *moderate* risk of extinction. The mean overall risk scores for alewife in the Aw-Northern New England DPS correspond to a 74 percent likelihood of a *low* risk and 26 percent *moderate* risk of extinction. The mean overall risk scores for alewife in the Aw-Southern New England DPS correspond to a 69 percent likelihood of a *low* risk and 31 percent *moderate* risk of extinction. The mean overall risk scores for alewife in the Aw-Mid-Atlantic DPS correspond to a 70 percent likelihood of a *low* risk and 30 percent *moderate* risk of extinction.

Blueback Herring

For blueback herring rangewide, SRT members indicated that there was a 66 percent *low* risk of extinction, a 30 percent *moderate* risk of extinction, and a 4 percent *high* risk of extinction. SRT members attributed the *high* extinction points to concerns associated with the complex anadromous fish life history, uncertainty in climate change and vulnerability, incidental catch, potential habitat modification (e.g. increased coastal development and water use), and concern about the adequacy of current and future regulatory mechanisms, including fisheries rangewide.

The SRT noted blueback herring have been subjected to habitat impacts for centuries and to considerable fishing pressure for many decades. The SRT also acknowledged that blueback herring are at historically low levels, but noted that improved fisheries management efforts in recent years have reduced fishing mortality rates for blueback herring stocks and that hundreds of habitat improvement projects have been completed in the past 20 years. While over one third of the SRT’s allocation points were in the *moderate/high* categories, indicating that blueback herring are at a greater risk of extinction compared to alewives due to lower overall abundances, increased vulnerability to anthropogenic disturbances in combination with climate change, greater distances between populations, poorer performance at fishways, and uncertainties surrounding accurate distribution information rangewide, a majority of the points were still allocated to the *low* risk category based on resilient life history traits and current abundance information.

SRT members also applied the same likelihood point method to each blueback herring DPS. The mean overall risk scores for blueback herring in the Bb-Canada/Northern New England DPS correspond to a 67 percent *low* risk of extinction, a 30 percent *moderate* risk of extinction, and a 3 percent *high* risk of extinction. The mean overall risk scores for blueback herring in the Bb-Mid-Atlantic DPS correspond to a 69 percent *low* risk of extinction, a 30 percent *moderate* risk of extinction, and a 1 percent *high* risk of extinction. The mean overall risk scores for blueback herring in the Bb-Southern Atlantic DPS correspond to a 69 percent *low* risk of extinction, a 30 percent *moderate* risk of extinction, and a 1 percent *high* risk of extinction.

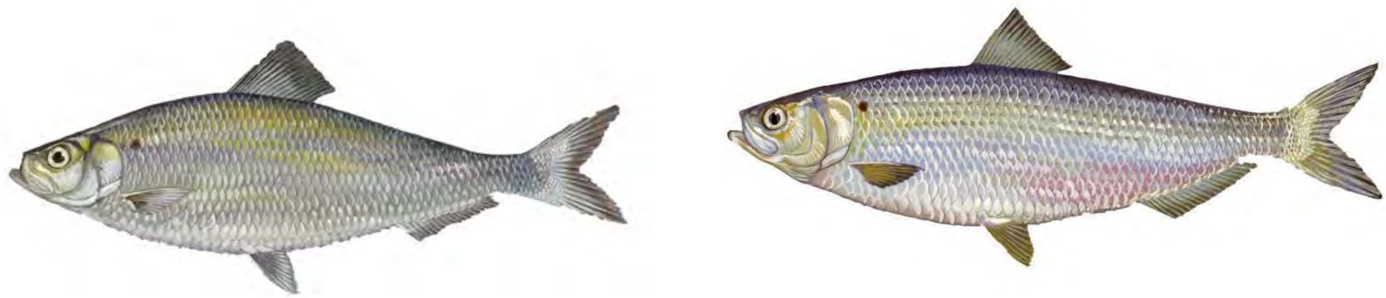
Finally, the SRT members considered questions related to a Significant Portion of Its Range (SPR) analyses. After a review of the best available information, the SRT did not find any portion of alewife or blueback herring ranges that met the criteria for Significant Portion of Its Range according to NMFS policy.

TABLE OF CONTENTS

Table of Tables

Table of Figures

STATUS REVIEW OF THE ALEWIFE (Alosa pseudoharengus) AND BLUEBACK HERRING (Alosa aestivalis)



Alewife (left) and blueback herring (right) images courtesy U.S. Fish and Wildlife Service

Greater Atlantic Regional Fisheries Office

National Marine Fisheries Service

National Oceanic and Atmospheric Administration

Gloucester, MA

1 Introduction

1.1 Scope and Intent of this Document

On August 5, 2011, the Natural Resources Defense Council (NRDC) petitioned NMFS to list alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) under the Endangered Species Act (ESA) as threatened throughout all or a significant portion of their ranges. In the alternative, the petitioner requested that NMFS designate Distinct Population Segments (DPSs) of alewife and blueback herring (collectively, "river herring") as specified in the petition (Central New England, Long Island Sound, Chesapeake Bay, and Carolina for alewives and Central New England, Long Island Sound, and Chesapeake Bay for blueback herring). Under the ESA, if a petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. 1533(b)(3)(A)). In response to the petition, NMFS published a positive 90-day finding on November 2, 2011, concluding that listing these species under the ESA may be warranted and initiated a status review (76 FR 67652).

On August 12, 2013, the National Marine Fisheries Service (NMFS), determined that listing alewife and blueback herring as threatened or endangered under the ESA was not warranted (78 FR 48943). At that time, NMFS committed to revisiting the status of both species in three to five years. Three to five years equates to approximately one generation time for each species and allowed for time to complete ongoing scientific studies.

The NRDC and Earthjustice filed suit against NMFS on February 10, 2015, challenging NMFS' decision not to list blueback herring as threatened or endangered. On March 25, 2017, the presiding judge issued a finding vacating the blueback herring listing determination and remanded the listing determination back to NMFS. As part of a negotiated agreement with NRDC et al., NMFS committed to publishing a revised listing determination for blueback herring by January 31, 2019. On August 15, 2017, NMFS published a notice initiating a status review for alewife and blueback herring (82 FR 38672).

This report comprehensively reviews the best available scientific information on the status of alewife and blueback herring, evaluates the factors contributing to the species' status, assesses whether either species consists of DPSs, and includes an assessment of the species' risk of extinction. This provides the information necessary for NMFS to make a determination whether the listing of these species (or its DPSs) under the ESA is warranted.

1.2 Summary of the Alewife and Blueback Herring Listing Petitions

On August 5, 2011, NMFS received a petition from the NRDC, requesting that NMFS list alewife and blueback herring under the ESA as threatened throughout all or a significant portion of their ranges. In the alternative, the petitioner requested that NMFS designate Distinct Population Segments (DPSs) of alewife and blueback herring as specified in the petition (Central New England, Long Island Sound, Chesapeake Bay, and Carolina for alewives and Central New England, Long Island Sound, and Chesapeake Bay for blueback herring). The petitioners described these groupings as behaviorally and physiologically discrete due to affiliations with and differentiation between natal rivers and ecological settings of where they spawn. These petitioners described these groups as significant based on the four unique ecological settings where they are found. The petition contained information on the two species, including the taxonomy, historical and current distribution, physical and biological characteristics of their habitat and ecosystem relationships, population status and trends, and factors contributing to the species' decline. The following five factors identified in section 4(a)(1) of the ESA were addressed in the petition: (1) present or threatened destruction, modification, or curtailment of habitat or range; (2) over-utilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; and (5) other natural or man-made factors affecting the species' continued existence.

2 LIFE HISTORY AND ECOLOGY

2.1 Taxonomy and Distinctive Characteristics

In determining whether to list a species, the first issue is whether the petitioned subject is a valid species. The petitioned subject, alewife (*Alosa pseudoharengus*, Mitchill 1814) and blueback herring (*Alosa aestivalis*, Wilson 1811), are valid species for listing. The species description history and synonyms are provided by Eschmeyer (2017). The taxonomic breakdown of *A. pseudoharengus* and *A. aestivalis*, respectively, is as follows:

Kingdom: Animalia

Phylum: Chordata

Class: Actinopterygii

Subclass: Teleostei

Order: Clupeiformes

Family: Clupeidae

Genus: *Alosa*

Species: *pseudoharengus*

Kingdom: Animalia

Phylum: Chordata

Class: Actinopterygii

Subclass: Teleostei

Order: Clupeiformes

Family: Clupeidae

Genus: *Alosa*

Species: *aestivalis*

2.2 Landlocked Populations

Landlocked populations of alewives and blueback herring also exist. Landlocked alewife populations occur in many freshwater lakes and ponds from Canada to North Carolina as well as the Great Lakes (Rothschild 1966, Boaze and Lackey 1974). Many landlocked alewife populations occur as a result of stocking to provide a forage base for game fish species (Palkovacs et al. 2007).

Landlocked blueback herring occur mostly in the southeastern United States and the Hudson River drainage. The occurrence of landlocked blueback herring is primarily believed to be the result of accidental stockings in reservoirs (Prince and Barwick 1981), unsanctioned stocking by recreational anglers to provide forage for game fish, and through the construction of locks, dams and canal systems that have subsequently allowed for blueback herring occupation of several lakes and ponds along the Hudson River drainage up to, and including, Lake Ontario (Limburg et al. 2001).

Recent efforts to assess the evolutionary origins of landlocked alewives indicate that they rapidly diverged from their anadromous cousins between 300 and 5,000 years ago and now represent a discrete life history variant of the species, Alosa pseudoharengus (Palkovacs et al. 2007). Given their relatively recent divergence from anadromous populations, one plausible explanation for the existence of landlocked populations may be the construction of dams by either Native Americans or early colonial settlers that precluded the downstream migration of juvenile herring (Palkovacs et al. 2007). Some landlocked populations of blueback herring do occur in the Mid-Atlantic and southeastern United States. Given the similarity in life histories between anadromous alewife and blueback herring, we assume that landlocked populations of blueback herring would exhibit a similar divergence from anadromous blueback herring, as has been documented with alewives (noted above).

Since their divergence, landlocked alewives evolved to possess significantly different mouthparts than their anadromous cousins, including narrower gapes and smaller gill raker spacings to take advantage of year round availability of smaller prey in freshwater lakes and ponds (Palkovacs et al. 2007). Furthermore, the landlocked alewife, compared to its anadromous cousin, matures earlier, has a smaller adult body size, and reduced fecundity (Palkovacs et al. 2007). At this time, there is no substantive information documenting that landlocked populations have reverted back to an anadromous life history, though there is anecdotal evidence of this in Atlantic salmon.

The discrete life history and morphological differences between the two life history variants (anadromous and landlocked) provide substantial evidence that upon evolving to landlocked, landlocked populations become largely independent and separate from anadromous populations and occupy largely separate ecological niches (Palkovacs and Post 2008). There is the possibility that landlocked alewife and blueback herring may have the opportunity to mix with anadromous river herring during high discharge years and through dam removals that could provide passage over dams and access to historic spawning habitats restored for anadromous populations, where it did not previously exist.

A Memorandum of Understanding (MOU) between the U.S. Fish and Wildlife Service (USFWS) and NMFS (collectively, the Services) regarding jurisdictional responsibilities and listing procedures under the ESA was signed August 28, 1974. This MOU states that NMFS shall have jurisdiction over species ‘‘which either (1) reside the major portion of their lifetimes in marine waters; or (2) are species which spend part of their lifetimes in estuarine waters, if the major portion of the remaining time (the time which is not spent in estuarine waters) is spent in marine waters.'' Given that landlocked populations of river herring remain in freshwater throughout their life history and are genetically divergent from the anadromous species, pursuant to the aforementioned MOU, NMFS did not include the landlocked populations of alewife and blueback herring in the review of the status of the species.

2.3 Range and Habitat Use Including Diet

Collectively, blueback herring and alewives are known as river herring. River herring are found along the Atlantic coast of North America, from the southern Gulf of St. Lawrence, Canada to the southeastern United States (Mullen et al. 1986, Schultz et al. 2009, Figure 1 and Figure 2). The coastal ranges of the two species overlap. Blueback herring range from Nova Scotia south to the St. Johns River, Florida (Figure 1), and alewife range from Labrador and Newfoundland south to North Carolina (Figure 2), though their occurrence in the extreme southern range is less common (Collette and Klein-MacPhee 2002, ASMFC 2009a). In Canada, river herring (often referred to as gaspereau) have been monitored at varying frequencies in the St. Croix, St. John, Gaspereau, Tusket, Margaree and Miramichi River (J. Gibson, pers. comm) and are reportedly most abundant in the Miramichi, Margaree, LaHave, Tusket, Shubenacadie and Saint John Rivers (DFO 2001). They are proportionally less abundant in smaller coastal rivers and streams (DFO 2001). Generally, blueback herring in Canada occur in fewer rivers than alewives and are less abundant in rivers where both species coexist (DFO 2001).

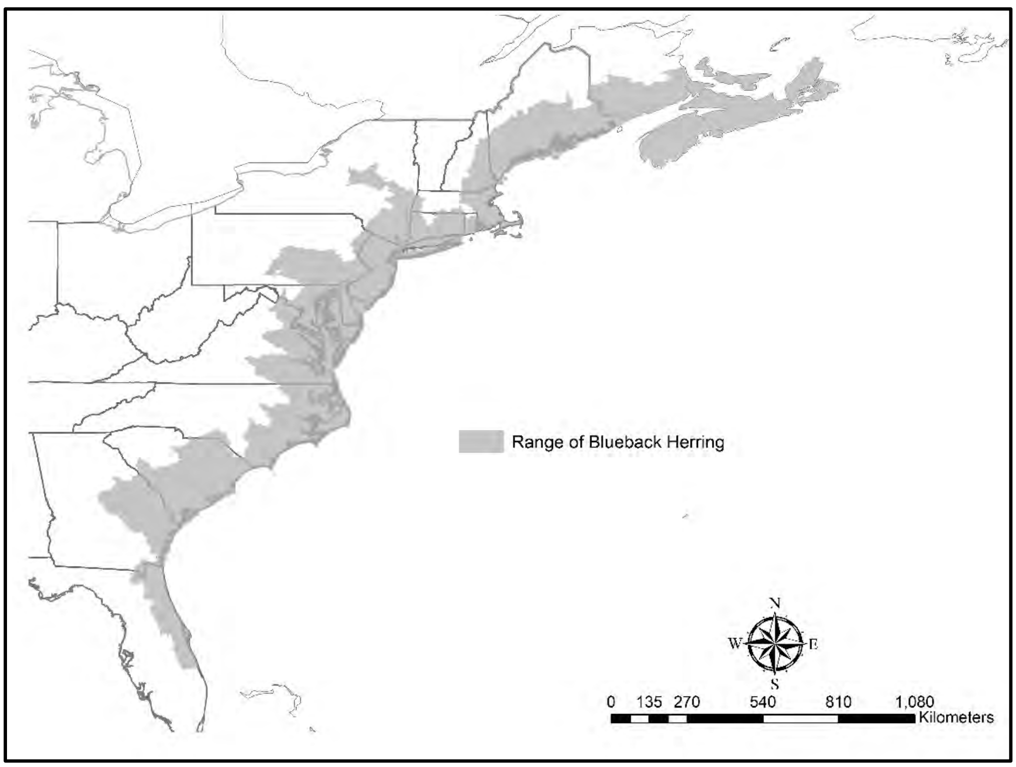


Figure 1. Map of blueback herring range.

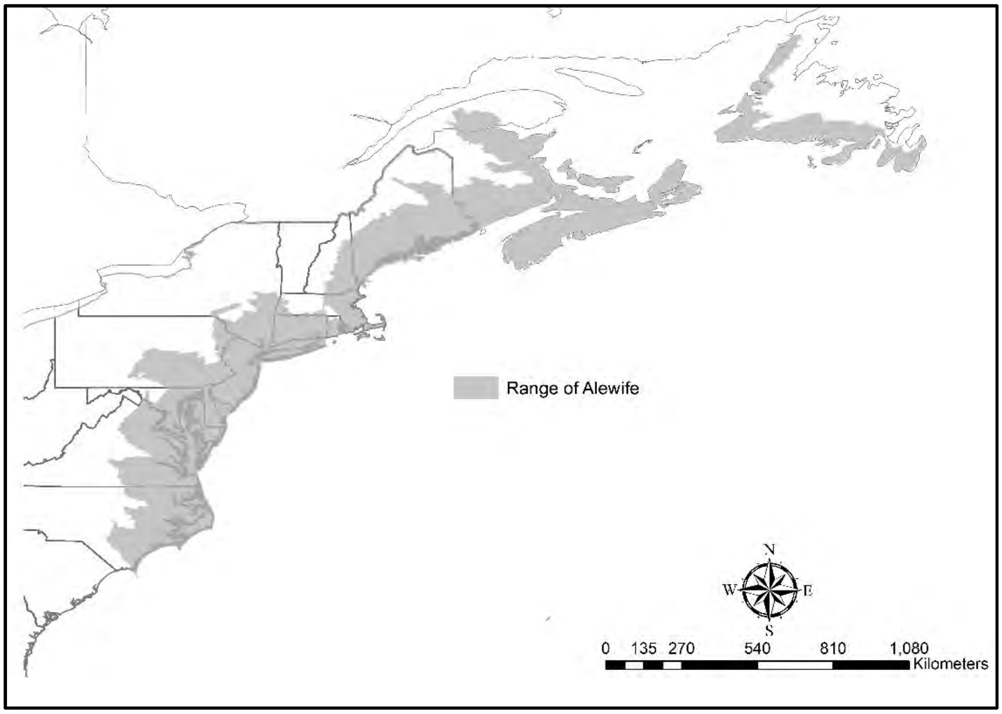


Figure 2. Map of alewife range.

River herring are anadromous, meaning that they mature in the marine environment and then migrate up coastal rivers to estuaries and into freshwater rivers, ponds, and lake habitats to spawn (Collette and Klein-MacPhee 2002, ASMFC 2009a). In general, adult river herring are found at depths less than 328 feet (ft) (100 meters (m)) in waters along the continental shelf (Neves 1981, ASMFC 2009a, Schultz et al. 2009).

River herring are highly migratory, pelagic, schooling species with seasonal spawning migrations cued by water temperature (Collette and Klein-MacPhee 2002, Schultz et al. 2009). The spawning migration for alewives typically occurs when water temperatures range from 50–64 °F (10–18 °C) and for blueback herring when temperatures range from 57–77 °F (14–25 °C; Klauda et al. 1991). Depending upon temperature, in the U.S., blueback herring typically spawn from late March through mid-May. However, they spawn in the southern parts of their U.S. range as early as December or January and as late as August in the northern portions (ASMFC 2009a). Alewives have been documented spawning as early as February in the southern portion of their U.S. range and as late as August in the northern portions (ASMFC 2009a). The river herring migration in Canada extends from late April through early July, with the peak occurring in late May and early June. Blueback herring generally make their spawning runs about two weeks later than alewives (DFO 2001).

Blueback herring and alewives consume a variety of zooplankton. Blueback herring subsist chiefly on ctenophores, calanoid copepods, amphipods, mysids and other pelagic shrimps, and small fishes while at sea (Bigelow and Schroeder 1953, Brooks and Dodson 1965, Neves 1981, Stone 1985, Stone and Daborn 1987, Scott and Scott 1988, Bowman et al 2000). Alewives consume euphausiids, calanoid copepods, mysids, herperiid amphopods chaetognaths, pteropods, decapod larvae, and salps (Edwards and Bowman, 1979, Neves 1981, Vinogradov 1984, Stone and Daborn 1987, Bowman et al. 2000).

Little is known about their habitat preference in the marine environment, however, marine distributions of fish are often linked to environmental variables such as prey availability and predation, along with seascape features Studies have shown alewife and blueback herring distribution linked to bottom temperature, salinity, and depth (Neves 1981, Bethoney et al. 2014, Lynch et al. 2015). Recent papers described marine co-occurrences of alewife and blueback herring with Atlantic herring and mackerel (Turner et al. 2016, Turner et al. 2017, Figure 3), providing further evidence in addition to observed bycatch estimates (Bethoney *et al.* 2014), that river herring school with Atlantic herring and mackerel. Turner *et al.* (2016) modeled associations of alewife and blueback herring, finding that alewife and blueback herring distributions overlapped with Atlantic herring (68-72 percent correct predictions) and Atlantic mackerel (57-69 percent correct predictions).

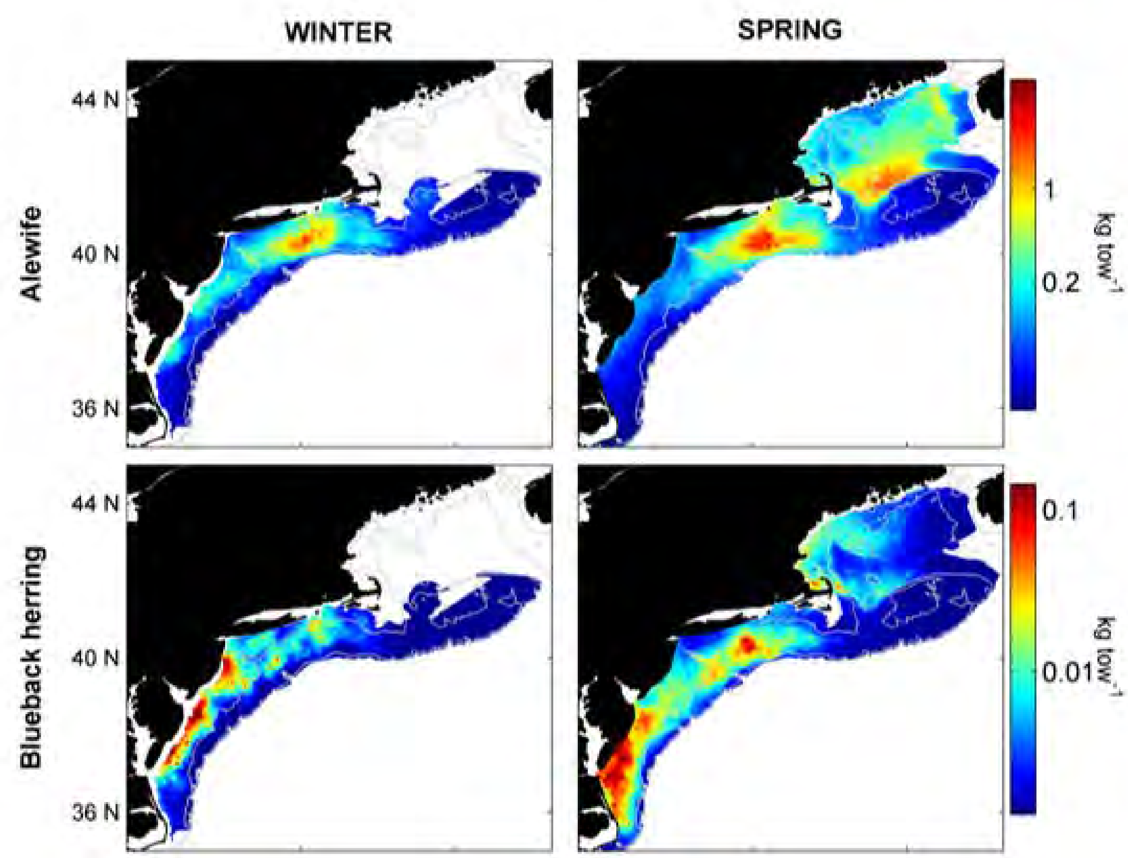


Figure 3. *From Turner et al. 2015.* Distributions of alewife and blueback herring by season for the study periods (Winter 1993-2007, Spring 1991-2013) from NEFSC survey trawl data.

NMFS Bottom Trawl Survey

Cieri (2012) analyzed NMFS bottom trawl survey data to identify seasonal population clusters of river herring along the East Coast of the U.S. (N. Carolina to Maine). The spring trawl survey (1968-2008 NMFS Spring Bottom Trawl Survey) indicated that river herring are widespread across the survey area. Highest occurrences during the spring are off Maine’s Downeast coast (roughly from Penobscot Bay north-eastwards to the Canadian border) and areas offshore, near Cape Ann and Cape Cod in Massachusetts, and a large area between Block Island, Rhode Island, and Long Island Sound. During the summer (1948 – 1995 NMFS Bottom Trawl Survey), river herring occur less frequently across the survey area, with most herring along the New England coast north of Rhode Island, and the highest occurrences off Maine’s Downeast coast and south of Cape Cod, Massachusetts. During the fall survey (1963 – 2008 NMFS bottom trawl surveys), the occurrence of river herring shifts northward with highest occurrences north of Cape Cod, along the Maine Coast to the Bay of Fundy, and another cluster off the eastern shore of Nova Scotia.

Maine/New Hampshire Inshore Survey

Alewife fork lengths in the spring survey most frequently range from 7 to 13 cm; in the fall survey, lengths most frequently range from 10 to 15 cm. Blueback herring length in the spring survey most frequently range from 10 to 15 cm; in the fall survey, they most frequently range from 18 to 24 cm. With respect to seasonal spatial occurrence, Cieri (2008) identified alewives as being the most dominant species in the Maine/New Hampshire trawl surveys. During the fall 2000–2006 surveys, the Casco Bay region had the largest aggregation of alewives. The fall 2007–2011 trawl surveys were similar to the 2000–2006 surveys although more fish appeared in the Penobscot Bay region, which could be a result of sampling stratification. In the Maine/New Hampshire fall survey, abundance of sub-adult fish (Age-0 and Age-1) proximate to river mouths was higher than abundances observed in southern New England. For both the 2000–2006 and 2007–2011 fall trawl surveys, blueback herring occurred less frequently along the Maine coast than alewives, except for an area clustered around the mouth of the Kennebec River. The Maine/New Hampshire spring inshore trawl survey further reveals the broad distribution of alewives along Maine’s coast, with areas of highest occurrence in the Casco Bay region.

Seasonal migrations have been observed in the marine environment as described above but are not well understood (NMFS 2012a). Hypothesized overwintering areas and migration pathways were presented (Figure 4) at the NMFS 2012 Stock Structure workshop, but little tagging data exits. The working group, from the 2012 workshop, was not able to determine the migration patterns and mixing patterns of alewives and blueback herring in the ocean, though they strongly suspected regional stock mixing (NMFS 2012a). Therefore, the conclusion from the 2012 Stock Structure workshop was that the ocean phase of alewives and blueback herring were mixed stocks.

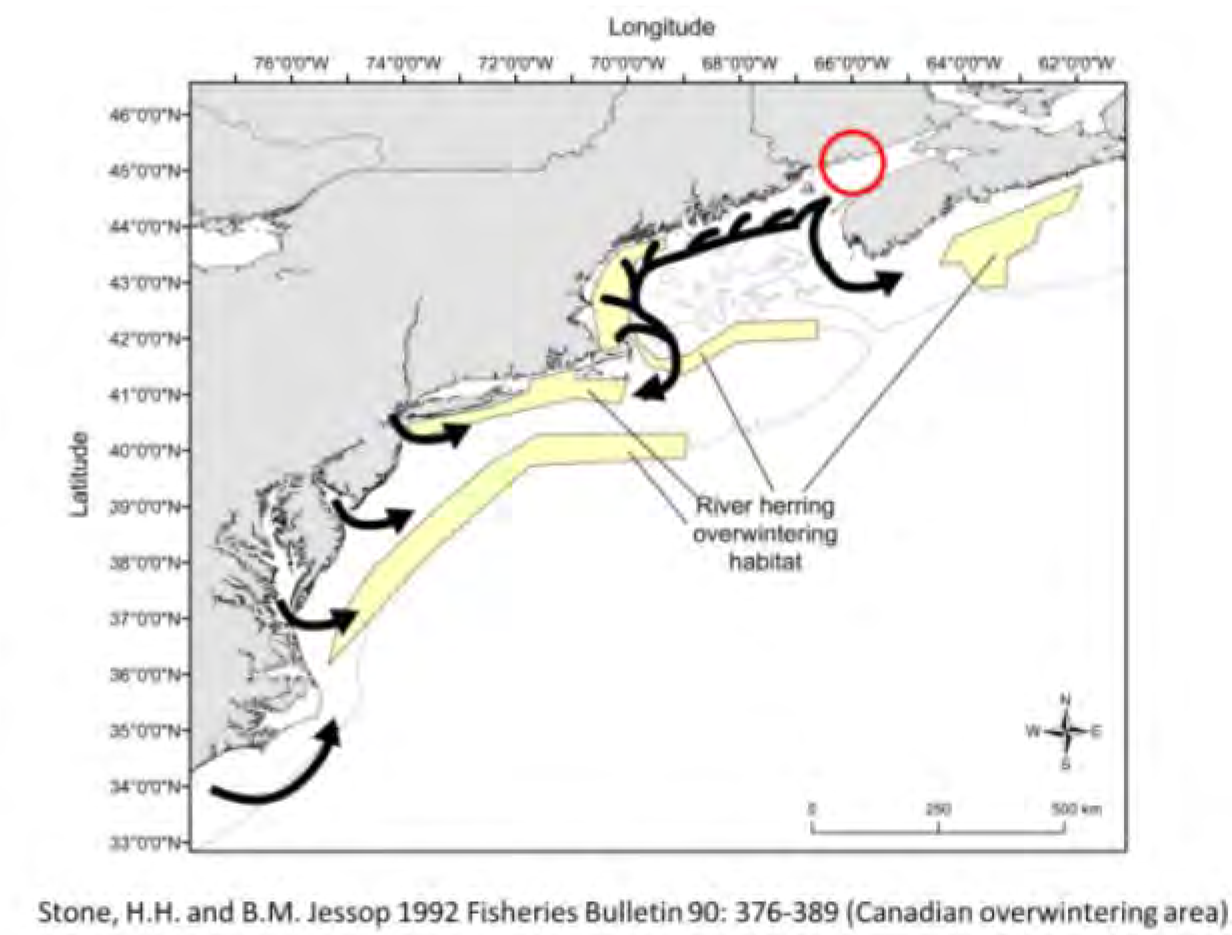


Figure 4**.** Hypothesized river herring overwintering areas and migration pathways from Jordaan presentation on 06/22/12 in Gloucester, MA. The Scotian shelf overwintering area was previously identified in Stone and Jessop (1992).

2.4 Reproduction, Growth, and Demography

Overall, alewife and blueback herring are habitat generalists found over a wide variety of substrates, depths and temperatures in freshwater lakes and ponds, rivers, estuaries, and the Atlantic ocean. The substrate preferred for spawning varies greatly and can include gravel, detritus, and submerged aquatic vegetation. Alewife prefer spawning over sand or gravel bottoms (Galligan 1962), usually in quiet waters of ponds and coves (Marcy 1967, Loesch and Lund 1977). Blueback herring prefer spawning over hard substrates, where the flow is relatively swift (Loesch and Lund 1977). Nursery areas include freshwater and semi-brackish waters to fully saline waters for both species (Gahagan 2012, Turner et al. 2014, Payne Wynne et al. 2015).

Alewife and blueback herring are fast growing, quick to mature species with a high fecundity rate. Estimates of fecundity for alewife range from 45,800 to 400,000 eggs (Foster and Goodbred 1978, Klauda et al. 1991, Loesch and Lund 1977). Estimates of fecundity for blueback herring range from 30,000 to 400,000 eggs (Loesch 1981, Jessop 1993). Fecundity estimates range widely based on the length and weight of the females (Schmidt and Limburg 1989) and geographic recruitment (Gainias et al. 2015). Both species spawn 3-4 times throughout the spawning season (McBride et al. 2010, Gainias et al. 2015). Recent literature has shown that some Alosa species, including alewife are indeterminate spawners (Hyle et al. 2014, Gainas et al 2015, McBride et al. 2016). For indeterminate spawners, the potential annual fecundity is not fixed before the onset of spawning. In these species, eggs can develop at any time during the spawning season. This is likely the case for alewife and blueback herring but more research is needed.

Egg size for alewife is 0.87 to 1.27 mm (Mansueti 1956, Jones et al. 1978). Egg size for blueback herring is 0.87 to 1.11 mm. Incubation time depends on temperature (low water temperatures, slow development) and is estimated to take 2 to 4 days after deposit for blueback herring (Klauda et al. 1991, Jones et al. 1978). Incubation time for alewife takes between 2 to 6 days depending on temperature (Mansueti 1956, Jones et al. 1978). Alewife egg deposition most often occurs when temperatures range between 50–72 °F (10- 22 °C), and for blueback herring when temperatures range between 70–77 °F (21- 25 °C). Alewife egg and larval development is optimal when temperatures range from 63-70 °F (17–21 °C), and for blueback herring when temperatures range from 68–75 °F (20–24 °C).

Age at maturity was estimated to be higher in populations spawning in the northern portion of the species range for alewife and blueback herring. Ages ranged from 3-5 years for females (Rounsfell and Springer 1943, Jessop et al. 1983) with males tending to mature faster than females (Jessop et al. 1983). Little age at maturity information is available for blueback herring.

Estimates of population growth and per capita population growth are relatively rare for both species. The Multivariate Auto-Regressive State-Space (MARSS) modeling approach documented in NEFSC (2013) and this status review (see **3.1.3 Trends in Range-wide Abundance**) provides an estimate of the long term population growth. The 2013 rangewide estimated population growth rate (realized r) and associated standard error was 0.032± 0.006 for alewife and 0.039 ± 0.040 for blueback herring (NMFS 2013). Crecco and Gibson (1990) calculated an intrinsic growth rate (r_m), the maximum per capita population growth rate, for 15 stocks between New Brunswick, Canada, and North Carolina using regressions of population increases in rivers with newly opened habitat or form life history models. Alewife comprised 9 of these 11 populations and had an average r_m of .431 with a low of .303 and high of .540. The two blueback populations, in the Saint John River, New Brunswick and Connecticut River, had r_m of 0.437 and 0.550 respectively. Intrinsic growth rates following Crecco and Gibson's methods were calculated in the 2012 ASMFC Benchmark Assessment, however many of the new r_m calculations were created using short time series and covered periods of population rebounds rather than expansion into virgin habitats. Finally, Hutchings et al. (2012) calculated a similar statistic, r_{max}, for 4 populations of alewife and 3 populations of blueback herring, although information on the locations and time periods this data were collected is no longer available. For the populations considered, they found that blueback herring, which averaged 0.85, had slightly higher values of r_{max} than alewife, which averaged 0.56. Both species had r_{max} values higher than the median for bony fishes as a group.

2.5 Population Structure

2.5.1 Natural Markers

Studies have evaluated using otolith chemistry as a proxy for natal origin (i.e., to determine where fish spawn) in alewife and blueback herring with varying success. Across areas where distinct geochemical signatures exist, otolith microchemistry may be an appropriate tool for natal population assignment. Gahagan et al. (2012) examined the use of otolith microchemistry for characterizing river of origin for alewife and blueback herring in Connecticut rivers. As part of this study, the researchers attempted to correctly classify known individuals back to their site of collection. Ten sites were sampled for juvenile and adult fish along with water chemistry in 2008 and 2009. Reclassification for juvenile alewives to natal rivers ranged from 50-100% with adult alewives ranging from 10-85%. Reclassification for adult blueback herring to natal rivers ranged from 15-81%. The similar water chemistry in the sampled streams within the Connecticut River drainage potentially affected the ability to discern between runs.

Turner et al. (2015) furthered the use of otolith microchemistry (Sr:Ca, Ba:Ca, isotopics ratio of 87:86Sr) as a method of characterizing alewife and blueback herring to natal rivers in the United States. Model reclassification using microchemistry was 69.7% and 69.0% for alewife and blueback herring, respectively. Model reclassification improved with the use of genetic stocks as filters, with alewife assigned to the correct river 81.5% of the time and blueback herring correctly assigned 79.8% of the time.

2.5.2 Tagging Information

Little tagging data is available for marine migrations of alewife and blueback herring. In 1985-1986, approximately 19,000 river herring were tagged and released in the upper Bay of Fundy, Nova Scotia (Rulifson et al. 1987). These conventional tags rely on recapture and reporting and generally only provide information on the location where the fish was recaptured in relation to where it was originally tagged. The overall recapture rate was 0.39 (Rulifson et al.1987). Returned alewife tags were from freshwater locations in Nova Scotia, and marine locations in Nova Scotia and Massachusetts. Blueback herring tag returns were from freshwater locations in Maryland and North Carolina, and marine locations in Nova Scotia. The authors suspected from recapture data that alewives and blueback herring tagged in the Bay of Fundy were of different origins, hypothesizing that alewives were likely regional fish from as far away as New England, while the blueback herring recaptures were likely not regional fish, but those of U.S. origin from the mid-Atlantic region. However, the low tag return numbers from outside of Nova Scotia (n=2) made it difficult to generalize about the natal rivers of blueback herring caught in the Bay of Fundy.

Acoustic tags transmit a unique signal that is collected by a receiver or an array of receivers. This type of tag allows the detection and/or remote tracking of fish. Eakin (2017) acoustically tagged 25 river herring (n=13 alewives and n=12 blueback herring) in the Hudson River during 2013 to measure in-river residence time. In-river data was collected from 23 fish. Tagged fish in-river residence times ranged from two to three weeks, with fish exiting the system three to six days post-spawn. Coastal movements were also detected from four blueback herring (2 male, 2 female) (Figure 5**).** This study shows coastal movements over a six-month period (June to November) release in the Hudson River and detected as far away as the Gulf of Maine, near Matinus Island. The study also demonstrates the potential of using acoustic tagging to tease out marine movements of alewife and blueback herring.

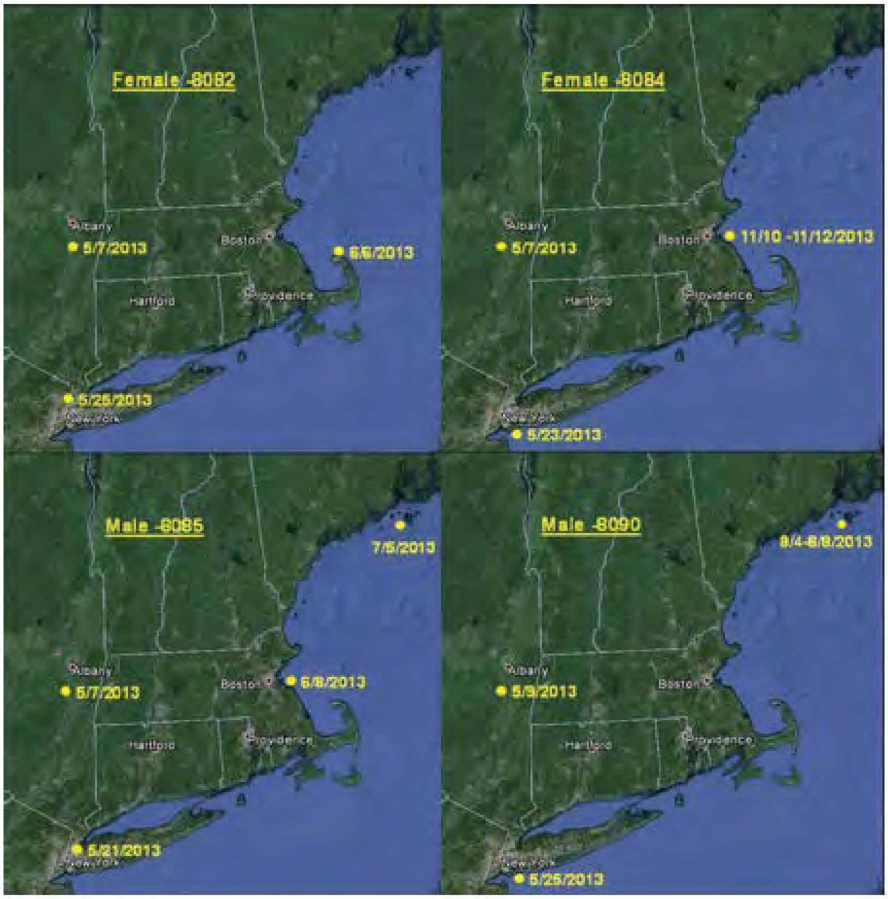


Figure 5. *From Eakin 2017*. Map of acoustic tag detections from Acoustic Telemetry (ACT) network receivers for two female and two male blueback herring.

2.5.3 Genetic Studies

Studies show that there is evidence of genetic structure at a regional scale, and available genetic studies prior to 2012 were discussed at the 2012 NMFS Stock Structure Workshop (see NMFS 2012a). At that time, the Stock Structure Expert Working group recommended five stock complexes for alewife and five for blueback herring.

For alewife, the 2012 group recommended the following stock complexes: Carolina (all rivers south of, and including the Chowan River); Mid-Atlantic (all Virginia rivers up to, and including New Jersey rivers); Southern New England (all New York rivers up to, and including Massachusetts rivers); Northern New England (Lamprey River up to, and including the St. Croix River), and; Canada (all Canadian Rivers east of the St. Croix).

For blueback herring, the 2012 group recommended the following stock complexes: Southern (St. Johns River to Cape Fear River); Mid-Atlantic (Neuse River to Connecticut River); Southern New England (Gilbert-Stewart River to Mystic River); Northern New England (Exeter River up to and including the St. Croix River), and; Canada (all Canadian Rivers east of the St. Croix).

Research published since the workshop by Palkovacs et al. (2014) found significant differences in 15 microsatellite markers among three alewife stock complexes (Northern New England, Southern New England, and Mid-Atlantic) and four blueback herring stock complexes (Northern New England, Southern New England, Mid-Atlantic, and South Atlantic; Figure 6**)**. For alewife, 778 samples were collected from spawning runs in 15 different rivers. For blueback herring, 1,201 samples were collected from 20 rivers. The researchers used Principal Component Analysis (PCoA) to examine genetic affinities among rivers. PCoA is a tool that simplifies the complexity in high-dimensional data while retaining trends and patterns with the goal of finding the best summary of the data using a limited number of principal components. Latitude was strongly correlated to genetic differentiation for both species (alewife R^2= 0.85; blueback herring R^2=0.81). The researchers also used isolation by distance tests to evaluate correlations between geographic distance and genetic differentiation. The isolation by distance relationship was strong for both species as well (alewife R^2= 0.53; blueback herring R^2=0.50), inferring lower straying rates among populations than within and an overall higher straying (see Straying section below) for blueback herring compared to alewife.

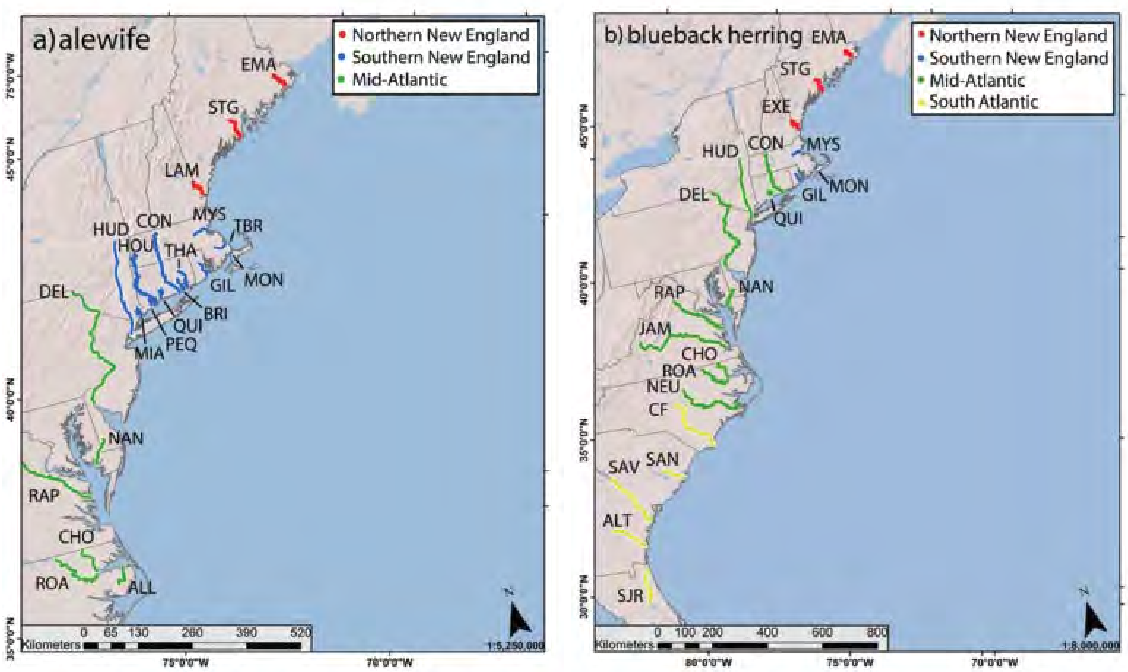


Figure 6. *From Hasselman et al. 2016.* Map showing a subsample of populations and all genetic stocks identified in Palkovacs et al. 2014 for a) alewife and b) blueback herring. Populations are color coded by genetic stock assignment.

McBride et al. (2014) implemented a two-part genetic analysis of river herring to evaluate the genetic diversity of alewives in Maine and Maritime Canada and to assess the regional effects of stocking on alewives and blueback herring in Maine. For Part 1 of the study, alewife and blueback herring genetic samples (n=881) from 15 different sites throughout mid-coast Maine were genotyped using 10 microsatellite markers. For Part 2 of the study, over 2,000 alewife samples from Maine and Atlantic Canada were genotyped using 14 microsatellite markers. The genetic analysis of alewives and blueback herring along mid-coast Maine revealed significant genetic differentiation among populations. Despite significant differentiation, the patterns of correlation did not closely correspond with geography or drainage affiliation. The genetic analysis of alewives from rivers in Maine and Atlantic Canada detected using Isolation by Distance suggests homing behavior indicative of alewives' metapopulation conformance does produce genetically distinguishable populations. However, differences in Isolation by Distance between populations, suggest different homing/straying rates range for each population (Bay of Fundy, Gulf of Maine, Gulf of St. Lawrence and Atlantic Coast. McBride et al. (2014) identified five possible groupings based on genetic similarities between sites. These groupings include Cape Breton, Nova Scotia (3 populations), Gulf of St. Lawrence (9 populations), East Shore of Nova Scotia (8 populations), Bay of Fundy (3 populations), and Maine (13 populations). Results also suggest there may be interbreeding between alewives and blueback herring, especially at sample sites with impassible dams.

Ogburn et al. (2017) sampled five additional rivers in the Chesapeake Bay from 2014 to 2015, collecting genetic samples from alewife (n=277) and blueback herring (n=234). The study encompassed the Choptank, Nanticoke, Susquehanna, Patuxent, and Potomac, sampling rivers on both the eastern and western shores of Chesapeake Bay, and used the same 15 microsatellite loci identified in Palkovacs et al. (2014). Results showed genetic diversity even within regional stock complexes. Bayesian model-based clustering is a tool to infer the number of genetically homogeneous clusters among rivers. The analysis suggested two genetic clusters for alewives, eastern shore (Choptank and Nanicoke) and western shore (Potomac and Susquehanna); and three genetic clusters for blueback herring, eastern shore (Choptank and Nanicoke), western shore (Patuxent) and head of tide/western shore mix (Potomac and Susquehanna). Results also showed a temporal component to genetic differentiation or potential straying, with alewives sampled from the Potomac in one week belonging to a completely different genetic group than those sampled one week later.

Single nucleotide polymorphisms (SNPs) are small genetic variations that occur in a genome. These variations are used as molecular markers in genetic research. SNPs have been developed using 96 individual loci for alewife and for blueback herring (Baetscher et al. 2017). These markers can be used to assign individual fish to its river of origin. Self-assignment analyses from river of origin using SNPs, on average, correctly assigned 67% of both alewife (range 49% to 84%) and blueback herring (range 33% to 100%). Assignment to grouping assignment of origin was 93% for alewife and 96% for blueback herring. The fixation index (Fst) is a measure of population differentiation due to genetic structure. Alewife displayed low differentiation across the species range with Fst values ranging from 0.006 to 0.140, which correlated with over half of the alewife samples remaining unassigned and further supporting a lack of fine-scale population structure in alewife. STRUCTURE cluster analysis showed similar results to previous regional stock structure groupings, with the addition of two additional blueback herring populations (Peticodiac and Margaree) which were grouped with the Northern New England stock complex. It also confirmed a Canadian alewife grouping (Waughs and Tusket).

Additional recent work by Reid et al. (2018) examined river herring from 108 locations ranging from Florida to Newfoundland using the same SNPs markers developed by Baetcher et al. (2017). The study identified the following regional groupings for alewife:

- Canada- Garnish River and Otter Pond, Newfoundland to Saint John River, New Brunswick
- Northern New England- St. Croix River, ME to Merrimack River, NH
- Southern New England- Parker River, MA to Carll's River, NY
- Mid Atlantic- Hudson River, NY to Alligator River, NC

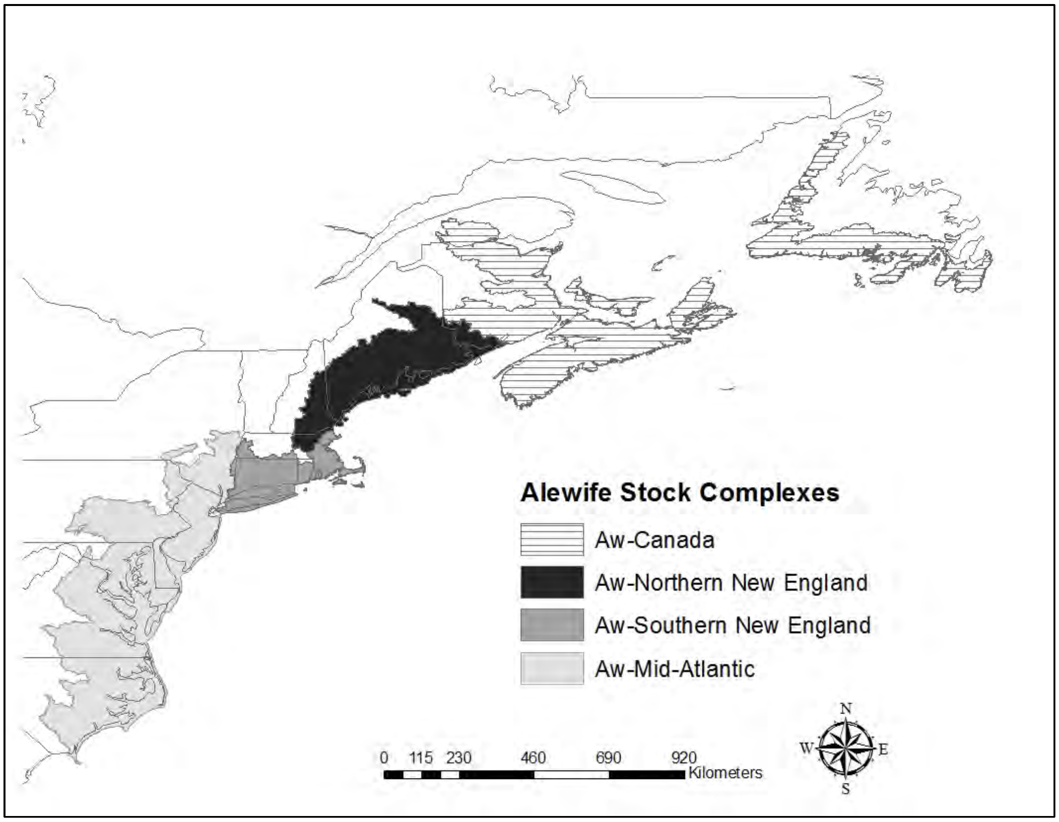


Figure 7. Map of Alewife regional stock complexes: Aw-Canada; Aw-Northern New England; Aw-Southern New England; and Aw-Mid-Atlantic.

And the following regional groupings for blueback herring:

- Canada- Northern New England- Margaree River, Nova Scotia to Kennebec River, ME
- Mid New England- Oyster River, NH to Parker River, MA
- Southern New England- Mystic River, MA to Gilbert-Stuart Pond, RI
- Mid Atlantic- Connecticut River, CT to Neuse River, NC
- Southern Atlantic- Cape Fear River, NC to St. Johns River, FL

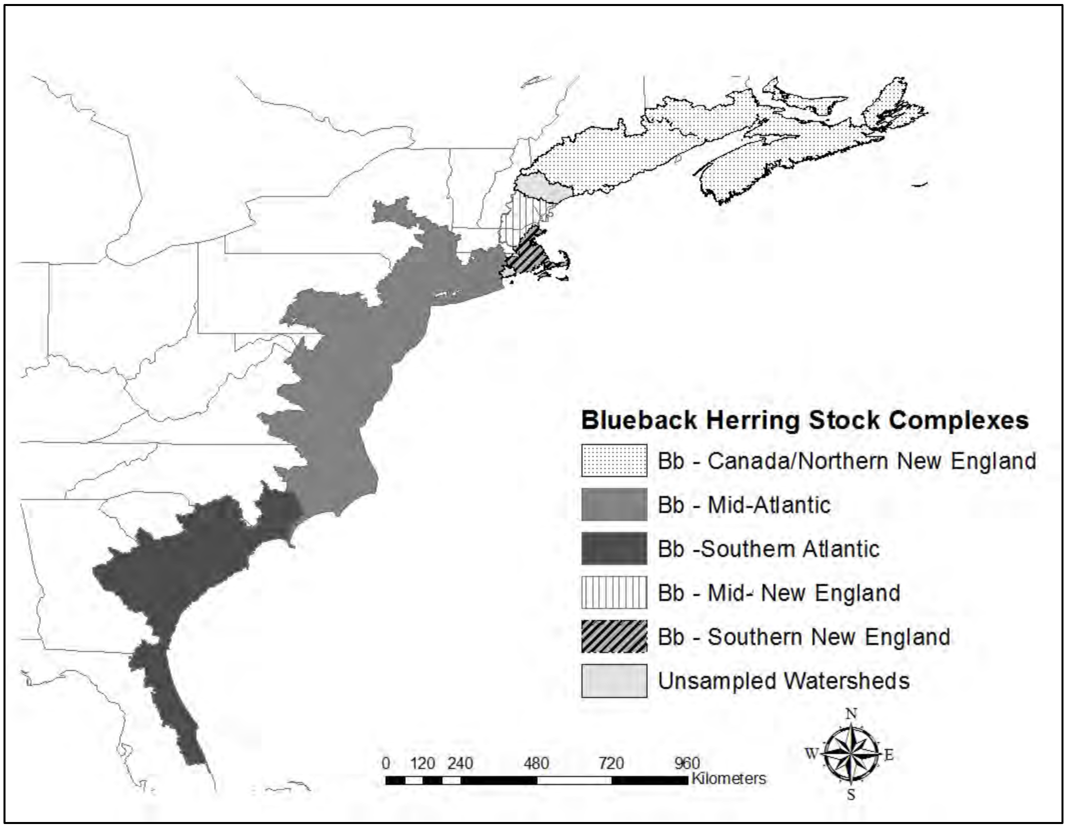


Figure 8. Map of Blueback Herring regional stock complexes: Bb-Canada/Northern New England; Bb-Mid-New England; Bb-Southern New England; Bb-Mid-Atlantic; Bb-Southern Atlantic; and unsampled watersheds.

Because the similarity in geographic naming of these stock complexes makes them difficult to distinguish between species, hereafter, alewife regional groupings are prefaced with Aw- and blueback herring regional groupings with Bb-. For example, the Mid Atlantic regional groupings of these two species would be referred to as Aw-Mid Atlantic and Bb-Mid Atlantic (as noted in the figures above).

Self-assignment tests to region ranged from 86-92% for alewife and 76-95% for blueback herring. Assignment to individual rivers was low. The study also found that the extent of gene flow across regional grouping was higher than previously reported, with rivers such as the Hudson and Connecticut acting as transition zones for alewife and blueback herring, respectively.

Recent work has also demonstrated that stocking practices influence genetic differentiation among populations (McBride et al. 2014, McBride et al. 2015). McBride et al. (2015) used 12 microsatellite loci to evaluate the genetic structure of 16 alewife populations in Maine to determine whether past stocking influenced current populations and the genetic composition of alewives. Results showed that most stocked populations exhibited no significant difference in isolation, while non-stocked populations showed significant isolation by distance results.

The unusual genetic groupings of river herring in Maine are likely a result of Maine's complex stocking history. Alewife populations in Maine have been subject to considerable within and out of basin stocking for the purpose of enhancement, recolonization of extirpated populations, and stock introduction. Alewife stocking in Maine dates back at least to 1803 when alewives were reportedly moved from the Pemaquid and St. George Rivers to create a run of alewives in the Damariscotta River (Atkins and Goode 1887). These efforts were largely responsive to considerable declines in alewife populations following the construction of dams, over exploitation and pollution. Although there has been considerable alewife stocking and relocation throughout Maine, there are very few records documenting these efforts. In contrast, considerably less stocking of alewives has occurred in Maritime Canada. The study further demonstrates that past stocking patterns influence contemporary genetic diversity and stocking history should be taken into account when interpreting genetic groupings.

In summary, the best available genetic data suggests that alewife and blueback herring may be distinguished by regional groupings. Recent studies show a minimum of four stock complexes of alewife and five stock complexes of blueback herring. Transfer of river herring within and out of basin has likely altered the genetic diversity of alewife and blueback herring observed today in several ways. First, stocked areas are most likely to have already low populations (or local extirpation) and second, this reduced population is then stocked with a likely different genetic stock, further masking the previous population's genetics.

2.5.4 Straying

River herring conform to a metapopulation paradigm (i.e., a group of spatially separated populations of the same species that interact at some level) with adults frequently returning to their natal rivers for spawning with straying occurring between rivers (Jones 2006; ASMFC 2009a). There have been very few studies to quantify straying rates, despite evidence of straying in the literature (Jessop 1994, Palkovacs et. al 2014, McBride et al. 2014, Turner and Limburg 2014, McBride et al. 2015, Ogburn et al. 2017). Jessop (1994) reported straying rates of 3-37% in the St. John River, New Brunswick. McBride et al. (2014) and Palkovacs et al. (2014) reported greater isolation by distance for alewives than for blueback herring, suggesting higher overall straying rates for blueback herring. Additionally, isolation by distance evidence from Palkovacs et al. (2014) and McBride et al. (2015), suggest that genetic exchange (straying) is more likely to happen with nearest neighbor rivers over such distances as 100-200 km. Straying has also been reported in other anadromous fishes, such as American shad (Jolly et al. 2012) and striped bass (Gauthier et al. 2013). Pess et al. (2014) reviewed basic life history traits of diadromous fish and hypothesized recolonization rates. Alewife and blueback herring were considered to have a moderate to strong tendency to colonize new streams. Both species were considered to have the highest tendencies of all the east coast diadromous fish, with blueback herring scoring slighltly higher than alewife. Alewife and blueback herring were also considered to have strong tendancies to expand into habitat within existing streams. Both species scored higher than all other diadromous fish, except for sea lamprey in this conceptual model.

3 DISTRIBUTION AND ABUNDANCE

3.1 Description of Population Abundance and Trends

3.1.1 United States Waters

3.1.1.1 *Atlantic States Marine Fisheries Commission Stock Assessment Update 2017*

A 2017 alewife and blueback herring stock assessment update was prepared and compiled by the River Herring Stock Assessment Subcommittee, hereafter referred to as the 'subcommittee,' of the Atlantic States Marine Fisheries Commission (ASMFC) Shad and River Herring Technical Committee. Data and reports used for this assessment were obtained from federal and state resource agencies, power generating companies, and universities.

The 2017 stock assessment followed the same methods and analyses outlined in the 2012 benchmark report (ASMFC 2012a) and updated the existing time series by adding data when available for the years 2011-2015. The subcommittee assessed the coastal stocks of alewife and blueback herring by individual rivers as well as coast-wide based on available data. As this assessment provides the most up-to-date abundance and trends data of river herring, the Status Review Report includes many excerpts from the 2017 ASMFC stock assessment (see sections on Commercial Catch Per Unit Effort (CPUE), Run Counts, Young-Of-The-Year Seine Surveys, Juvenile-Adult Fisheries-Independent Seine, Gillnet and Electrofishing Surveys, Juvenile and Adult Trawl Surveys, Mean Length, Maximum Age, Mean Length-at-Age, Repeat Spawner Frequency, Total Mortality (Z) Estimates, and Exploitation Rates).

Of the 54 in-river stocks of river herring for which data were available, the 2017 ASMFC Stock Assessment indicates that from 2006 through 2015, 16 experienced increasing trends, two experienced decreasing trends, eight were identified as stable by the ASMFC working group, 10 experienced no discernible trend/high variability, and 18 did not have enough data to assess recent trends, including one that had no returning fish (see Table 1; ASMFC 2017a). The coastwide meta-complex of river herring stocks on the U.S. Atlantic coast remains depleted to near historic lows. A depleted status indicates that there was evidence for declines in abundance due to a number of factors, but the relative importance of these factors in reducing river herring stocks could not be determined.

The following was taken from the ASMFC River Herring Stock Assessment Update Volume I: Coastwide Summary (2017a). For the full report (including additional tables and figures), see River Herring Stock Assessment Update Volume I (http://www.asmfc.org/uploads/file/59b1b81bRiverHerringStockAssessmentUpdate_Aug2017.pdf). For a comprehensive review, see the coastwide stock assessment update (ASMFC 2017a) and associated state reports (ASMFC 2017b).

Excerpt from ASMFC (2017a):

> The subcommittee concluded that river herring should ideally be assessed and managed by individual river system, though the marine portion of their life history likely influences survival through mixing in this portion of their range. The subcommittee also noted that most state landings records list alewife and blueback herring together as 'river herring' rather than identifying to species. The practice of lumping both species together as "river herring" still occurs today in some state reporting.
>
> These landings averaged 30.5 million pounds (lbs) (13,847 metric tons (mt)) per year from 1889 to 1938, and severe declines were noted coast-wide starting in the 1970s. Beginning in 2005, states began enacting moratoria on river herring fisheries, and as of January 2012, all directed harvest of river herring in state waters is prohibited unless states have approved sustainable fisheries management plans (FMP) under ASMFC's Amendment 2 to the Shad and River Herring FMP. The subcommittee summarized its findings for trends in commercial catch-per-unit-effort (CPUE); run counts; young-of-the-year (YOY) seine surveys; juvenile-adult fisheries independent seine, gillnet and electrofishing surveys; juvenile-adult trawl surveys; mean length; maximum age; mean length-at-age; repeat spawner frequency; total mortality (Z) estimates; and exploitation rates.

Table 1**.** *From ASMFC 2017a.* Summary of river herring trends from select rivers along the Atlantic Coast.

State	River**	Commercial CPUE		Run Counts		YOY survey		Z		Trawl Survey†		Mean Length	Max Age	Percent Repeat Spawners	Updated Recent Trends*
		2006-2015	Full Time-series	2006-2015	Full Time-series	2006-2015	Full Time-series	2006-2015	Full Time-series	2006-2015	Full Time-series	Full Time-series	Full Time-series	Full Time-series	2006-2015
NE U.S. Continental Shelf (NMFS Bottom Trawl)^										$\uparrow^{A,B}$	$\searrow\nearrow^{A}, \rightarrow\nearrow^{B}$	$\downarrow^{A}$, n.s.^{B}			Increasing^{A,B}
ME	Androscoggin			$\uparrow^{A}$	$\uparrow^{A}$			$\leftrightarrow^{A}$	$\leftrightarrow^{A}$			n.s.^{A}	$\leftrightarrow^{A}$	$\downarrow^{A}$	Increasing^{A}
ME	Kennebeck			$\uparrow^{RH}$	$\uparrow^{RH}$										Increasing^{RH}
ME	Sebasticook			$\uparrow^{RH}$	$\uparrow^{RH}$	$\leftrightarrow^{A,B}$	$\leftrightarrow^{A}, \uparrow^{B}$	$\leftrightarrow^{A}$	$\leftrightarrow^{A}$						Increasing^{RH}
ME	Damariscotta			$\uparrow^{A}$	$\searrow\nearrow^{A}$										Increasing^{A}
ME	Union			$\leftrightarrow^{A}$	$\leftrightarrow^{A}$										No Trend^{A}
NH	Cocheco			$\uparrow^{RH}$	$\uparrow^{RH}$			$\downarrow^{B}$	$\downarrow^{AF}, \leftrightarrow^{BM}$	$\uparrow^{A}, \leftrightarrow^{B}$	$\uparrow^{A}, \downarrow^{B}$	n.s.^{AF}, $\downarrow^{BM}$	$\leftrightarrow^{A,B}$	n.s.^{A,B}	Increasing^{A,B}
NH	Exeter			$\leftrightarrow^{RH}$	$\leftrightarrow^{RH}$							$\downarrow^{AM}$, n.s.^{AF}	$\leftrightarrow^{A}$	n.s.^{A}	Stable^{RH}
NH	Lamprey			$\uparrow^{RH}$	$\uparrow^{RH}$			$\downarrow^{AM}, \leftrightarrow^{A}$	$\downarrow^{AM}, \leftrightarrow^{AF}$			n.s.^{A}	$\uparrow^{A}$	n.s.^{A}	Increasing^{RH}
NH	Oyster			$\leftrightarrow^{RH}$	$\nearrow\searrow^{RH}$			$\leftrightarrow^{B}$	$\leftrightarrow^{B}$			$\downarrow^{B}$	$\leftrightarrow^{B}$	n.s.^{B}	Decreasing^{RH}
NH	Taylor			D (2015)	$\downarrow^{RH}$									D (2010)	No Returns^{RH}
NH	Winnicut			D (2011)	$\leftrightarrow^{RH}$			D (2011)	$\leftrightarrow^{A,B}$			n.s.^{A,B}	D (2011)	D (2010)	Unknown^{A,B}
MA	Mattapoisett			$\uparrow^{A}$	$\leftrightarrow^{A}$										Increasing^{A}
MA	Monument			$\uparrow^{A,B}$	$\nearrow\searrow^{A}, \downarrow^{B}$			$\leftrightarrow^{A}$	$\downarrow^{AM,BF}, \leftrightarrow^{AF,BM}$			$\downarrow^{A,B}$	$\leftrightarrow^{A,B}$	$\downarrow^{A,B}$	Increasing^{A,B}
MA	Nemasket			$\uparrow^{A}$	$\leftrightarrow^{A}$			$\leftrightarrow^{A}$	$\leftrightarrow^{A}$					n.s.^{A}	Increasing^{A}
MA	Parker			$\leftrightarrow^{A}$	$\downarrow^{A}$				$\leftrightarrow^{A}$						Stable^{A}
MA	Stony Brook														Unknown^{A}
RI	Buckeye			$\leftrightarrow^{A}$	$\leftrightarrow^{A}$										Increasing^{A}
RI	Gilbert			$\leftrightarrow^{A}$	$\nearrow\searrow^{A}$	$\leftrightarrow^{RH}$	$\leftrightarrow^{RH}$	$\leftrightarrow^{A}$	$\uparrow^{A}$	$\leftrightarrow^{A}, \downarrow^{B}$	$\uparrow^{A}, \leftrightarrow^{B}$		$\leftrightarrow^{A}$	$\downarrow^{A}$	Stable^{A}
RI	Nonquit			$\leftrightarrow^{A}$	$\downarrow^{A}$			$\downarrow^{A}$	$\downarrow^{A}$					n.s.^{A}	Decrease^{A}
CT	Bride Brook			$\uparrow^{A}$	$\uparrow^{A}$										Increasing^{A}
CT	Connecticut			$\leftrightarrow^{B}$	$\nearrow\searrow^{B}$	$\leftrightarrow^{B}$	$\downarrow^{B}$								Stable^{B}
CT	Farmington			X	X										Unknown^{A,B}
CT	Mianus			$\leftrightarrow^{A,B}$	$\leftrightarrow^{A,B}$					$\leftrightarrow^{A,B}$	$\uparrow^{A}, \downarrow^{B}$				No Trend^{A},Increasing^{B}
CT	Mill Brook			$\leftrightarrow^{A}$	$\leftrightarrow^{A}$										No Trend^{A}
CT	Naugatuck			X	X										Unknown^{A,B}
CT	Shetucket			$\leftrightarrow^{A,B}$	$\leftrightarrow^{A,B}$										No Trend^{A}, Stable^{B}
State	River**	Commercial CPUE 2006-2015	Commercial CPUE Full Time-series	Run Counts 2006-2015	Run Counts Full Time-series	YOY survey 2006-2015	YOY survey Full Time-series	Z 2006-2015	Z Full Time-series	Trawl Survey† 2006-2015	Trawl Survey† Full Time-series	Mean Length Full Time-series	Max Age Full Time-series	Percent Repeat Spawners Full Time-series	Updated Recent Trends* 2006-2015
NY	Hudson	$\uparrow^{RH}$	$\searrow\nearrow^{RH}$			$\downarrow^{A}, \leftrightarrow^{B}$	$\leftrightarrow^{A,B}$					$\leftrightarrow^{A,B}$			Increasing^{RH}
NJ, DE,PA	Delaware	D (2012)	$\downarrow^{RH}$			$\leftrightarrow^{A,B}$	$\leftrightarrow^{A}, \downarrow^{B}$			$\uparrow^{A}, \leftrightarrow^{B}$	$\leftrightarrow^{A}, \uparrow^{B}$				No Trend^{A,B}
MD, DE	Nanticoke	D (2012)	$\downarrow^{RH}$			$\leftrightarrow^{A,B}$	$\leftrightarrow^{A,B}$	$\leftrightarrow^{A,B}$	$\leftrightarrow^{A,B}$			$\downarrow^{A,B}$	$\downarrow^{A,B}$	$\downarrow^{AM,B}$, n.s.^{AF}	Stable^{A},No Trend^{B}
VA, MD, DC	Potomac	D (2012)	$\downarrow^{RH}$			$\leftrightarrow^{A}, \uparrow^{B}$	$\downarrow^{A}, \uparrow^{B}$								Stable^{A},Unknown^{B}
VA	James	D (2013)	$\leftrightarrow^{A}$												Unknown^{A,B}
VA	Rappahannock	D (2013)	$\nearrow\searrow^{A}$			$\leftrightarrow^{A}, \uparrow^{B}$	$\leftrightarrow^{A,B}$								No Trend^{A},Increasing^{B}
VA	York	D (2013)	$\rightarrow\nearrow^{A}$												Unknown^{A,B}
NC	Alligator								$\leftrightarrow^{A,B}$						Unknown^{A,B}
NC	Chowan	$\leftrightarrow^{A,B}$	$\downarrow^{A,B}$	$\leftrightarrow^{B}$	$\downarrow^{A,B}$	$\leftrightarrow^{A,B}$	$\leftrightarrow^{A}, \downarrow^{B}$	$\leftrightarrow^{B}$	$\leftrightarrow^{A,B}$	$\leftrightarrow^{A,B}$	$\searrow\nearrow\searrow^{A}, \downarrow^{B}$	$\downarrow^{A,B}$	$\downarrow^{A,B}$	n.s.^{A,B}	No Trend^{A},Stable^{B}
NC	Scuppernog								$\leftrightarrow^{A,B}$						Unknown^{A,B}
SC	Santee-Cooper	$\leftrightarrow^{B}$	$\searrow\nearrow^{B}$		$\uparrow^{B}$				$\downarrow^{B}$			n.s.^{B}			No Trend^{B}
FL	St. Johns River											$\downarrow^{BF}$, n.s.^{BM}			Unknown^{B}

†: Adult or all age fish only; trawl surveys take place in bay or inshore state ocean waters
n.s. Trend was not statistically significant
Supers Data Available for
A Alewife only
B Blueback herring only
A,B Alewife and blueback herring by species
RH Alewife and blueback herring combined (river herring)
F Female. If sex is not noted, trends were either the same between sexes or the trend was evaluated for sexes combined.
M Male. If sex is not noted, trends were either the same between sexes or the trend was evaluated for sexes combined.
↔ No trend (flat or high inter-annual variability)
XXX Consensus not reached
No data. If data sets ended before the benchmark terminal year of 2010, the cell for recent trends is left blank.
*Updated recent trends reflects the most recent ten years (2006-2015). No trend indicates high inter-annual variability and stable indicates flat.
** Table reflects rivers that had data in addition to landings. Refer to the state chapter and/or coastwide summary for a complete list of assessed rivers and trends.
D Data collection discontinued since the terminal year of the benchmark assessment. Year data collection discontinued in parenthesis.
X Data collection continuous, but recommended against use in assessment update (see state chapter for details).
^NE shelf trends are from the spring, coastwide survey data which encounters river herring more frequently than the fall survey

The 2017 assessment updated the peer-reviewed, and Management Board-accepted benchmark assessment approaches with data added since the previous benchmark data terminal year (2010). The data terminal year of the 2017 update is 2015. The benchmark assessment included Atlantic coastal river herring stocks on an individual river basis for a few systems and also on a limited coastwide basis. The complex life history of anadromous species complicates coastwide assessments as it is difficult to partition in-river factors from marine factors governing population dynamics. Also complicating the assessment of river herring is the variability in data quality among rivers along the coast.

Severe declines in landings began coastwide in the early 1970s and domestic landings are now a fraction of what they were at their peak. They have remained at persistently low levels since the mid-1990s. Moratoria were enacted in Massachusetts (commercial and recreational in 2005), Rhode Island (commercial and recreational in 2006), Connecticut (commercial and recreational in 2002), Virginia (for waters flowing into North Carolina in 2007), and North Carolina (commercial and recreational in 2007, with the exception of a four-day open season in the Chowan River during the week of Easter). As of January 1, 2012, states or jurisdictions without an approved sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River Herring FMP, were also closed. As a result, prohibitions on harvest (commercial or recreational) extended to the following states: New Jersey, Delaware, Pennsylvania, Maryland, D.C., Virginia (for all waters), Georgia, and Florida. As of 2018, Maine, Massachusetts, New Hampshire, New York, and South Carolina have Sustainable Fisheries Management Plans for River Herring.

Commercial Catch Per Unit Effort (CPUE)

Of the available CPUE datasets considered in the ASMFC stock assessment (Figure 9), six datasets were not updated due to discontinuation or changes in methodology.

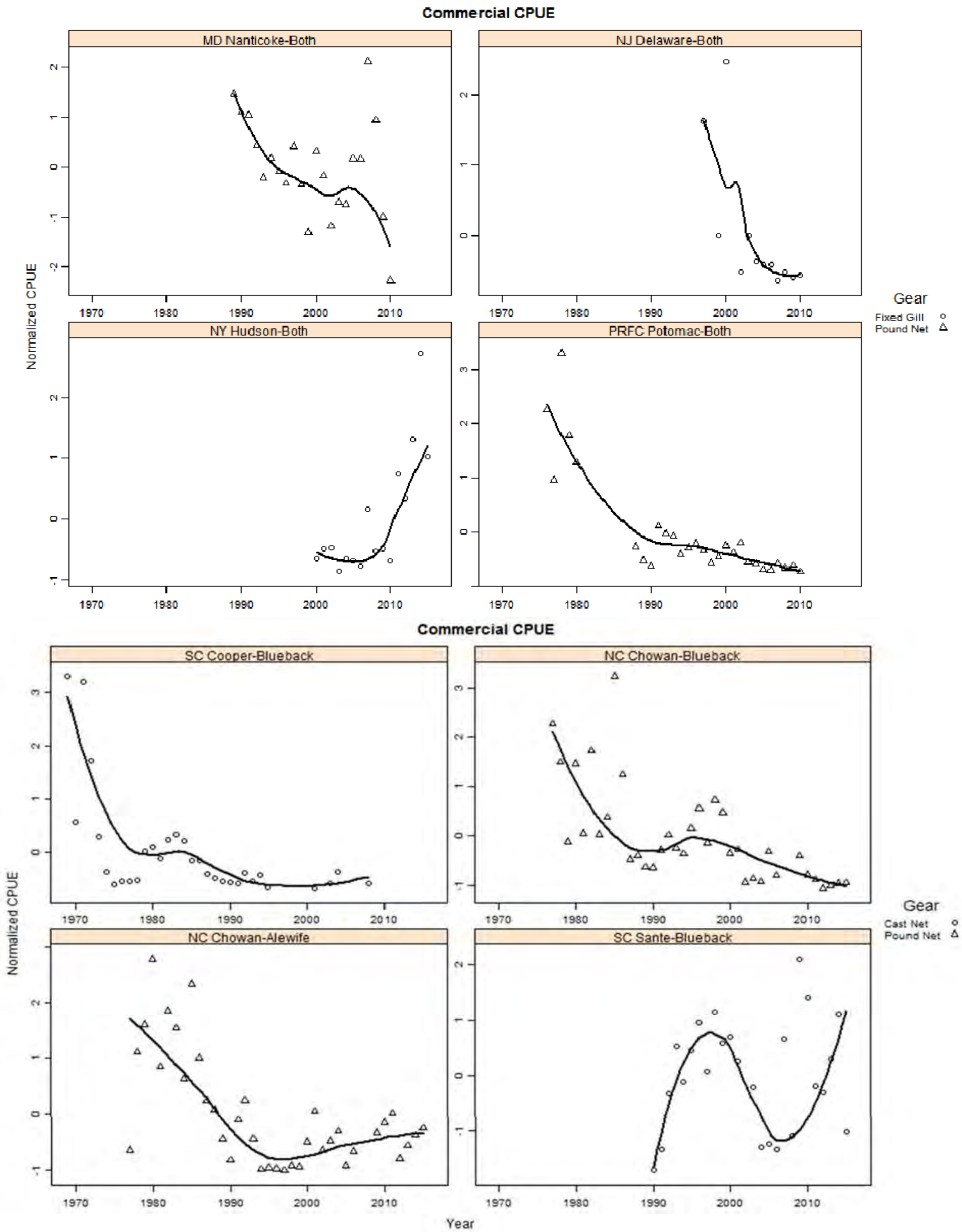


Figure 9**.** *From ASMFC 2017a.* Normalized CPUE (catch per unit effort for river herring in the Hudson River (NY), Delaware Bay (NJ), Nanticoke River (MD), Potomac River (PRFC), Chowan River (NC), Cooper River (SC), and Santee River Diversion Canal (SC) by year and gear type. Loess smooths are shown as indications of general trends.

All indices were normalized and graphed for comparative purposes. Linear and loess smoothers (Maindonald and Braun, 2003) were applied to all time series for a given state and species to elucidate trends in the annual estimates. Although offered as indices of relative abundance, the catch-per-unit effort indices discussed below need to be validated in the future.

<u>New York</u>

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 lower Hudson River 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 is summarized as total catch divided by total effort, separately by gear type (fixed gill nets, drift gill nets, and scap nets). CPUE is calculated as the number of river herring caught per unit effort (square yards of net x hours fished). CPUE of the fixed gear fishery is used as an estimate of relative abundance as the fishery is located downriver of the spawning reach and it captures river herring moving through the reach to upriver spawning locations. Only data since 2000 was used as this is when mandatory reporting was enforced. CPUE for this gear declined slightly from 2000 to about 2006 then has slowly increased since (Figure 9**:** NY Hudson). Since 2010, the CPUE for the Hudson is increasing.

<u>New Jersey</u>

New Jersey landing estimates for river herring were obtained from the NMFS for 1950 to 1999. These estimates are for the entire state and not solely from the Delaware Bay. River herring estimates for 2000 to 2010 were obtained from mandatory logbooks of the small mesh gill net fishery in Delaware Bay. The average reported landings for the time period is estimated at 8,263 pounds. There are no estimates of underreporting, however it is assumed that the current data for river herring are grossly underreported since the majority of landings are categorized as bait. New Jersey has voluntary effort data from reliable commercial fishermen in Delaware Bay. The fishery is directed towards white perch 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. CPUE has declined since 1997 (Figure 9). No additional data was entered for the update due to ongoing moratorium.

<u>Maryland</u>

River herring commercial landings and effort data from pound nets are available from the Nanticoke River. In general, CPUE has declined over time (Figure 9). No additional data was entered for the update due to ongoing moratorium.

<u>Potomac River Fisheries Commission</u>

River herring harvest in the Potomac River is almost exclusively taken by pound nets. In 1964, licenses were required to commercially harvest fish. After Maryland and Virginia established limited entry fisheries in the 1990's, the PRFC responded to industry's request and, in 1995, capped the Potomac River pound net fishery at 100 licenses. Catch-per-unit effort indices (kilograms of herring per pound net days- fished) are available from 1976-1980 and 1988-2010. CPUE indices from 1998-2008 for alewives are much lower than CPUE indices from 1976-1980 and values have declined since 1988 (Figure 9). No additional data was entered for the update due to ongoing moratorium.

Virginia

Annual commercial fishery harvest rates for alewives are available from 1994 to 2010 for selected Virginia waters. The harvest rates are computed as a ratio by dividing commercial harvest (kilograms) by the number of fishing trips for each area and gear. Only fishing trips with positive harvest of alewife were included in the calculations because only positive harvest is reported. Gill net harvest rates for alewife have been variable among Virginia water bodies from 1994 to 2007 (Figure 9). Harvest rates in the James River have been variable, but the data suggest a general decline through 2009 and an increase in 2010. In the Rappahannock River, there was no obvious trend in harvest rates over time, though a small peak is evident in 2000. A three-year period of relatively higher rates occurred from 2002 to 2004 and an increase in 2010. Gill net harvest rates in the York River were highest after 2002 and showed an increasing trend through 2010. No additional data was entered for the update due to ongoing moratorium.

North Carolina

Harvest and effort data from the pound net fishery are available for alewife and blueback herring form the Chowan River from 1977 – 2015. CPUE (harvest divided by pound net weeks fished) for alewife declined from 1977 through the late 1990s, while CPUE for blueback herring declined from 1977 through the late 1980s (Figure 9). A slight increase in CPUE for alewife was observed through 2006. Blueback CPUE increased through the late 1990s but declined thereafter. The CPUE for blueback herring has continued to decline post 2010 assessment, while alewife numbers have been variable.

South Carolina

Annual estimates of CPUE (kg catch/man day) are available since 1969 from surveys of the Santee River and Cooper River blueback herring fisheries. Estimates of CPUE fluctuated widely over the time series, trends were also affected by changes in regulations over time, especially prior to the 1990s. Estimates of CPUE were highest early in the time series in the Cooper River and declined dramatically soon after to a low that lasted through the late 1970s (Figure 9). Estimates increased 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. CPUE increased in the Rediversion Canal and the Santee River but then began to decline in the late 1990s through 2006 and have since increased. Since 2010 the CPUE has been highly variable with no discernible trend

Run Counts

It is important to note that run counts (i.e., counts of migrating fish in a particular waterbody) are only available for a small fraction of the total number of waterbodies with blueback herring or alewife populations. None of the 29 run counts considered in the 2017 stock assessment reflected declining trends over the last ten years of the updated data time series (i.e., put in the years). Eleven of 29 showed increasing trends, 14 showed no trend, and 4 were not updated (2 due to discontinuation and 2 due to state agency recommendation).

An updated cluster analysis using the most recent eight years (2008-2015; Figure 10) did not result in groupings or runs similar to the corresponding eight year period (2003-2010; Figure 11) used in the benchmark analysis. It is difficult to discern any consistent trends as to why the two periods differ, but the data suggests that rivers along the Atlantic Coast that were previously grouped together for similar trends have not been experiencing similar population trends in the years since the benchmark.

Young-Of-The-Year Seine Surveys

Inclusion of datasets from 2011 (after the benchmark assessment) through 2015 did not show any changes in trends outlined in the benchmark assessment. One of 16 young of year (YOY) seine surveys indicated a declining trend over the last ten years, 2 indicated increasing trends, and 13 indicated no trend. Indices of alewife from YOY seine surveys remained at relatively low levels similar to those seen prior to 2011. Blueback herring also remained similar to levels observed in the terminal years of the benchmark assessment, although some surveys (Virginia, Maryland, and District of Columbia) have seen increases in 2014-2015.

Juvenile-Adult Fisheries-Independent Seine, Gillnet and Electrofishing Surveys

Fisheries-independent seine CPUE for combined species in Narragansett Bay fluctuated without trend from 1988-1997, increased through 2000, declined, and then remained stable from 2001-2004, increased again in 2005, and declined in 2009. In Rhode Island's coastal pond survey, CPUE increased during 1993-1996, declined through 1998, increased in 1999, declined through 2002, peaked in 2012, and then declined and fluctuated without trend thereafter. The addition of data from 2011 to 2015 does not show a significant correlation (p=0.413) with the addition of more years of data, suggesting that the pond survey may not fully capture year-class strength.

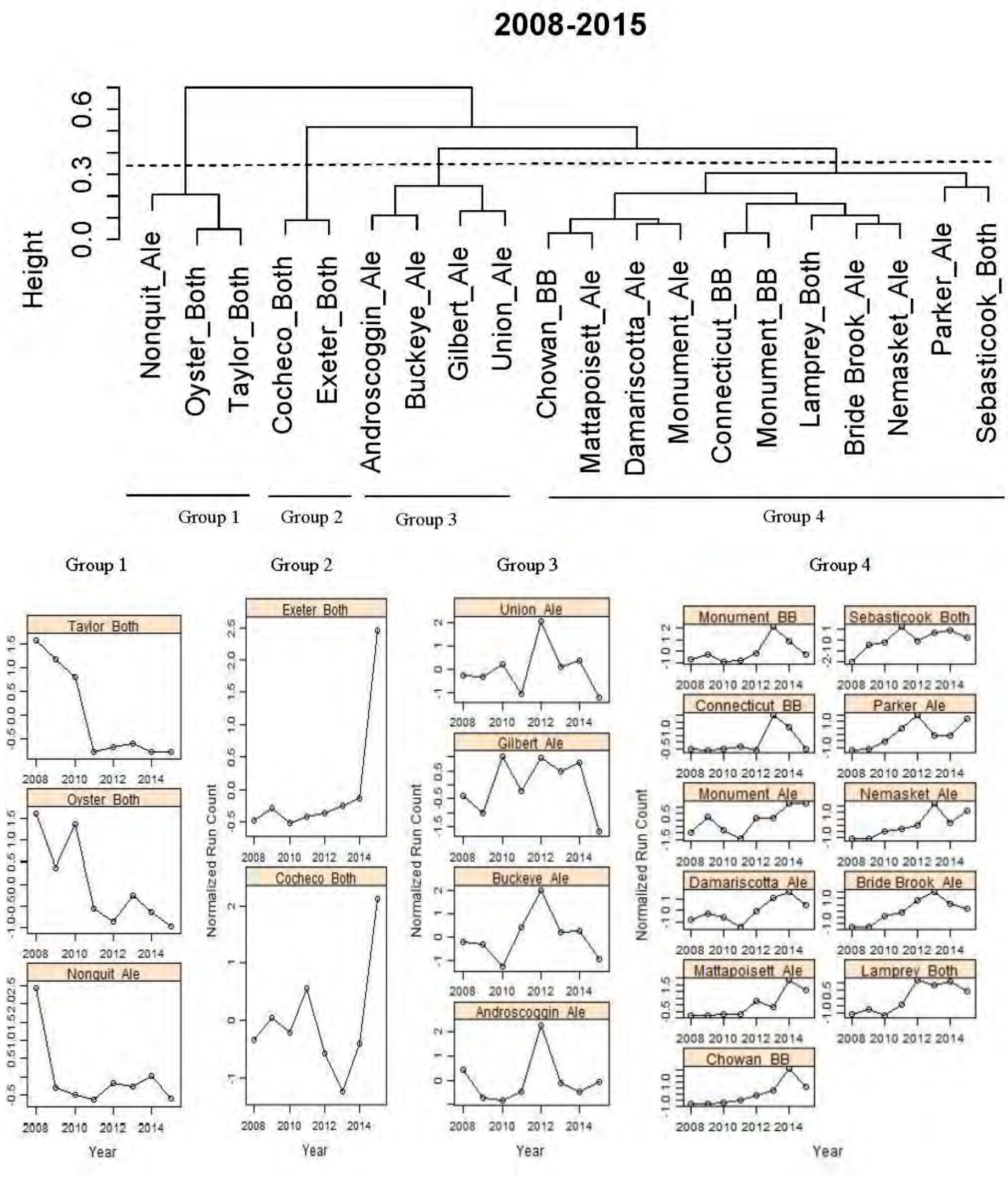


Figure 10. *From ASMFC 2017a.* Plots of river counts for each grouping associated with the cluster analysis of data from 2008-2015.

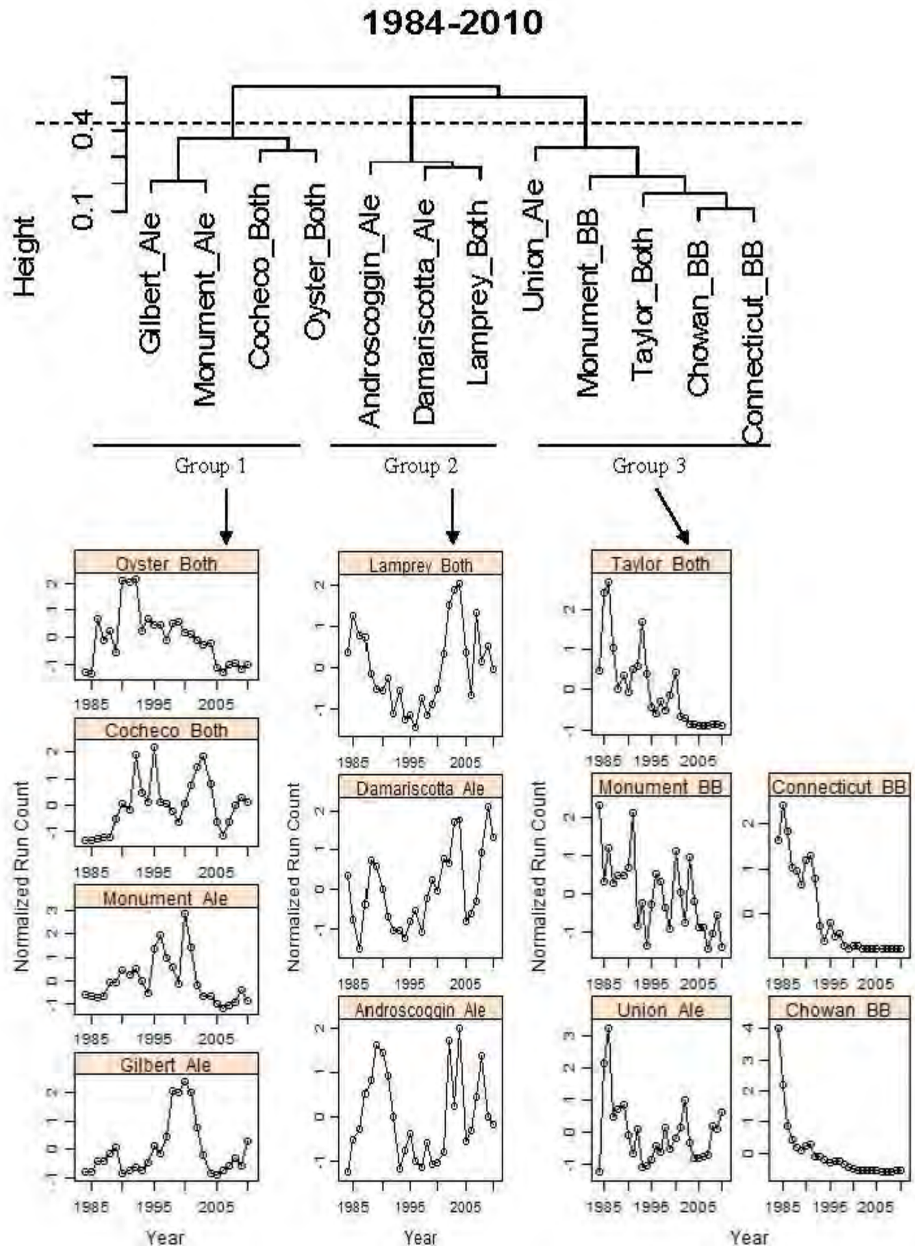


Figure 11. *From ASMFC 2017a.* Plots of river counts for each grouping associated with the cluster dendrogram analysis of data from 1984 to 2010.

In Virginia, the electrofishing CPUE indices for alewives and blueback herring in the Rappahannock and James Rivers were highly variable for the time series (2001 – 2015). The electrofishing CPUE indices for blueback herring in the St. Johns River in Florida declined precipitously from 2001 to 2002 and have fluctuated without trend since 2003. The only common trend between the Virginia and Florida electrofishing surveys occurred in 2004 and 2015 when the Rappahannock River alewife index, James River blueback herring index, and St. Johns River blueback herring index increased.

Juvenile and Adult Trawl Surveys

Trends in trawl survey indices varied greatly with one of twelve indicating a declining trend over the last ten years, four indicating increasing trends, and seven indicating no trend. Observed time series of relative abundance indices represent true changes in abundance, within survey sampling error, and varying catchability over time. One approach to minimize measurement error in the survey estimates is by using Autoregressive Integrated Moving Average Models (ARIMA, Box and Jenkins 1976). The probability of the final year of the survey being less than the 25th percentile reference point [P(<0.25)], as estimated with ARIMA, ranged from 0 to 0.464 for alewives and 0 to 0.540 for blueback herring **(**Table 2**)**. Overall, the results of the 2015 ARIMA assessment update suggest similar spatial trends as were observed in 2010 for river herring. There appeared to be a greater likelihood of trawl surveys showing a decrease for those surveys in the southern areas, particularly for alewife. However, general spatial trends in blueback were less apparent compared to alewife by region, as well as when compared to values observed in 2010 despite the updated analyses showing a greater mean likelihood of surveys below the reference point than the northern region.

Table 2. *From ASMFC 2017a.* Summary of P(<0.25) values comparing northern and southern trawl surveys for river herring. Coastwide NMFS surveys were not included in this summary. N is the number of surveys included in each region.

Species	Region	n	Min.	Max.	Median	Average
Alewife	North	7	0.000	0.148	0.009	0.037
	South	5	0.007	0.464	0.056	0.173
Blueback	North	6	0.006	0.342	0.177	0.166
	South	5	0.000	0.540	0.067	0.191

Mean Length

Updated trend analyses shows a continuation of the declining mean size of both species described in the benchmark assessment. A significant decline in mean length of alewives was found in four of the nine river systems examined. Similarly, blueback herring mean length was significantly declining in six of the nine river systems examined. Trends in mean lengths from the NEFSC bottom trawl survey were similar to those of the benchmark.

Maximum Age

Data provided in the update added little information to this visual analysis. In terms of maximum age, no trends appear reversed and most runs had stable ages. Lamprey River (NH) alewife maximum age appears to be trending upward, while Nanticoke River (MD) alewife and blueback herring and Chowan River (NC) blueback herring maximum ages appear to have dropped.

Mean Length-at-Age

Of the 112 Rivers-Species-Age combinations updated (111 with data, as there were no data available for Gilbert-Stuart Alewife Male age 6), 26 have reversed in terms of their significance when compared to the analysis performed in the benchmark assessment. Declines in mean length for at least one age were observed in most rivers examined. There is little indication of a general pattern of size changes along the Atlantic coast.

Repeat Spawner Frequency

There have been no increasing trends in the percent repeat spawners over the full data time series, with declining trends in three rivers assessed and no significant trends for all other data sets.

Total Mortality (Z) Estimates

There have been no increasing trends in empirical total mortality estimates over the last ten years of the updated data time series. Total mortality benchmarks were established during the benchmark assessment based on spawning stock biomass per recruit analyses in order to provide reference points for empirical measurements of Z. Reference points were calculated for two age-constant natural mortality estimates (0.3 and 0.7) to evaluate sensitivity of reference points to a range of potential natural mortality. The higher natural mortality results in higher reference points. Therefore, reference points calculated with the lower natural mortality can be considered more precautionary. The SAS and peer review panel favored reference points calculated with the higher natural mortality (ASMFC 2012). Three trends have declined and 10 have shown no trend. The average total mortality estimates for 2013-2016 in twelve rivers exceeded $Z_{40\%}$, M=0.7 benchmarks, while averages for two rivers were below these benchmarks. All 2008-2010 average estimates from the benchmark assessment exceeded $Z_{40\%}$, M=0.7 benchmarks.

Exploitation Rates

The annual percentage of stock removed by fishing (commercial and recreational) is known as exploitation. A relative exploitation rate of river herring was calculated using the NEFSC bottom trawl data. The data were used to calculate a minimum swept area estimate of total biomass for spring surveys (1976 to 2015; Figure 12). Minimum swept area estimates are stratified total biomass estimates calculated by expanding the biomass caught within each NEFSC bottom trawl stratum to the area of the stratum and then summing over all strata. Spring surveys were used because river herring are more readily caught during the spring than during the fall surveys (see NEFSC trawl report section in ASMFC 2017a). Estimated total catch was calculated from total reported landings, NAFO landings reported from other countries, and total incidental catch derived via hindcasting methods using the survey-scaling method (NEFSC 2008, Palmer et al. 2008). Estimated total catch was divided by total swept area estimates of biomass to yield an index of relative exploitation. The relative exploitation index was developed for the coastwide population rather than regional populations because estimates of total incidental catch could not be partitioned among regions or discrete river stocks. Coastwide relative exploitation since the benchmark stock assessment is the lowest of the time series, averaging 0.05 (Figure 13)

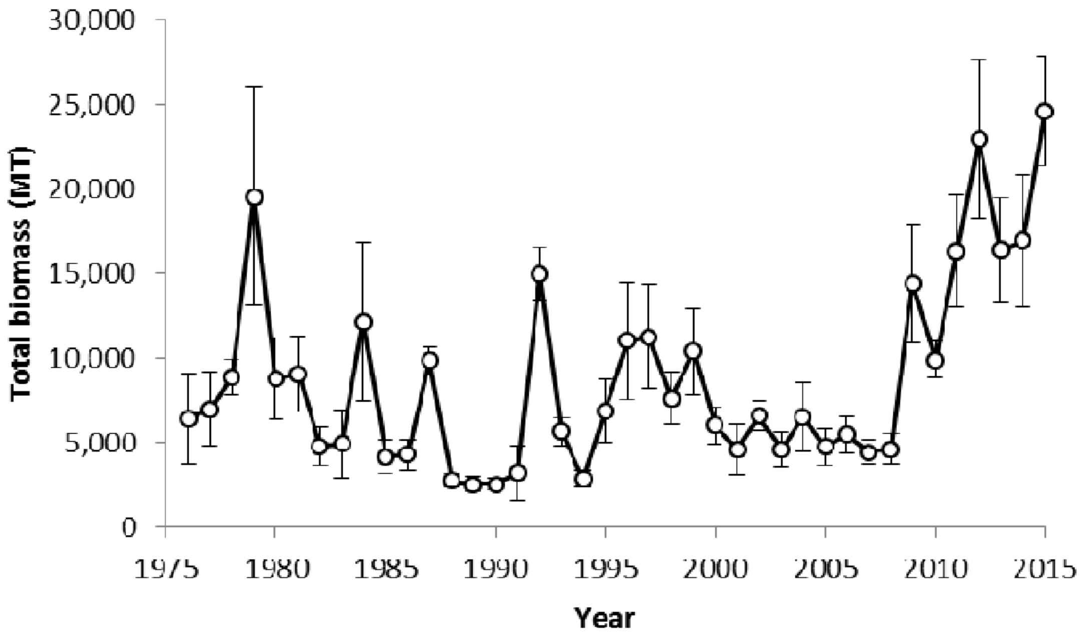


Figure 12. From ASMFC 2017a. Minimum swept area estimates of total river herring biomass from NEFSC spring bottom trawl surveys (1976-2015).

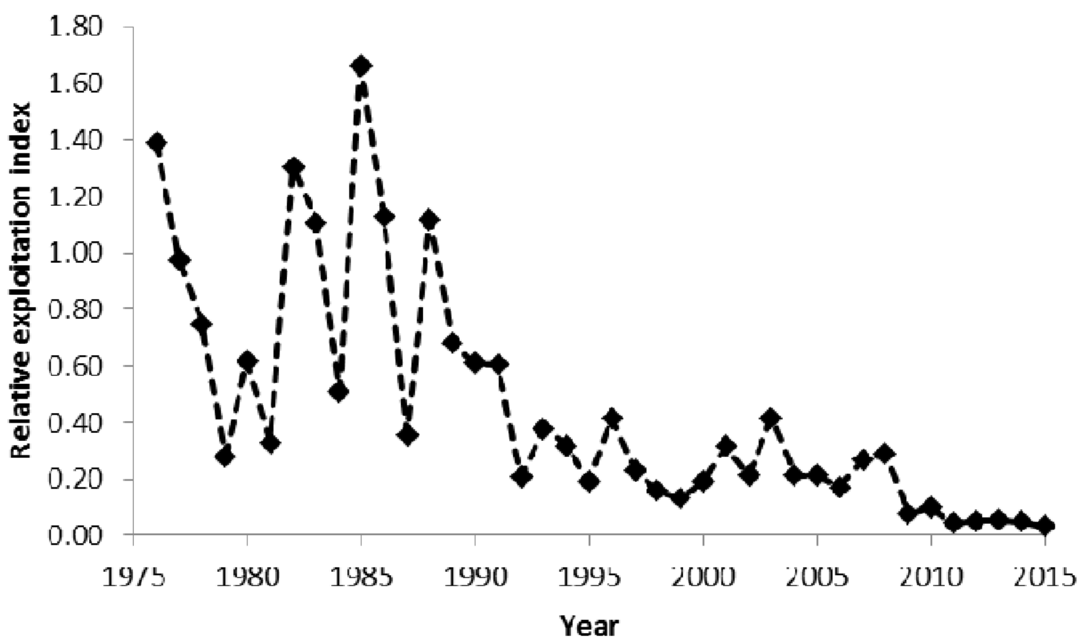


Figure 13. From ASMFC 2017a. Relative exploitation of river herring (1976-2015).

Summary

Of the 54 in-river stocks of river herring for which data were available, 16 experienced increasing trends from 2006 through 2015, 2 experienced decreasing trends, 8 were stable, 10 experienced no discernible trend/high variability, and 18 did not have enough data to assess recent trends, including one that had no returning fish. The coastwide meta-complex of river herring stocks on the U.S. Atlantic coast remains depleted to near historic lows. A depleted status indicates that there was evidence for declines in abundance due to a number of factors, but the relative importance of these factors in reducing river herring stocks could not be determined. Commercial landings of river herring peaked in the late 1960s, declined rapidly through the 1970s and 1980s and have remained at levels less than 3 percent of the peak over the past decade. Estimates of run sizes varied among rivers, but in general, declining trends in run size were evident in many rivers over the last decade. Fisheries-independent surveys did not show consistent trends and were quite variable both within and among surveys. Those surveys that showed declines tended to be from areas south of Long Island. A problem with the majority of fisheries-independent surveys was that the length of their time series did not overlap the period of peak commercial landings (i.e., prior to 1970). There appears to be a consensus among various assessment methodologies that exploitation has decreased. The decline in exploitation over the past decade is not surprising because river herring populations are at low levels and more restrictive regulations or moratoria have been enacted by states.

3.1.2 Canadian Waters

The Department of Fisheries and Oceans (DFO) monitors and manages river herring runs in Canada. River herring monitoring in the Maritime region falls into two categories, rivers where abundances can be directly estimated (e.g. monitoring at fishways), and rivers where information is available from the commercial fishery (Gibson *et al.* 2017). River herring runs in the Miramichi River in New Brunswick and the Margaree River in Cape Breton, Nova Scotia were monitored intensively from 1983 to 2000 (DFO 2001). More recently (1997 to 2017), the Gaspereau River alewife run and harvest has been intensively monitored and managed partially in response to a 2002 fisheries management plan that had a goal of increasing spawning escapement to 400,000 adults (DFO 2007). During the period of 1970 to 2017, Billard (2017) estimated run size of alewife in the Gaspereau from 265,000 to 1.2 million. The exploitation rate for this same period ranged from 33 percent to 89 percent. Billard (2017) classified the most recent years 2015 and 2016 as having healthy escapement rates, but overexploited as a fishery. Elsewhere, river herring runs have been monitored less intensively, though harvest rates are monitored throughout Atlantic Canada through license sales, reporting requirements, and a logbook system that was enacted in 1992 (DFO 2001). At the time DFO conducted their last stock assessment in 2001, they identified river herring harvest levels as being low (relative to historical levels) and stable to low and decreasing across most rivers where data were available (DFO 2001).

With respect to the commercial harvest of river herring, reported landings of river herring peaked in 1980 at slightly less than 25.5 million lbs (11,600 metric tons (mt) and declined to less than 11 million lbs (5,000 mt) in 1996. Landings data reported through DFO indicate that river herring harvests have continued to decline through 2010.

3.1.3 Trends in Range-wide Abundance (U.S. and Canada)

Trends in the range-wide relative abundance of each species were quantitatively assessed by updating the Multivariate Autoregressive State-Space (MARSS) models developed for the 2013 status review to include the most recent years of data (through 2017). MARSS modeling is an established method for estimating population growth rates (Holmes et al. 2012, Holmes et al. 2018, Holmes et al. 2019). Using methodology outlined in NEFSC (2013), two model runs were updated for the SRT: 1) alewife range-wide and, 2) blueback herring range-wide. While the technical methodology remained the same, the classifications (described in the *Population Projections and Model Analysis* section of NEFSC 2013) were abandoned. Only the growth rate and corresponding uncertainty estimates were presented to SRT for consideration in the qualitative assessment (see Section 6 Extinction Risk Analysis).

When originally analyzing potential datasets for this rangewide analysis, the 2011 Extinction Risk Analysis working group (NMFS 2012b) selected surveys that occurred entirely in coastal/oceanic waters and therefore were considered to be representative of the mixed stock for each species (i.e. a combination of all alewife stock complexes or all blueback herring stock complexes) and not representative of only one particular stock complex. The 2011 working group determined that including datasets from specific rivers, bays or sounds would depict the specific stock complex in which it was located (and would therefore potentially bias the analysis), not the mixing of stock complexes that occurs in coastal/oceanic waters. Therefore, the 2013 status review team chose to include the NEFSC spring and fall bottom trawl surveys (number-per-tow) as well as Canada's Scotian Shelf survey (tonnes). The NEFSC bottom trawl surveys, due to their large geographic footprint (Cape Hatteras NC through the Gulf of Maine) are thought to be representative of the mixed stocks in coastal waters. Furthermore, the Scotian Shelf summer survey was included because the Scotian Shelf is not fully sampled by the two NEFSC bottom trawl surveys and this survey was also thought to be representative of the mixed stocks. Additional details about these surveys can be found in NEFSC (2013).

In the updated models for this status review, relative abundance estimates for spring 2014 and fall 2017 from the NEFSC bottom trawl surveys were omitted due to incomplete sampling of the survey area (in spring 2014 stations south of Delaware Bay were not sampled and in fall 2017 most of southern New England and the mid-Atlantic were not sampled). Relative abundance (i.e. an index of abundance) "is a relative measure of the size of a population or sub-unit of the population.... it is usually measured as number (or weight) of fish caught per standard unit of fishing effort" (VIMS 2018). For example, the indices developed from the NEFSC bottom trawl surveys are relative abundance estimates because the units are number of fish per tow where the tow is the standard unit of fishing effort.

The growth rate estimated in each MARSS model represents a population growth rate (in contrast to a per-capita (i.e. per individual fish) rate). In Holmes et al. (2019), the growth rate estimated in the MARSS model is described as "the average long-term population growth rate." Whether the estimated growth rate is an average population or per-capita population growth rate, it still is representative of the average trends of the population, which is what this analysis sought to quantify. The estimated growth rates represent a 'realized' growth rate not a 'maximum' growth rate.

The estimated population growth rate for alewife was 0.038 with 95% confidence intervals of 0.006-0.071. For blueback herring, the estimated population growth rates was 0.066 with a 95% confidence interval of -0.013-0.144. This range-wide perspective represents a mixing of the stock complexes identified in Reid et al. (2018); as individual stock complexes are thought to mix extensively in the ocean environment.

3.1.4 Age and Mortality Uncertainty

Uncertainty Related to Age and Mortality Estimates

River herring have been aged historically using scales, using protocols first developed by Cating (1953) for American shad and Marcy (1969) for river herring. Although used extensively, these protocols have not been validated with known-age fish, and there had not been many efforts to standardize river herring ageing across states prior to the benchmark assessment. In recent years, several studies focused on American shad have concluded that Cating's (1953) method for ageing shad scales should no longer be used (Duffy et al. 2012, Elzey et al. 2015). Additionally, some labs have switched to ageing river herring with otoliths since the benchmark assessment. Otolith protocols have not been validated with known-age fish either. As with any ageing method, there is the potential for bias both between labs and within labs over time as personnel change and methods are not consistently standardized. An age sample exchange and subsequent workshop were conducted stemming from recommendations in the benchmark assessment. A report details the varying degree of ageing error identified during this process between age structures and among labs providing age data for assessments (ASMFC 2014). Recommendations were made in an effort to standardize ageing practices across labs, but efforts should continue to assess ageing error and best practices.

Total mortality rates reflect the combined impact of intensive fisheries, spawning mortality, predation, and mortality associated with downstream passage at hydroelectric dams in some systems. Almost no rivers have sufficient information to separate mortality into these sources. There are no empirical estimates of natural mortality associated with spawning. Inferences about its magnitude are based almost entirely on total mortality rates and spawning marks on scales. Although interpretation of spawning marks on scales is not yet a validated method, spawning marks may help in establishing the magnitude of spawning mortality in the future.

4 ASSESSMENT OF THE ESA SECTION 4(A)(1) FACTORS

4.1 Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

The ESA requires an evaluation of any present or threatened destruction, modification, or curtailment of habitat or range. The SRT identified the following threats (discussed in the sections below) may impact the habitat of alewife and blueback herring: global climate change, habitat modifications from dams and other barriers, dredging, water quality, and water withdrawal/outfall.

4.1.1 Climate Change and Climate Variability

River herring range from Canada through Florida in both marine and freshwater environments, and, in many of these areas, there has been reported environmental change. For example, the climate of the Northeast U.S. Continental Shelf is changing both as a result of anthropogenic climate change and natural climate variability (Hare et al. 2016a, Hare et al. 2016b). Ocean temperature over the last decade in the U.S. Northeast Shelf and surrounding Northwest Atlantic waters have warmed faster than the global average (Pershing et al. 2015). New projections also suggest that this region will warm two to three times faster than the global average from a predicted northward shift in the Gulf Stream (Saba et al. 2016). Hare et al. (2016a) provides a literature summary of how the climate system is changing on the U.S. Northeast Shelf including a high rate of sea-level rise, as well as increases in annual precipitation and river flow, magnitude of extreme precipitation events, and magnitude and frequency of floods. NMFS (2017a) provides a literature summary of climate change drivers in the South Atlantic, which include warming ocean temperatures and sea level rise. Increases in water temperature, coupled with associated changes in water composition, are believed to be one of the most significant risk drivers related to the oceans and freshwater in Canada (DFO 2012). Research to better understand how climate change and variability impact living resources is important (Hare et al. 2016a, Hare et al. 2016b, DFO 2012).

4.1.2 Climate Change and Vulnerability

Diadromous fish are amongst the functional groups with the highest overall climate vulnerability to climate change based on a recent fish vulnerability assessment (Hare et al. 2016a). Functional groups in the analysis included coastal fish, diadromous fish, elasmobranchs, groundfish, benthic invertebrates, and pelagic fish and cephalopods. Hare et al. (2016a) rated both alewife and blueback herring as having a "high" biological sensitivity and a "very high" climate exposure likelihood (on a scale of "low" to "very high") off the Northeast U.S. Continental Shelf. Vulnerability was defined as the likelihood that the productivity or abundance of the species could be impacted in response to climate change (Hare et al. 2016a). The factors responsible for the "very high" overall vulnerability rating for both alewife and blueback herring included, but were not limited to, early life history requirements (which is "high" for biological sensitivity) and ocean surface and air temperature (which is "very high" for climate exposure) (Hare et al. 2016a). This vulnerability analysis concluded that there was also a "medium" distributional vulnerability rank for blueback herring and "low" distributional vulnerability rank for alewife. Regarding the distributional vulnerability rank results, Hare et al. (2016a) described the high degree of spawning site fidelity for both species, but noted the wide distributional range for blueback herring provided more opportunity for straying (Hare et al. 2016a). The effect of climate change on alewife is expected to be "negative" with changes in marine distribution and decreases in productivity primarily in the southern portion of the range, whereas the effect of climate change on blueback herring is estimated to be "neutral" although this estimate had a high degree of uncertainty (Hare et al. 2016a). Hare et al. (2016a) noted that the quality of information available for ranking (i.e., data quality scores) in the vulnerability assessment for both blueback herring and alewife was "moderate."

There have been observed changes in river herring biology related to environmental conditions (e.g., NMFS 2012c), but few detailed analyses are available to distinguish climate change from climate variability (NMFS 2017b). Detailed studies on the impacts of climate change and variability on river herring throughout their range are important. The recent vulnerability assessment identified attributes that influence resilience to climate change and characterized the risk posed to specific species but did not measure species shifts in distribution spatially or temporally (Kleisner et al. 2017). Quantitative studies on the impacts of climate changes on river herring in marine and freshwater environments have been completed recently which provide information to help further understand the issue and needed next steps.

Lynch et al. (2015) projected potential effects of ocean warming along the U.S. Atlantic coast on river herring in the marine environment by linking species distribution models to projected temperature changes from global climate models. They considered the spring and fall seasons during two future periods (2020-2060 and 2060-2100). Lynch et al. (2015) found that climate change will likely result in reduction in the amount of preferred marine habitat and a potential northward shift in marine distribution. They also found that both blueback herring and alewife densities will likely decrease in fall but may increase in spring (Lynch et al. 2015). Lynch et al. (2015) also reported that under a low abundance scenario, river herring may have greater sensitivity to climate change. They suggested additional studies to further the work and address uncertainties associated with their study.

Tommasi et al. (2015) assessed how river flow and temperature affects young of the year river herring recruitment in five freshwater habitats in the Northeast United States. They found that the conditions in nursery habitats are important as early summer river flow and temperature had the greatest influence (Tommasi et al. 2015). Spring or fall conditions were also important indicators of survival in some systems and suggested additional environmental effects on spawning of juvenile and adults egress from freshwater nursery habitats (Tommasi et al. 2015). This study allowed for a preliminary discussion of potential mechanisms that influence river herring and suggested additional focused laboratory and field studies (Tommasi et al. 2015). Klauda et al. (1991a) provides an extensive review of temperature thresholds for alewife and blueback herring (also see **Reproduction, Demography and Growth**).

Important efforts have occurred the last few years to help understand how river herring will respond to a changing climate, and many are underway. Studies to date indicate river herring are highly vulnerable to climate change. Although information on the climate drivers and impacts of climate change on river herring are available, gaps still remain. Detailed information is needed on climate change and climate variability impacts to these vulnerable species to inform management (Hare et al. 2016b). These include considering the entire life history of river herring dynamics and the effects of climate change and variability as an important next step (Tommasi et al. 2015).

4.1.3 Dams and Other Barriers

Dams and other barriers to upstream and downstream passage (e.g., culverts) can block or impede access to habitats necessary for spawning and rearing; can cause direct and indirect mortality from injuries incurred while passing over dams, through downstream passage facilities, or through hydropower turbines; and can degrade habitat features necessary to support essential river herring life history functions. As described in more detail below, dams are also known to impact river herring through various mechanisms, such as habitat alteration, fish passage delays, and entrainment (injury from transport along with the flow of water) and impingement (injury related to colliding with any part of a dam; Ruggles 1980, NRC 2004). River herring can experience delayed mortality from injuries such as scale loss, lacerations, bruising, eye or fin damage, or internal hemorrhaging when passing through turbines, over spillways, and through bypasses (Amaral et al. 2012). Man-made barriers that block or impede access to rivers throughout the entire historical range of river herring have resulted in significant losses of historical spawning habitat for river herring.

Dams and other man-made barriers have contributed to the historical and current declines in abundance of both blueback herring and alewife populations. While estimates of habitat loss over the entire range of river herring are not available, estimates from studies in Maine show that less than 5% of lake spawning habitat and 20% of river habitat remains accessible for river herring (Hall et al. 2010). Mattocks et al. (2017) estimated that, due to damming, only 6.7% and 7.9% of stream habitat in the Connecticut and Merrimack Rivers, respectively, is accessible. The Merrimack and Thames-Pawtucket watersheds had the greatest losses in lake habitat due to damming with 2.8% and 6.4%, respectively, available in 1900. Total biomass lost due to damming from 1630 to 2014 was estimated to be 7 million mt in freshwater and 2.4 million mt in marine waters (Mattocks et al. 2017).

Excerpt from ASMFC (2009):

> Dams and spillways impeding rivers along the East Coast of the United States have resulted in a considerable loss of historical spawning habitat for river herring. Permanent man-made structures pose an ongoing barrier to fish passage unless fishways are installed or the structures are removed. Low-head dams can also pose a problem, as fish are unable to pass over them except when tides or river discharges are exceptionally high (Loesch and Atran 1994).
>
> Historically, major dams were constructed at the site of natural formations conducive to waterpower, such as natural falls. Diversion of water away from rapids at the base of falls can reduce fish habitat at the base or, in some cases, cause rivers to run dry at the base for much of the summer (MEOEA 2005). Prior to the early 1990s, it was thought that migrating shad and river herring suffered significant mortality going through turbines during downstream passage (Mathur and Heisey 1992). Juvenile shad emigrating from rivers were to accumulate in larger numbers near the forebay of hydroelectric facilities, where they become entrained in intake flow areas (Martin et al. 1994). Relatively high mortality rates were reported (62% to 82%) at a hydroelectric dam for juvenile American shad and blueback herring, depending on the power generation levels tested (Taylor and Kynard 1984). In contrast, Mathur and Heisey (1992) reported a mortality rate of 0% to 3% for juvenile American shad (2 to 6 in fork length (55 to 140 mm)) and 4 percent for juvenile blueback herring (3 to 4 in fork length (77 to 105 mm)) through Kaplan turbines. Mortality rates for all species increased to 11% in passage through a low-head Francis turbine (Mathur and Heisey 1992). Other studies reported less than 5% mortality when large Kaplan and fixed- blade, mixed-flow turbines were used at a facility along the Susquehanna River (RMC 1990, RMC 1994). At the same site, using small Kaplan and Francis runners, the mortality rate was as high as 22% (NA 2001). At another site, mortality rate was about 15% where higher revolution, Francis-type runners were used (RMC 1992). Additional studies reported that changes in pressure had a more pronounced effect on juveniles with thinner and weaker tissues as they moved through turbines (Taylor and Kynard 1984). Furthermore, some fish may die later from stress, or become weakened and more susceptible to predation, and as such, losses may not be immediately apparent to researchers (Gloss 1982).
>
> Changes to the river system, resulting in delayed migration among other things, were also identified in Amendment 2 as affecting river herring. Amendment 2 notes that when juvenile alosines delay out-migration, they may concentrate behind dams and become more susceptible to actively feeding predators. They may also be more vulnerable to anglers that target alosines at fixed structures as a source of bait. Delayed out-migration can also make juvenile alosines more susceptible to marine predators that they may have avoided if they had followed their natural migration patterns (McCord 2005). In open rivers, juvenile alosines gradually move seaward in groups that are likely spaced according to the spatial separation of spawning and nursery grounds (Limburg 1996). Releasing water from dams and impoundments (or reservoirs) may alter water flow and sediment transport, disrupt nutrient availability, change downstream water quality and temperature, erode streambanks, concentrate sediments and pollutants, change species

composition, and solubilize iron and manganese and their absorbed or chelated ions, and hydrogen sulfide (Yeager 1995, Erkan 2002).

Many dams spill water over the top of the structure where water temperatures are the warmest, essentially creating a series of warm water ponds in place of the natural stream channel (Erkan 2002). Other times, water is released from deep reservoirs. These waters may be poorly oxygenated, at below-normal seasonal water temperature, or both, thereby causing loss of suitable spawning or nursery habitat in otherwise habitable areas.

Reducing flows can reduce the amount of water available and cause increased water temperature or reduced dissolved oxygen levels (ASMFC 1985, ASMFC 1999, USFWS et al. 2001). Such conditions have occurred along the Susquehanna River at the Conowingo Dam, Maryland, from late spring through early fall, and have historically caused large fish kills below the dam (Krauthamer and Richkus 1987). Disruption of seasonal flow rates in rivers can impact upstream and downstream migration patterns for adult and juvenile alosines (ASMFC 1985, Limburg 1996, ASMFC 1999, USFWS et al. 2001). Changes to natural flows can also disrupt natural productivity and availability of zooplankton that larval and early juvenile alosines feed on (Crecco and Savoy 1987, Limburg 1996).

Most dams that affect diadromous fish are located upstream from the mouth of the river. However, these fish can also be affected by hydroelectric projects at the mouths of rivers, such as the large tidal hydroelectric project at the Annapolis River in the Bay of Fundy, Canada. This particular basin and surrounding waters are used as foraging areas during summer months by river herring American shad from all runs along the East Coast of the United States (Dadswell et al. 1983). Because the facilities are tidal hydroelectric projects, fish may move in and out of the impacted areas with each tidal cycle. While turbine mortality is relatively low with each passage, the repeated passage in and out of these facilities may cumulatively result in substantial overall mortalities (Scarratt and Dadswell 1983).

Additional man-made structures that may obstruct upstream passage include: tidal and amenity barrages (barriers constructed to alter tidal flow for aesthetic purposes or to harness energy); tidal flaps (used to control tidal flow); mill, gauging, amenity, navigation, diversion, and water intake weirs; fish counting structures; and earthen berms (Durkas 1992, Solomon and Beach 2004). The impact of these structures is site-specific and will vary with a number of conditions including head drop, form of the structure, hydrodynamic conditions upstream and downstream, condition of the structure, and presence of edge effects (Solomon and Beach 2004). Road culverts are also a significant source of blockage. Culverts are popular, low-cost alternatives to bridges when roads must cross small streams and creeks. Although the amount of habitat affected by an individual culvert may be small, the cumulative impact of multiple culverts within a watershed can be substantial (Collier and Odom 1989). Roads and culverts can also impose significant changes in water quality. Winter runoff in some states may include high concentrations of road salt, while stormwater flows in the summer may cause thermal stress and bring high concentrations of other pollutants (MEOEA 2005).

> Sampled sites in North Carolina revealed river herring upstream and downstream of bridge crossings, but no herring were found in upstream sections of streams with culverts. Even structures only 8 to 12 in (20 to 30 cm) above the water can block river herring migration (ASMFC 1999). Rivers can also be blocked by non- anthropogenic barriers, such as beaver dams, waterfalls, log piles, and vegetative debris. These blockages may hinder migration, but they can also benefit by providing adhesion sites for eggs, protective cover, and feeding sites (Klauda et al. 1991b). Successful passage at these natural barriers often depends on individual stream flow characteristics during the fish migration season.

4.1.4 Dredging and Habitat Alteration

Wetlands provide migratory corridors and spawning habitat for river herring. The combination of incremental losses of wetland habitat, changes in hydrology, and inputs of nutrients and chemicals over time, can be extremely harmful, resulting in diseases and declines in the abundance and quality of habitat. Wetland loss is a cumulative impact that results from activities related to dredging/dredge spoil placement, port development, marinas, solid waste disposal, ocean disposal, and marine mining. In the late 1970s and early 1980s, the United States was losing wetlands at an estimated rate of 300,000 acres (1,214 sq km) per year. The Clean Water Act and state wetland protection programs helped decrease wetland losses to 117,000 acres (473 sq km) per year between 1985 and 1995. Estimates of total wetland loss vary according to the different agencies. The U.S. Department of Agriculture attributes 57% of wetland loss to development, 20% agriculture, 13% creation of deepwater habitat, and 10% forest land, rangeland, and other uses. Of the wetlands lost between 1985 and 1995, the USFWS estimates that 79% wetlands were lost to upland agriculture. Urban development and other types of land use activities were responsible for 6% and 15% of wetland loss, respectively.

Excerpt ASMFC (2009):

> Channelization can cause significant environmental impacts (Simpson et al. 1982, Brookes 1988), including bank erosion, elevated water velocity, reduced habitat diversity, increased drainage, and poor water quality (Hubbard 1993). Dredging and disposal of spoils along the shoreline can also create spoil banks, which block access to sloughs, pools, adjacent vegetated areas, and backwater swamps (Frankensteen 1976). Spoil banks are often unsuitable habitat for fishes. Suitable habitat is often lost when dredge disposal material is placed on natural sand bars and/or point bars. The spoil is too unstable to provide good habitat for the food chain. Dredging may also release contaminants, resulting in bioaccumulation, direct toxicity to aquatic organisms, or reduced dissolved oxygen levels (Morton 1977). Furthermore, careless land use practices may lead to erosion, which can lead to high concentrations of suspended solids (turbidity) and substrate (siltation) in the water following normal and intense rainfall events. This can displace larvae and juveniles to less desirable areas downstream and cause osmotic stress (Klauda et al. 1991, ASMFC 2009). Draining and filling, or both, of wetlands adjacent to rivers and creeks in which alosines spawn has eliminated spawning areas in North Carolina (NCDENR 2000, ASMFC 2009).

Migrating adult river herring avoid channelized areas with increased water velocities. Several channelized creeks in the Neuse River basin in North Carolina have reduced river herring distribution and spawning areas (Hawkins 1979). Frankensteen (1976) found that the channelization of Grindle Creek, North Carolina removed in-creek vegetation and woody debris, which had served as substrate for fertilized eggs.

Channelization can also reduce the amount of pool and riffle habitat (Hubbard 1993), which is an important food-producing area for larvae (Keller 1978, Wesche 1985).

Dredging can negatively affect alosine populations by producing suspended sediments (Reine et al. 1998), as migrating alosines are known to avoid waters of high sediment load (ASMFC 1985, Reine et al. 1998). Filter-feeding fishes, such as alosines, can be negatively impacted by suspended sediments on gill tissues (Cronin et al. 1970). Suspended sediments can clog gills that provide oxygen, resulting in lethal and sub-lethal effects to fish (Sherk et al. 1974 and 1975). Nursery areas along the shorelines of the rivers in North Carolina have been affected by dredging and filling, as well as by erection of bulkheads; however, the degree of impact has not been measured. In some areas, juvenile alosines were unable to enter channelized sections of a stream due to high water velocities caused by dredging (ASMFC 2000).

Secondary impacts from channel formation include loss of vegetation and debris, which can reduce habitat for invertebrates and result in reduced quantity and diversity of prey for juveniles (Frankensteen 1976). Additionally, stream channelization often leads to altered substrate in the riverbed and increased sedimentation (Hubbard 1993), which in turn can reduce the diversity, density, and species richness of aquatic insects (Chutter 1969, Gammon 1970, Taylor 1977). Suspended sediments can reduce feeding success in larval or juvenile fishes that rely on visual cues for plankton feeding (Kortschal et al. 1991). Sediment resuspension from dredging can also deplete dissolved oxygen, and increase bioavailability of any contaminants that may be bound to the sediments (Clark and Wilber 2000).

4.1.5 Water Quality

Nutrient enrichment has become a major cumulative problem for many coastal waters. Nutrient loading results from the individual activities of coastal development, marinas and recreational boating, sewage treatment and disposal, industrial wastewater and solid waste disposal, ocean disposal, agriculture, and aquaculture. Excess nutrients from land-based activities accumulate in the soil, pollute the atmosphere, and groundwater, and move into streams and coastal waters. Nutrient inputs have a direct effect on water quality. For example, nutrient enrichment can stimulate growth of phytoplankton that consumes oxygen when they decay, which can lead to low dissolved oxygen that may result in fish kills (Correll 1987, Tuttle et al.1987, Klauda et al. 1991b); this condition is known as eutrophication.

From the 1950s to the present, increased nutrient loading has made hypoxic conditions more prevalent (Officer et al. 1984, Mackiernan 1987, Jordan et al. 1992, Kemp et al. 1992, Cooper and Brush 1993, Secor and Gunderson 1998). Hypoxia is most likely caused by eutrophication, due mostly to non-point source pollution (e.g., industrial fertilizers used in agriculture) and point source pollution (e.g., urban sewage). In addition to the direct cumulative effects incurred by development activities, inshore and coastal habitats are also threatened by persistent increases in certain chemical discharges. The combination of incremental losses of wetland habitat, changes in hydrology from chanelization, and nutrient and chemical inputs produced over time can be extremely harmful to marine and estuarine biota, including river herring, resulting in diseases and declines in the abundance and quality of the affected resources.

Excerpt from ASMFC (2009):

> The effects of land use and land cover on water quality, stream morphology, and flow regimes are numerous, and may be the most important factors determining quantity and quality of aquatic habitats (Boger 2002). Studies have shown that land use influences dissolved oxygen (Limburg and Schmidt 1990), sediments and turbidity (Comeleo et al. 1996, Basnyat et al. 1999), water temperature (Hartman et al. 1996, Mitchell, 1999), pH (Osborne and Wiley 1988, Schofield 1992), nutrients (Peterjohn and Correll 1984, Osborne and Wiley 1988, Basnyat et al. 1999), and flow regime (Johnston et al. 1990, Webster et al. 1992). O'Connell and Angermeier (1999) found that in some Virginia streams, there was an inverse relationship between the proportion of a stream's watershed that was agriculturally developed and the overall tendency of the stream to support river herring runs. In North Carolina, cropland alteration along several creeks and rivers significantly reduced river herring distribution and spawning areas in the Neuse River basin (Hawkins 1979).
>
> Atmospheric deposition occurs when pollutants (e.g. nitrates, sulfates, ammonium, and mercury) are transferred from the air to the earth's surface. Pollutants can get from the air into the water through rain and snow, falling particles, and absorption of the gas form of the pollutants into the water. Atmospheric pollutants can result in increased eutrophication (Paerl et al. 1999) and acidification of surface waters (Haines 1981). Atmospheric nitrogen deposition in coastal estuaries can lead to accelerated algal production (or eutrophication) and water quality declines (e.g., hypoxia, toxicity, and fish kills) (Paerl et al. 1999). Nitrate and sulfate deposition is acidic and can reduce stream pH (measure of the hydronium ion concentration) and elevate toxic forms of aluminum (Haines 1981). When pH declines, the normal ionic salt balance of the fish is compromised and fish lose body salts to the surrounding water (Southerland et al. 1997). Sensitive fish species can experience acute mortality, reduced growth, skeletal deformities, and reproductive failure (Haines 1981).
>
> Decreased water quality from sedimentation became a problem with the advent of land-clearing agriculture in the late 18th century (McBride 2006). Agricultural practices can lead to sedimentation in streams, riparian vegetation loss, influx of nutrients (e.g., inorganic fertilizers and animal wastes), and flow modification (Fajen and Layzer 1993). Agriculture, silviculture, and other land use practices can lead to sedimentation, which reduces the ability of semi-buoyant eggs and adhesive eggs to adhere to substrates (Mansueti 1962).

Siltation, caused by erosion due to land use practices, can kill submerged aquatic vegetation (SAV). SAV can be adversely affected by suspended sediment concentrations of less than 15 ppm (15 mg/L) (Funderburk et al. 1991) and by deposition of excessive sediments (Valdes-Murtha and Price 1998). The vegetation improves water quality (Carter et al., 1991). It consumes nutrients in the water and, as the plants die and decay, nutrients are released back into the water column. Additionally, through primary production and respiration, SAV affects the dissolved oxygen and carbon dioxide concentrations, alkalinity, and pH of the waterbody. SAV beds also bind sediments to the bottom resulting in increased water clarity, and they provide refuge habitat for migratory fish and planktonic prey items (Maldeis 1978, Monk 1988, Killgore et al. 1989).

Logging activities can modify hydrologic balances and in-stream flow patterns, create obstructions, modify temperature regimes, and add nutrients, sediments, and toxic substances into river systems. Loss of riparian vegetation can result in fewer refuge areas for fish from fallen trees, fewer insects for fish to feed on, and reduced shade along the river, which can lead to increased water temperatures and reduced dissolved oxygen (EDF 2003). Threats from deforestation of swamp forests include: siltation from increased erosion and runoff; decreased dissolved oxygen (Lockaby et al. 1997); and disturbance of food-web relationships in adjacent and downstream waterways (Batzer et al. 2005).

Urbanization can cause elevated concentrations of nutrients, organics, or sediment metals in streams (Wilber and Hunter 1977; Kelly and Hite 1984; Lenat and Crawford 1994). More research is needed on how urbanization affects diadromous fish populations; however, Limburg and Schmidt (1990) found that when the percent of urbanized land increased to about 10 percent of the watershed, the number of alewife eggs and larvae decreased significantly in tributaries of the Hudson River, New York (ASMFC 2009). Additionally, sewage can directly and indirectly affect anadromous fish. Major phytoplankton and algal blooms that reduced light penetration (Dixon 1996) and ultimately reduced SAV abundance (Orth et al. 1991) in tidal freshwater areas of the Chesapeake Bay in the 1960s and early 1970s may have been caused by ineffective sewage treatment.

4.1.6 Water Withdrawal/Outfall (Physical)

Water withdrawal facilities and toxic and thermal discharges have also been identified as impacting river herring

Excerpt from ASMFC (2009):

Large volume water withdrawals (e.g., drinking water, pumped-storage hydroelectric projects, irrigation, and snow-making) can alter local current characteristics (e.g., reverse river flow), which can delay movement past a facility or result in entrainment in water intakes (Layzer and O’Leary 1978). Planktonic eggs and larvae entrained at water withdrawal projects experience high mortality rates due to pressure changes, shear and mechanical stresses, and heat shock (Carlson and McCann 1969, Marcy 1973, Morgan et al. 1976). While juvenile mortality rates are generally low at well-screened facilities, large numbers of juveniles can be entrained at facilities with insufficient screening (Hauck and Edson 1976, Robbins and Mathur 1976).

Fish impinged against water filtration screens can die from asphyxiation, exhaustion, removal from the water for prolonged periods of time, removal of protective mucous, and descaling (DBC 1980). Studies conducted along the Connecticut River found that larvae and early juveniles of alewife, blueback herring, and American shad suffered 100% mortality when temperatures in the cooling system of a power plant were elevated above 82 °F (28 °C); 80% of the total mortality was caused by mechanical damage, 20% by heat shock (Marcy 1976). Ninety-five percent of the fish near the intake were not captured by the screen, and Marcy (1976) concluded that it did not seem possible to screen fish larvae effectively.

The physical characteristics of streams (e.g., stream width, depth, and current velocity; substrate; and temperature) can be altered by water withdrawals (Zale et al. 1993). River herring can experience thermal stress, direct mortality, or indirect mortality when water is not released during times of low river flows and water temperatures are higher than normal. Water flow disruption can also result in less freshwater input to estuaries (Rulifson 1994), which are important nursery areas for river herring and other anadromous species. Industrial discharges may contain toxic chemicals, such as heavy metals and various organic chemicals (e.g., insecticides, solvents, herbicides) that are harmful to aquatic life (ASMFC1999). Many contaminants can have harmful effects on fish, including reproductive impairment (Safe 1990, Mac and Edsall 1991, Longwell et al. 1992). Chemicals and heavy metals can move through the food chain, producing sub-lethal effects such as behavioral and reproductive abnormalities (Matthews et al. 1980). In fish, exposure to polychlorinated biphenyls (PCBs) can cause fin erosion, epidermal lesions, blood anemia, altered immune response, and egg mortality (Post 1987, Kennish et al. 1992). Steam power plants that use chlorine to prevent bacterial, fungal, and algal growth present a hazard to all aquatic life in the receiving stream, even at low concentrations (Miller et al. 1982).

Pulp mill effluent and other oxygen-consuming wastes discharged into rivers and streams can reduce dissolved oxygen concentrations below what is required for river herring survival. Low dissolved oxygen resulting from industrial pollution and sewage discharge can also delay or prevent upstream and downstream migrations. Everett (1983) found that during times of low water flow when pulp mill effluent comprised a large percentage of the flow, river herring avoided the effluent. Pollution may be diluted in the fall when water flows increase, but fish that reach the polluted waters downriver before the water has flushed the area will typically succumb to suffocation (Miller et al. 1982).

Effluent may also pose a greater threat during times of drought. Such conditions were suspected of interfering with the herring migration along the Chowan River, North Carolina, in 1981. In the years before 1981, the effluent from the pulp mill had passed prior to the river herring run, but drought conditions caused the effluent to remain in the system longer that year. Toxic effects were indicated, and researchers suggested that growth and reproduction might have been disrupted by eutrophication and other factors (Winslow et al. 1983).Thermal effluent from power plants outside these temperature ranges when river herring are present can disrupt schooling behavior, cause disorientation, and may result in death.

4.2 Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

The ESA contains no guidance on how to assess overutilization, nor does it outline levels of population decline relative to an endangered or threatened status. For the purposes of this status review, population dynamic characteristics, such as current population size, abundance trends by regions, recruitment and dispersal, and the effects of utilization (primarily harvest via fishing) on the population were considered for evaluating the status of the species.

4.2.1 Commercial Landings

4.2.1.1 *State Fisheries*

The ASMFC stock assessment committee calculated in-river exploitation rates of the spawning runs for five rivers (Damariscotta River (ME - alewife), Union River (ME – alewife), Monument River (MA - both species combined), Mattapoisett River (MA - alewife), and Nemasket River (MA – alewife)) by dividing in-river harvest by total run size (escapement plus harvest) for a given year (ASMFC 2012). Exploitation rates were highest (range: 0.53 to 0.98) in the Damariscotta River and Union River prior to 1985, while exploitation was lowest (range: 0.26 to 0.68) in the Monument River. In Massachusetts, exploitation rates of both species in the Monument River and of alewives in the Mattapoisett River and Nemasket River were variable (average = 0.16) and, except for the Nemasket River, declined generally through 2005 until the moratorium was imposed. Exploitation rates of alewives in the Damariscotta River were low (<0.05) during 1993 to 2000, but they increased steadily through 2004 and remained greater than 0.34 through 2008. Exploitation in the Damariscotta dropped to 0.15 in 2009 to 2010. In-river exploitation of alewives has continued to decline in the Damariscotta River with the lowest levels occurring in the last five years, with the exception of very low values that occurred in the 1990s (due to lack of harvest) (ASMFC 2017a). Exploitation rates of alewives in the Union River declined through 2005 but have remained above 0.50 since 2007 (ASMFC 2012). In-river exploitation of alewives has remained relatively stable in the Union River, but did decline to the lowest level of the time series (2010 – 2015) in the terminal year of the update. Exploitation has essentially ceased on other rivers assessed during the benchmark due to moratoria (MA rivers) (ASMFC 2017a).

The coastwide index of relative exploitation also declined following a peak in the late 1980s and has remained fairly stable over the past decade. In all model runs except for one, exploitation rates coastwide declined. Exploitation rates estimated from the statistical catch-at-age model for blueback herring in the Chowan River (see the NC state report in the stock assessment) also showed a slight declining trend from 1999 to 2007, at which time a moratorium was instituted.

There appears to be a consensus that exploitation has decreased in recent times. The stock assessment indicates that the decline in exploitation over the past decade is not surprising because river herring populations are at low levels and more restrictive regulations or moratoria have been enacted by states (ASMFC 2017a).

4.2.1.2 *U.S. Fisheries*

This following section on river herring fisheries in the United States is based on information presented in ASMFC's benchmark assessment of river herring (alewife and blueback *Alosa aestivalis*) stocks of the U.S. Atlantic Coast from Maine through Florida (ASMFC 2012) and the River Herring Stock Assessment update (ASMFC 2017a).

Fisheries for anadromous species have existed in the United States for a very long time. They not only provided sustenance for early settlers but a source of income as the fisheries were commercialized. It is difficult to fully describe the characteristics of these early fisheries because of the lack of quantifiable data.

Domestic commercial landings of river herring were presented in the stock assessment update by state and by gear from 1887 to 2015 where available (Table 3). Landings of alewife and blueback herring were collectively classified as "river herring" by most states. Only a few states had species-specific information recorded for a limited range of years. Commercial landings records were available for each state since 1887, except for Florida and the Potomac River Fisheries Commission (PRFC) which began recording landings in 1929 and 1960, respectively. It is important to note that historical landings presented in the stock assessment do not include all landings for all states over the entire period and are likely an underestimate, particularly for the first third of the time series, since not all river landings were reported (ASMFC 2012, ASMFC 2017a).

During 1887 to 1938, reported commercial landings of river herring along the Atlantic Coast averaged approximately 30.5 million lbs (13,835 mt) per year (Table 3). The majority of river herring landed by commercial fisheries in these early years are attributed to the mid-Atlantic region (NY to VA). The dominance of the mid-Atlantic region is, in part, due to the apparent bias in the spatial coverage of the canvas. During this early period, landings were predominately from Maryland, North Carolina, Virginia, and Massachusetts (overall, harvest is likely underestimated because landings were not recorded consistently during this time). Virginia made up approximately half of the commercial landings from 1929 until the 1970s, and the majority of Virginia's landings came from the Chesapeake Bay, Potomac River, York River, and offshore harvest.

Table 3. *From ASMFC (2017a):* Annual reported coastal commercial landings (lbs) of river herring 1887-2015.

Year	Total	Year	Total	Year	Total	Year	Total
1887	21,952,075	1920	101,850	1953	46,535,253	1986	10,378,923
1888	22,641,527	1921	10,852	1954	48,153,600	1987	6,939,347
1889	18,297,800	1922	73,431	1955	41,952,500	1988	6,547,357
1890	16,480,263	1923	6,573,144	1956	48,394,404	1989	3,562,566
1891	0	1924	2,649,620	1957	53,767,400	1990	2,816,214
1892	3,651,000	1925	92,188	1958	70,334,100	1991	3,332,586
1893	0	1926	131,535	1959	45,326,300	1992	4,066,425
1894	0	1927	14,230,024	1960	50,204,218	1993	2,189,389
1895	0	1928	10,055,525	1961	54,610,885	1994	1,432,175
1896	5,356,000	1929	24,870,348	1962	56,521,722	1995	1,638,639
1897	20,420,770	1930	27,136,169	1963	59,713,801	1996	1,750,306
1898	2,900,000	1931	27,630,327	1964	49,652,734	1997	1,511,009
1899	0	1932	21,691,925	1965	69,431,946	1998	1,744,105
1900	0	1933	20,275,417	1966	65,075,187	1999	1,590,890
1901	0	1934	20,939,048	1967	62,510,234	2000	1,554,219
1902	15,550,475	1935	12,207,505	1968	57,966,781	2001	1,692,161
1903	0	1936	20,825,582	1969	58,237,135	2002	1,994,595
1904	501,438	1937	22,195,865	1970	40,166,957	2003	1,673,856
1905	5,138,225	1938	30,103,611	1971	32,655,990	2004	1,469,063
1906	0	1939	23,689,906	1972	32,618,493	2005	791,326
1907	0	1940	21,193,653	1973	23,093,126	2006	1,484,741
1908	15,211,711	1941	12,173,975	1974	26,837,288	2007	1,033,421
1909	111,334	1942	10,392,322	1975	28,748,865	2008	1,435,629
1910	0	1943	1,795,339	1976	15,714,244	2009	1,656,560
1911	0	1944	20,264,444	1977	14,496,457	2010	1,565,591
1912	0	1945	23,752,819	1978	14,321,259	2011	1,293,472
1913	92,175	1946	13,408,602	1979	11,074,915	2012	1,627,364
1914	0	1947	22,912,389	1980	11,656,881	2013	1,361,845
1915	0	1948	20,268,718	1981	6,304,996	2014	1,548,723
1916	21,762	1949	24,118,735	1982	13,432,844	2015	1,344,101
1917	49,935	1950	40,999,400	1983	11,524,000		
1918	14,562,044	1951	50,408,400	1984	10,574,011		
1919	3,064,000	1952	41,494,400	1985	14,321,083		

Severe declines in landings began coast-wide in the early 1970s and domestic landings are now a fraction of what they were at their peak, having remained at persistently low levels since the mid-1990s. Moratoria were enacted in Massachusetts (commercial and recreational in 2005), Rhode Island (commercial and recreational in 2006), Connecticut (commercial and recreational in 2002), Virginia (for waters flowing into North Carolina in 2007), and North Carolina (commercial and recreational in 2007). As of January 1, 2012, river herring fisheries in states or jurisdictions without an approved sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River Herring FMP, were closed. As a result, prohibitions on harvest (commercial or recreational) were extended to New Jersey, Delaware, Pennsylvania, Maryland, D.C., Virginia (for all waters), Georgia and Florida (ASMFC 2012, ASMFC 2017a,b).

Pound nets were identified as the dominant gear type used to harvest river herring from 1887 through 2010. Seines were more prevalent prior to the 1960s, but by the 1980s, they were rarely used. Purse seines were used only for herring landed in Massachusetts, but made up a large proportion of the landings in the 1950s and 1960s. Historically, gillnets made up a small percentage of the overall harvest. However, even though the actual pounds landed continued to decline, the proportion of gillnets that contributed to the overall harvest has increased in recent years (ASMFC 2012).

4.2.1.3 *Canadian Fisheries*

Fisheries in Canada for river herring are regulated through limited seasons, gears, and licenses. Licenses may cover different gear types; however, few new licenses have been issued since 1993 (DFO 2001). River-specific management plans include closures and restrictions. River herring used locally for bait in other fisheries are not accounted for in river-specific management plans (DFO 2001). DFO estimated river herring landings at just under 25.5 million lbs (11,577 mt) in 1980, 23.1 million lbs (10,487 mt) in 1988, and 11 million lbs (4,994 mt) in 1996 (DFO 2001). The largest river herring fisheries in Canadian waters occur in the Bay of Fundy, southern Gulf of Maine, New Brunswick, and in the Saint John and Miramichi Rivers where annual harvest estimates often exceed 2.2 million lbs (1,000 mt) (DFO 2001)

4.2.1.4 *Northwest Atlantic Fisheries (Foreign Landings)*

There is little directed effort on river herring across the Northwest Atlantic. Foreign fleet landings of river herring (reported as alewife and blueback shad) are available through the Northwest Atlantic Fisheries Organization (NAFO). Offshore exploitation of river herring and shad (generally < 190 millimeters (mm) (7.5 inches) in length) by foreign fleets began in the late 1960s and landings peaked at about 80 million lbs (36,320 mt) in 1969 (ASMFC 2017a). After the Fishery Conservation and Management Act of 1976 (16 U.S.C. 1801 et seq.), later retitled the Magnuson Fishery and Conservation and Management Act, and the formation of the Fishery Conservation Zone in 1977, foreign allocation of river herring (to both foreign vessels and joint venture vessels) between 1977 and 1980 was 1.1 million lbs (499 mt). The foreign allocation was reduced to 220,000 lbs (100 mt) in 1981 because of the condition of the river herring resource. In 1985, a bycatch cap of no more than 0.25 percent of total catch was enacted for the foreign fishery. The cap was exceeded once in 1987, and this shut down the foreign mackerel fishery. In 1991, amendment 4 to the Atlantic Mackerel, squid and butterfish fisheries management plan added area restrictions to exclude foreign vessels from within 20 miles (32.2 km) of shore for two reasons: 1) in response to the increased occurrence of river herring bycatch closer to shore and 2) to promote increased fishing opportunities for the domestic mackerel fleet (50 CFR part 611.50; ASMFC 2012). There have been no reported landings by foreign fleets since 1990 (ASMFC 2012, ASMFC 2017). From 1991 to 2015, the only reported catch in Areas 5 and 6 (Figure 14) was from the United States (Figure 15).

Table 4. *From ASMFC (2017a):* Reported landings (pounds) of river herring in ICNAF/NAFO Areas 5 and 6 by country

Year	Bulgaria	Germany	Poland	USSR	USA	Grand Total
1967	0	0	0	14,356,355	57,220,393	71,576,748
1968	0	0	0	49,184,626	55,141,455	104,326,081
1969	1,333,164	249,120	0	78,322,824	55,974,794	135,879,902
1970	1,481,491	418,874	0	42,083,609	36,047,415	80,031,389
1971	2,290,579	18,538,481	4,905,235	24,887,729	28,227,698	78,849,722
1972	1,128,755	7,674,213	4,162,285	14,755,388	2,707,249	30,427,890
1973	1,787,931	3,593,498	7,167,155	2,347,899	22,729,426	37,625,909
1974	1,704,156	5,862,031	2,398,605	1,042,776	24,490,901	35,498,469
1975	1,219,144	4,675,957	136,685	2,290,579	23,803,066	32,125,431
1976	564,378	2,777,796	30,864	537,922	14,290,217	18,201,177
1977	0	152,117	0	264,552	13,584,745	14,001,414
1978	0	0	0	46,297	12,632,358	12,678,655
1979	0	0	0	26,455	9,607,647	9,634,102
1980	0	0	2,205	0	10,498,305	10,500,510
1981	0	0	22,046	0	7,087,789	7,109,835
1982	0	0	178,573	0	12,784,475	12,963,048
1983	0	0	169,754	0	9,224,046	9,393,800
1984	0	17,637	436,511	0	9,003,586	9,457,734
1985	0	50,706	346,122	0	2,206,805	2,603,633
1986	0	37,478	103,616	0	8,988,154	9,129,248
1987	0	59,524	48,501	0	4,261,492	4,369,517
1988	0	63,933	66,138	0	5,251,357	5,381,428
1989	0	50,706	52,910	0	3,362,015	3,465,631
1990	0	30,864	0	0	2,892,435	2,923,299
1991	0	0	0	0	2,925,504	2,925,504
1992	0	0	0	0	3,209,898	3,209,898
1993	0	0	0	0	551,150	551,150
1994	0	0	0	0	0	0
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
1997	0	0	0	0	0	0
1998	0	0	0	0	0	0
1999	0	0	0	0	0	0
2000	0	0	0	0	0	0
2001	0	0	0	0	0	0
2002	0	0	0	0	284,393	284,393
2003	0	0	0	0	0	0
2004	0	0	0	0	0	0
2005	0	0	0	0	0	0
2006	0	0	0	0	0	0
2007	0	0	0	0	315,258	315,258
2008	0	0	0	0	286,598	286,598
2009	0	0	0	0	509,263	509,263
2010	0	0	0	0	0	0
2011	0	0	0	0	416,673	416,673
2012	0	0	0	0	105,822	105,822
2013	0	0	0	0	30,865	30,865
2014	0	0	0	0	2,205	2,205
2015	0	0	0	0	11,023	11,023

*: Italy, the Netherlands, Romania, and Spain also reported catch, but only in one or two years; they are included in the Grand Total.

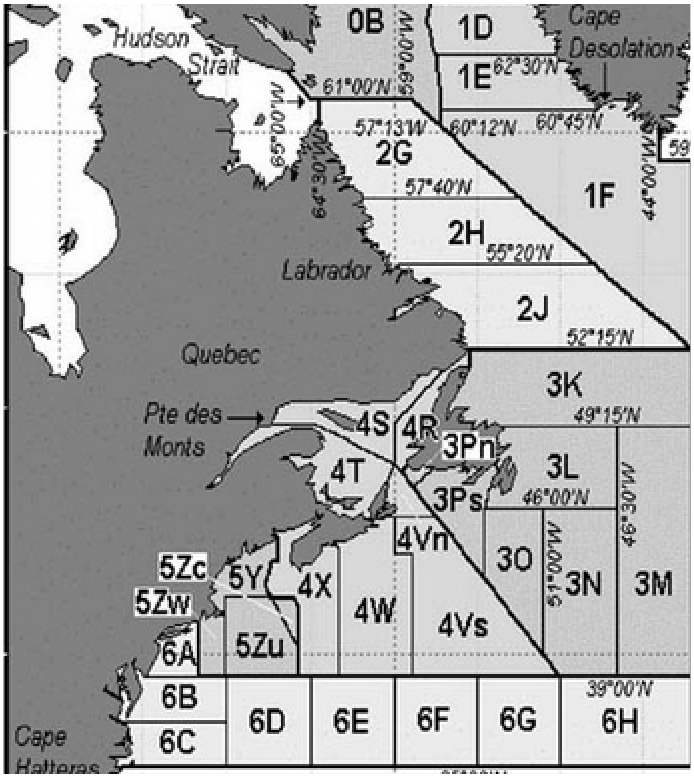


Figure 14**.** Northwest Atlantic Fisheries Organization Statistical Areas. River herring landings were reported for stat areas 5 and 6.

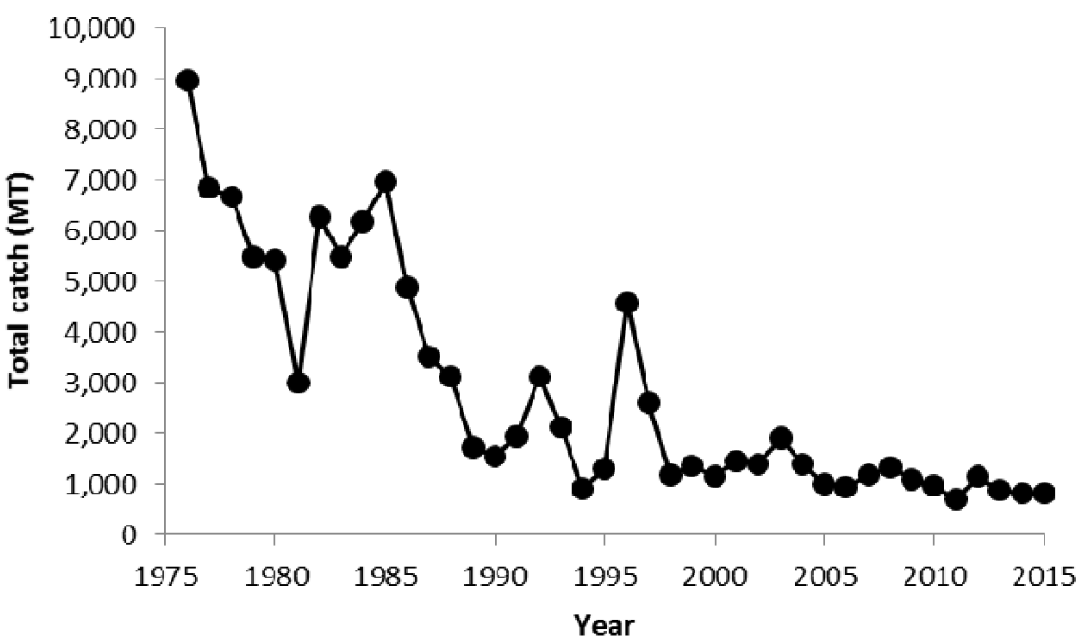


Figure 15. Total catch of river herring estimated from total reported landings plus total incidental catch using hindcasting methods.

4.2.2 Retained and Discarded Incidental Catch (including slippage)

4.2.2.1 *U.S. Fisheries*

River herring are caught incidentally at sea in federal fisheries targeting other species such as Atlantic herring, squid, and mackerel. The magnitude of this ocean catch is highly uncertain because of the short time series of incidental data, underreporting, and a lack of observer coverage. A concern regarding incidental catch is a process termed slippage, by which a midwater trawler does not bring the entire catch on board and releases part of the catch into the water (i.e., slips the net), thereby potentially biasing estimates of river herring incidental catch data. Slippage is a standard part of trawl operations and involves a partial or full release of catch. Slippage can occur for a number of reasons including an inability to pump the remainder of fish onto the vessel, detection of a prohibited species, or safety concerns regarding equipment or weather. In addition, there is limited data on the stock composition of the incidentally caught fish and, thus, no way to partition estimates of bycatch among river systems. With no estimates of coastwide or regional stock complex abundances, it is also difficult to assess the significance of these removals on the overall population or segments of it (ASMFC 2017a).

Several studies estimated river herring discards and incidental catch (Cieri et al. 2008, Wigley et al. 2009, Lessard and Bryan 2011). The discard and incidental catch estimates from these studies cannot be directly compared as they used different ratio estimators based on data from the Northeast Fishery Observer Program (NEFOP), as well as different raising factors to obtain total estimates. Cieri et al. (2008) estimated the kept (i.e., landed) portion of river herring incidental catch in the Atlantic herring fishery. Cieri et al. (2008) estimated an average annual landed river herring catch of approximately 71,290 lb (32.4 mt) in the Atlantic herring fishery for 2005 – 2007, and the corresponding coefficient of variation (CV) was 0.56. Cournane et al. (2012) extended this analysis with additional years of data. Further work is needed to elucidate how the incidental catch of river herring in the directed Atlantic herring fishery compares to total incidental catch across all fisheries. Since this analysis only quantified kept river herring in the Atlantic herring fishery, it underestimates the total catch (kept and discarded) of river herring across all fishing fleets. Wigley et al. (2009) quantified river herring discards across fishing fleets that had sufficient observer coverage from July 2007 – August 2008. Wigley et al. (2009) estimated that approximately 105,820 lb (48 mt) were discarded during the 12 months (July 2007 to August 2008), and the estimated precision was low (149% CV). This analysis estimated only river herring discards (in contrast to total incidental catch), and noted that midwater trawl fleets generally retained river herring while otter trawls typically discarded river herring.

Lessard and Bryan (2011) estimated an average incidental catch of river herring and American shad of 3.3 million lb (1,498 mt)/yr from 2000-2008. Lessard and Bryan (2011) analyzed NEFOP data at the haul level; however, the sampling unit for the NEFOP database is at the trip level. Within each gear and region, all data, including those from high volume fisheries, appeared to be aggregated across years from 2000 through 2008. However, substantial changes in NEFOP sampling methodology for high volume fisheries were implemented in 2005, limiting the interpretability of estimates from these fleets in prior years. The total number of tows from the fishing vessel trip report (VTR) database was used as the raising factor to estimate total incidental catch. The use of effort without standardization makes the implicit assumption that effort is constant across all tows within a gear type, potentially resulting in a biased effort metric.

In contrast, the total kept weight of all species is used as the raising factor in standardized bycatch reporting methodology (SBRM). SBRM is a methodology to assess the amount and type of bycatch in a fishery. When quantifying incidental catch across multiple fleets, total kept weight of all species is an appropriate surrogate for effective fishing power because it is likely that no trips will exhibit the same attributes. Lessard and Bryan (2011) also did not provide precision estimates, which are imperative for estimation of incidental catch.

The stock assessment update (ASMFC 2017a,b) presents the total incidental catch of river herring updated through 2015 following methods described in the benchmark assessment. These methods were developed during Amendment 14 to the Atlantic Mackerel, Squid and Butterfish (MSB) Fishery Management Plan, which includes measures to address incidental catch of river herring and shads (ASMFC 2017a). ASMFC (2017a) presents the total incidental catch estimates by species **(**Table 5**)**.

From 2005-2015, the total annual incidental catch of alewife ranged from 36.5-531.7 metric tons (mt) in New England and 10.9-295.0 mt in the Mid-Atlantic region (ASMFC 2017a). The dominant gear varied across years between paired midwater trawls and bottom trawls (Figure 16, ASMFC 2017a). Corresponding estimates of precision exhibited substantial inter-annual variation and ranged from 0-10.6 across gears and regions. Between 2005 and 2015, total annual blueback herring incidental catch ranged from 8.2–186.6 mt in New England and 1.4-388.3 mt in the Mid-Atlantic region (ASMFC 2017a). Across years, paired and single midwater trawls exhibited the greatest blueback herring incidental catches (Figure 17, ASMFC 2017a). Corresponding precision estimates ranged from 0-3.6.

Table 5. Species-specific total annual incidental catch (mt) and the associated coefficient of variation across all fleets and regions. Midwater trawl estimates were only included beginning in 2005.

	Alewife		**American shad**		**Blueback herring**		**Herring NK**		**Hickory shad**	
	Catch	CV	Catch	CV	Catch	CV	Catch	CV	Catch	CV
1989	44.16	0.49	229.10	0.98	37.65	0.42	17.53	1.13	0.00	
1990	101.63	0.85	45.20	0.34	170.01	0.45	681.30	0.59	0.00	
1991	148.56	0.44	176.09	0.25	285.07	0.40	265.61	0.51	39.35	0.00
1992	65.74	0.43	168.95	0.28	1190.98	0.42	786.21	0.39	0.00	
1993	381.05	2.42	211.34	1.00	745.60	0.28	135.86	4.83	0.00	
1994	5.56	0.30	109.93	0.64	240.17	0.87	58.34	0.47	0.95	0.82
1995	8.44	0.61	127.43	0.38	348.33	0.44	99.87	1.23	0.53	0.64
1996	704.10	1.14	64.52	0.39	2800.04	2.09	451.39	0.39	222.46	1.04
1997	49.42	1.36	65.95	0.61	1593.60	0.69	90.27	5.09	20.64	1.25
1998	145.64	1.47	161.03	0.23	76.81	1.52	228.12	2.08	479.82	0.72
1999	6.12	1.16	82.03	0.41	359.21	0.60	3457.27	0.74	208.75	0.94
2000	113.33	0.81	264.43	0.77	109.57	0.45	70.86	0.78	2.41	0.76
2001	189.63	0.84	67.82	0.39	309.86	0.32	2.51	0.44	330.44	0.27
2002	4.35	3.35	43.81	0.40	269.14	0.33	124.05	1.88	1.87	0.83
2003	388.04	1.43	60.20	0.54	526.83	0.56	26.21	1.17	18.80	0.85
2004	163.18	0.64	53.06	0.36	231.67	0.46	237.06	0.74	401.75	1.13
2005	404.42	0.40	94.50	0.28	254.68	0.34	29.46	0.58	27.42	0.34
2006	78.73	0.83	78.23	9.73	190.78	0.66	267.81	1.10	25.07	0.78
2007	543.58	0.71	79.08	0.56	187.99	1.42	357.43	0.91	16.72	0.90
2008	159.16	0.42	74.04	0.29	539.32	0.56	1669.08	0.50	5.56	0.80
2009	154.22	0.26	106.70	1.99	195.41	0.30	352.25	0.66	11.70	0.79
2010	134.60	0.19	60.61	0.16	132.42	0.20	106.67	0.32	1.26	0.59
2011	96.53	0.34	103.32	0.12	28.19	0.30	125.99	0.28	0.09	0.77
2012	173.85	0.24	76.53	0.16	249.35	0.31	91.72	0.30	0.51	0.55
2013	238.95	0.33	73.48	0.41	28.92	0.46	75.08	0.69	0.42	0.76
2014	83.61	0.14	63.46	0.19	29.55	0.25	76.68	0.44	0.68	0.39
2015	123.66	0.31	46.40	0.15	82.44	0.48	40.47	0.75	2.46	0.77

The temporal distribution of incidental catch was summarized by quarter and fishing region for the most recent 10-year period (2005 to 2015). River herring catches occurred primarily in midwater trawls (62%, of which 48% were from paired midwater trawls and the rest from single midwater trawls), followed by small mesh bottom trawls (24%). Catches of river herring in gillnets were negligible. Across gear types, catches of river herring were greater in New England (56%) than in the Mid-Atlantic (37%). The percentages of midwater trawl catches of river herring were similar between New England (31.3%) and the Mid-Atlantic region (30.5%). However, catches in New England small mesh bottom trawls were almost three times higher (27%) than those from the Mid-Atlantic (10%). Overall, the highest quarterly catches of river herring occurred in midwater trawls during Quarter 1 in the Mid-Atlantic (28%), followed by catches in New England during Quarter 4 (12%) (ASMFC 2017). Quarterly catches in small

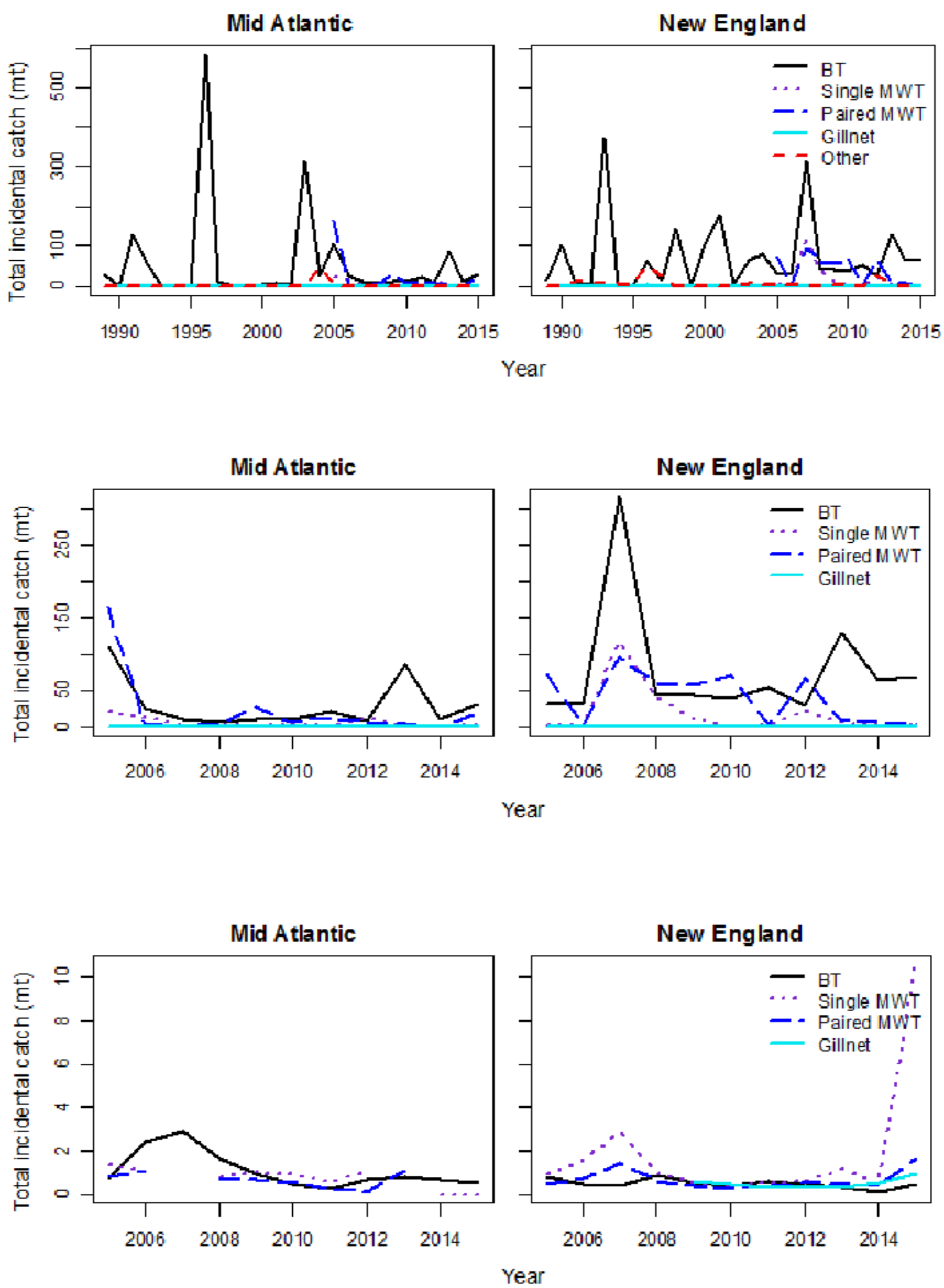
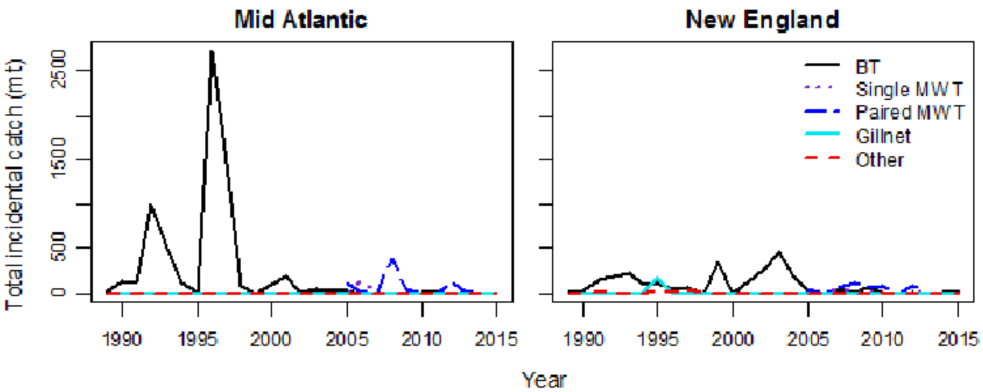
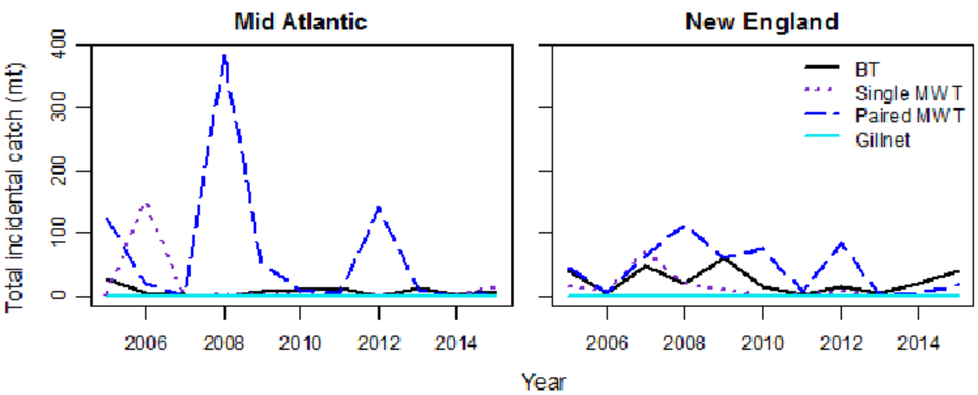


Figure 16**.** *From ASMFC 2017a.* Alewife total annual incidental catch (mt) by region for the four gears with the largest catches from a) 1989 – 2015 and b) 2005 – 2015, and c) the corresponding estimates of precision. Midwater trawl estimates are only included beginning in 2005.

a)



b)



c)

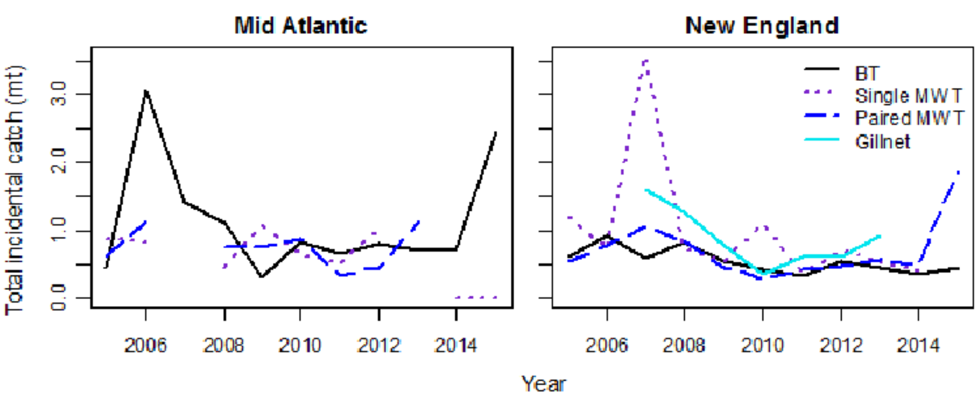


Figure 17. *From ASMFC 2017a.* Blueback herring total annual incidental catch (mt) by region for the four gears with the largest catches from a) 1989 – 2015 and b) 2005 – 2015, and c) the corresponding estimates of precision. Midwater trawl estimates are only included beginning in 2005.

mesh bottom trawls were highest in New England during Quarter 1 (9%) and totaled 5 to 7% during each of the other three quarters (ASMFC 2017a). The New England and Mid-Atlantic Fishery Management Councils have adopted measures for the Atlantic herring and mackerel fisheries intended to decrease incidental catch and bycatch of alewife and blueback herring.

Partitioning incidental catch in U.S. waters to river of origin or proposed stock complex is an ongoing area of research. Using the 15 microsatellites previously identified (Palkovacs et al. 2014), Hasselman et al. (2016) applied genetic stock identification (GSI) to determine potential regional stock composition of river herring incidental catch from the New England Atlantic herring fishery (2012-2013). GSI is biological tool to determine the composition of mixed stocks and the origin of individual fish. Results showed assignment of over 70% to the southern New England stock complex for alewife and 78% assignment to the Mid-Atlantic stock complex for blueback herring. The study also gives a marine spatial snapshot of stock complexes in the NOAA statistical areas sampled during 2012-2013 (Figure 18), though the authors noted extreme inter-annual variability in both the magnitude and composition of incidental catch, demonstrating that marine distributions for both species are highly dynamic from year to year.

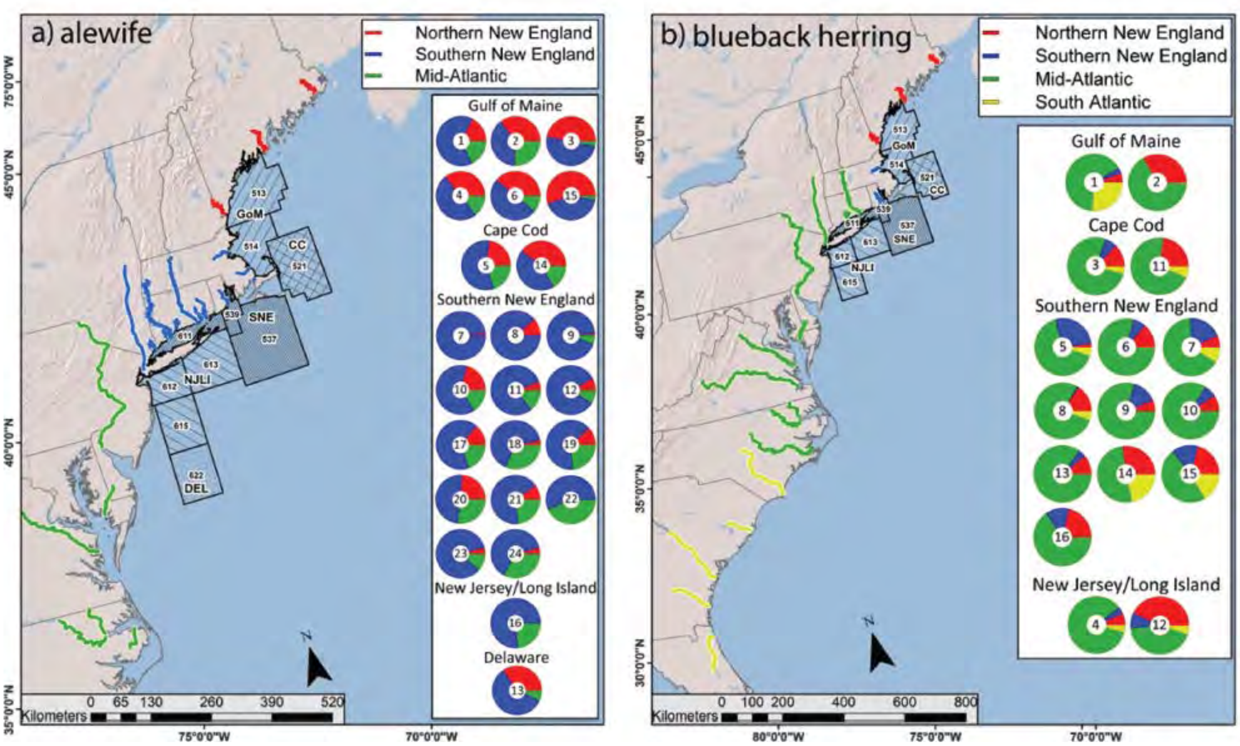


Figure 18. *From Hasselman et al. 2016.* Relative proportion of assignments to genetic stocks for each bycatch stratum for (*a*) alewife and (*b*) blueback herring. The map shows the baseline populations color-coded to coincide with their genetic stock designations and the NOAA statistical areas where bycatch was sampled (grouped by region using various degrees of shading). Pie charts illustrate the relative proportion of bycatch for each stratum, grouped by region that was assigned to each genetic stock.

4.2.3 Recreational Landings

The Marine Recreational Fishery Statistics Survey (MRFSS) provided estimates of numbers of fish harvested and released by recreational fisheries along the Atlantic coast. The stock assessment subcommittee extracted state harvest and release estimates for alewives and blueback herring from the MRFSS catch and effort estimates files (1987-2006) available on the web (http://www.sefsc.noaa.gov/about/mrfss.htm). Historically, there were few reports of river herring taken by recreational anglers for food. Most often, river herring were taken for bait. MRFSS estimates of the numbers of river herring harvested and released by anglers are very imprecise and show little trend. Thus, the 2017 stock assessment concluded that these data are not useful for management purposes. In general, MRFSS/MRIP concentrate their sampling strata in coastal water areas and do not capture any data on recreational fisheries that occur in inland waters. Few states conduct creel surveys or other consistent survey instruments (diary or logbooks) in their inland waters to collect data on recreational catch of river herring. Some individual state data are reported in the state chapters in the 2017 stock assessment; but the stock assessment committee concluded that data are too sparse to conduct any systematic comparison of trends (ASMFC 2012, 2017b).

Moratoria are in place on directed catch of these species throughout most of the United States; however, they are taken as incidental catch in several fisheries. The level of threat posed by directed and indirect recreational catch has not been fully evaluated in quantitative or qualitative assessments. The ASMFC 2017 blueback and alewife stock assessment concluded that recreational data are not useful for management purposes. Within east coast states, small recreational harvest of alewife and blueback herring is currently occurring in a few states with regulations that have been approved through a sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River Herring FMP. All other states had previously established moratoria or, as of January 1, 2012, harvest of river herring was prohibited, as required by ASMFC Amendment 2 to the Shad and River Herring FMP.

Excerpted from ASMFC (2017b):

> <u>Maine</u>
>
> The Department of Marine Resources (DMR), along with municipalities granted the rights to harvest river herring resources, cooperatively manage municipal fisheries. Towns must submit an annual harvesting plan to DMR for approval that includes a 3-day per week escapement period or biological equivalent to ensure conservation of the resource. River herring runs not controlled by a municipality and not approved as sustainable by the ASMFC River Herring and American Shad Management Board, as required under Amendment 2, are closed. Each run and harvest location is unique, either in seasonality, fish composition, or harvesting limitations. Some runs have specific management plans that require continuous escapement and are more restrictive than the 3-day closed period. Most towns operate a weir at one location on each stream and prohibit 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. If not provided, the municipality loses exclusive fishing rights. The state permitted 22 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.

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 is limited, and landings are low.

New Hampshire

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.

Massachusetts

River herring were commonly harvested for food in coastal towns in Massachusetts. Recreational use in recent decades was mainly for bait in the striped bass fishery. MRFSS estimated the numbers of river herring harvested and released by anglers in Massachusetts. These estimates are very imprecise and show little trend (ASMFC 2017b). Since spring of 2005, there has been no recreational fishery for alewife and/or blueback herring allowed in Massachusetts. As of January 1, 2012, commercial and recreational harvest of river herring was prohibited in Massachusetts, as required by ASMFC Amendment 2 to the Shad and River Herring FMP. The exception is for federally permitted vessels, which are allowed to land up to 5% baitfish per trip.

Rhode Island

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 2017.

Connecticut

Prior to the statewide fishery moratorium in 2002, the recreational limit for both inland and marine waters was 25 blueback herring or alewife, in aggregate, per person per day, for personal use purposes. Land-locked alewives from specific lakes were allowed to be taken recreationally by angling and scoop net. 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. Harvested primarily by scoop or dip netting, pressure on river herring was likely higher in rivers with the strongest runs. The magnitude of the recreational harvest has never been estimated (Savoy and Crecco 2004). There is no historical data on catch and effort in the river herring recreational fishery. Catches were most likely used for bait purposes, but no attempt has been made to determine the magnitude of these fisheries in Connecticut. As of January 1, 2012, commercial and recreational harvest of river herring was prohibited in Connecticut, as required by ASMFC Amendment 2 to the Shad and River Herring FMP.

New York

In the Hudson River Estuary, the recreational river herring fishery exists throughout the mainstem Hudson River and its tributaries including those in the tidal section and above the Troy Dam (Mohawk River). Some recreational herring fishers use their catch as food (smoking/pickling). However, the recreational river herring fishery is primarily for bait in the recreational striped bass fishery. In addition to the change in commercial regulations in 2013, new regulations were put into place for the recreational fishery in response to Amendment 2. The most significant changes were creel limit of 10 fish per day or 50 fish per boat, as well as the prohibition of personal net use in tributaries.

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

River herring use by striped bass anglers can also be evaluated using data obtained from the NYDEC's Cooperative Angler Program (CAP). The CAP was designed to gather data from recreational striped bass anglers through voluntary trip reports. Volunteer anglers log information for each striped bass fishing trip including fishing time, location, bait use, fish caught, length, weight, and bycatch. From 2006 through 2015, volunteer anglers were asked to provide specific information about river herring bait use. Due to the difficulties associated with differentiating between alewife and blueback herring, anglers were only asked to report the catch as river herring.

The most recent creel and CAP information were combined in an attempt to estimate the current recreational river herring harvest. Estimates of river herring use by striped bass anglers ranged from 78,491 fish in 2007 to 386,915 fish in 2015 with an increasing trend of herring use from 2006 to 2015. To put potential recreational herring harvest in context, the average estimated annual recreational harvest from 2013-2015 was 312,036 herring. During the same period, counts from Black Creek, a small tributary to the Hudson with approximately 1.8 km of available spawning habitat, averaged 409,233 alewives (roughly 139,000 pounds) annually. Black Creek is only one of the 68 primary tributaries to the Hudson River.

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

The number of river herring taken from the Hudson River and tributaries for personal use as food by recreational anglers is unknown but expected to be minimal. In Long Island, Bronx and Westchester counties, recreational river herring fisheries have been closed in the marine and coastal district of NY as of 2013.

Current regulations allow for a restricted river herring commercial and recreational fishery in the Hudson River and tributaries, while all other state waters prohibit river herring fisheries. These regulations have been approved through a sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River Herring FMP.

New Jersey

The recreational fishery for river herring was traditionally very small with few participants and low retention rates. Herring landed were typically frozen for bait, pickled, harvested for their roe, and other traditional uses. 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, and umbrella net.

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 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 recreational anglers in the Delaware River harvested 4,916 for 2002. Angler catch rate was estimated 0.0189 per angler hour and the harvest rate was estimated at 0.0123 per angler hour.

As of January 1, 2012, the recreational fishery in New Jersey waters has been closed. No harvest of river herring is permitted.

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 anglers 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 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, in 2008, Delaware's General Assembly approved legislation that prohibits the use of any net by any angler 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 anglers to use only hook and line and to limit landings to the possession limit**.**

There are over 500 'recreational' gillnet permits issued to Delaware anglers. The permit stipulates that an angler be entitled to set up to 200 feet of anchored or fixed gillnet 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 gillnet anglers abided by the same seasons, size and creel limits for food fish 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. The number of river herring harvested per trip declined steadily from 1998 through 2004. As of January 1, 2012, the recreational fishery in Delaware waters has been closed. No harvest of river herring are currently permitted.

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-1980s, the daily creel limit for river herring in the Delaware River and Estuary was 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. As of January 1, 2012, the recreational fishery in Pennsylvania waters has been closed. No harvest of river herring is permitted.

Maryland

Maryland's recreational river herring fishery historically was seasonally restricted, closed from June 5 to January 1 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 9herring 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 are not allowed in the Susquehanna River upstream of Deer Creek. Nets other than a landing net are banned in Deer Creek. As of January 1, 2012, the recreational fishery was closed.

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.

As of January 1, 2012, commercial harvest of river herring was prohibited in Maryland, as required by ASMFC Amendment 2 to the Shad and River Herring FMP. However, an exception is provided for anyone in possession of river herring as bait, as long as a receipt indicating where the herring was purchased is in hand (K. Taylor, Pers. comm). This will allow bait shops to sell, and anglers to possess, river herring for bait that was harvested from a state whose fishery remains open, as an ASMFC approved sustainable fishery.

Virginia

The MRFSS is the primary source of marine recreational fisheries statistics for Virginia. 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.

As of January 1, 2012, commercial and recreational harvest of river herring was prohibited in all waters of Virginia, as required by ASMFC Amendment 2 to the Shad and River Herring FMP. Additionally, it is unlawful for any person to possess river herring aboard a vessel on Virginia tidal waters or to land any river herring in Virginia (4 VAC 20-1260-30).

North Carolina

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 anglers 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 North Carolina Wildlife Resources Commission (NCWRC) at that time, changes in designations of coastal/joint/inland waters, changes in jurisdictional responsibilities between North Carolina Division of Marine Fisheries 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 patrolled 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 were 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 anglers 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.

South Carolina

In South Carolina, the South Carolina Department of Natural Resources (SCDNR) manages commercial herring fisheries using a combination of seasons, gear restrictions, and catch limits. Today, the commercial fishery for blueback herring has a 10-bushel daily limit (500 lb (226 kg)) per boat in the Cooper and Santee Rivers and the Santee-Cooper Rediversion Canal and a 250-lb-per-boat (113 kg) limit in the Santee-Cooper lakes. Seasons generally span the spawning season. All licensed anglers have been required to report their daily catch and effort to the SCDNR since 1998. The recreational fishery has a 1-bushel (49 lb (22.7 kg)) fish aggregate daily creel for blueback herring in all rivers; however, very few recreational anglers target blueback herring. These regulations have been approved through a sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River Herring FMP.

Georgia

As of January 1, 2012, harvest of river herring was prohibited in Georgia, as required by ASMFC Amendment 2 to the Shad and River Herring FMP.

Florida

The St. Johns River, Florida, harbors the southernmost spawning run of blueback herring. There is currently no active management of blueback herring in Florida. As of January 1, 2012, harvest of river herring was prohibited, as required by ASMFC Amendment 2 to the Shad and River Herring FMP.

Canada

Recreational fisheries in Canada for river herring are limited by regulations including area, gear and season closures with limits on the number of fish that can be harvested per day; however, information on recreational catch is limited. Licenses and reporting are not required by Canadian regulations for recreational fisheries, and harvest is not well documented.

4.2.4 Scientific Research and Education

The states of Maine, New Hampshire, Massachusetts and Rhode Island estimate run sizes using electronic counters or visual methods. In Massachusetts, various counting methods are used at the Holyoke Dam fish lift and fish ways on the Connecticut River. Young of year (YOY) surveys are conducted through fixed seine surveys capturing YOY alewife and blueback herring generally during the summer and fall in Maine, Rhode Island, Connecticut, New York, New Jersey, Maryland, District of Columbia, Virginia and North Carolina. Rhode Island conducts surveys for juvenile and adult river herring at large fixed seine stations. Virginia samples river herring using a multi-panel gill net survey and electroshocking surveys. Florida conducts electroshocking surveys to sample river herring. Maine, New Hampshire, Massachusetts, Rhode Island, Maryland, and North Carolina collect age data from both commercial and fisheries independent sampling programs, and length-at-age data. All of these scientific monitoring efforts are believed to have minimal impacts on river herring populations.

As noted previously, there is insufficient information available on river herring in many areas. Research needs were recently identified in the ASMFC River Herring Stock Assessment Report (ASMFC 2012, 2017); NMFS Stock Structure, Climate Change and Extinction Risk Workshop/Working Group Reports (NMFSa,b,c 2012) and associated peer reviews; and New England and Mid-Atlantic Fishery Management Council documents (NEFMC 2012, MAFMC 2012).

4.2.5 Tribal/First Nation Fisheries

There are nineteen federally-recognized tribes along the coast from Maine through South Carolina. Certain tribes may have tribal rights to sustenance and ceremonial fishing. The only tribe that has reported harvest numbers for river herring is the Mashpee Wampanoag Tribe. The Tribe has voluntarily reported harvest numbers to the Commonwealth of Massachusetts, and these numbers were incorporated into the ASMFC Management Plan as subsistence harvest. The reported harvest for 2010 to 2013 ranged between 1,200 and 3,500 fish per year, with removals coming from several rivers (ASMFC 2017b). No reports have occurred since 2013. No other information on harvest for sustenance and/ or ceremonial purposes was available. Present harvest of river herring for tribal purposes does not appear to be significantly affecting the status of river herring, as it results in low mortality.

4.3 Disease or Predation

The ESA requires an evaluation of disease and predation factors on alewife and blueback herring.

4.3.1 Disease

Little information exists on diseases that may affect river herring; however, there are reports of a variety of parasites that have been found in both alewife and blueback herring. The most comprehensive report is that of Landry et al. (1992) in which 13 species of parasites were identified in blueback herring and 12 species in alewives from the Miramichi River, New Brunswick, Canada. The parasites found included one monogenetic trematode, four digenetic trematodes, one cestode, three nematodes, one acanthocephalan, one annelid, one copepod and one mollusk. The same species were found in both alewife and blueback herring with the exception of the acanthocephalan, which was absent from alewives.

In other studies, Sherburne (1977) reported piscine erythrocytic necrosis (PEN) in the blood of 56 percent of pre-spawning and 10% of post-spawning alewives in Maine coastal streams. PEN was not found in juvenile alewives from the same locations. Coccidian parasites were found in the livers of alewives and other finfish off the coast of Nova Scotia (Morrison and Marryatt 1990). Marcogliese and Compagna (1999) reported that most fish species, including alewife, in the St. Lawrence River become infected with trematode metacercariae during the first years of life. Examination of Great Lakes fishes in Canadian waters showed larval *Diplostomum* (trematode) commonly in the eyes of alewife in Lake Superior (Dechtiar and Lawrie 1988) and Lake Ontario (Dechtiar and Christie, 1988), though intensity of infections was low (<9/host).

Heavy infections of *Saprolegnia*, a fresh and brackish water fungus, were found in 25% of Lake Superior alewife examined, and light infections were found in 33 percent of Lake Ontario alewife (Dechtiar and Lawrie 1988). Larval acanthocephala were also found in the guts of alewife from both lakes. *Saprolegnia* typically is a secondary infection, invading open sores and wounds, and eggs in poor environmental conditions, but under the right conditions, it can become a primary pathogen. *Saprolegnia* infections usually are lethal to the host.

More recently, alewives were found positive for Cryptosporidium for the first time on record by Ziegler et al. (2007). Mycobacteria, which can result in ulcers, emaciation, and sometimes death, have been found in many Chesapeake Bay fish, including blueback herring (Stine et al. 2010).

Lovy and Friend (2015) characterized two intestinal coccidians, *Goussia ameliae* and G. *alosii.* in alewives of the Maurice River, New Jersey. *G. ameliae* infected both landlocked and anadromous alewives. The parasites were prevalent in both juveniles and adult fish. While significant mortality seemed not to occur, researchers suggest that the energetic costs of these parasites should be considered when estimating impacts of climate change and habitat loss.

Another parasite recently discovered in New Jersey, *Myxobolus mauriensis*, attacks the ribs of juvenile river herring and can spread to other tissues (Lovy and Hutcheson 2016). This new species of *Myxobolus* was found mostly in the Maurice River (20%), but was also present in two other NJ river systems.

4.3.2 Predation

Alewife and blueback herring are an important forage fish for marine and anadromous predators, such as striped bass, spiny dogfish, bluefish, Atlantic cod, and pollock (Bowman et al. 2000, Smith and Link 2010). Historically, river herring and striped bass landings have tracked each other quite well, with highs in the 1960s, followed by declines through the 1970s and 1980s.

Although populations of Atlantic cod and pollock are currently low, the populations of striped bass and spiny dogfish have increased in recent years (since the early 1980s for striped bass and since 2005 for spiny dogfish), while the landings and run counts of river herring remain at historical lows. This has led to speculation that increased predation may be contributing to the decline of river herring and American shad (Hartman 2003, Crecco et al. 2007, Heimbuch 2008). Quantifying the impacts of predation on alewife and blueback herring is difficult. The diet of striped bass has been studied extensively, and the prevalence of alosines varies greatly depending on location, season, and predator size (Walter et al. 2003).

Studies from the northeast U.S. continental shelf show low rates of consumption by striped bass. Alewife and blueback herring each make up less than 5% of striped bass diet by weight (Smith and Link 2010). Studies that sampled striped bass in rivers and estuaries during the spring spawning runs found much higher rates of consumption, greater than 60% of striped bass diet by weight in some months and size classes (Walter and Austin 2003; Rudershausen et al. 2005). Translating these snapshots of diet composition into estimates of total removals requires additional data on both annual per capita consumption rates and estimates of annual abundance for predator species.

Two papers have become available since the ASMFC (2012) stock assessment that discuss striped bass predation on river herring in Massachusetts and Connecticut estuaries and rivers, showing temporal and spatial patterns in predation (Davis et al. 2012; Ferry and Mather 2012). Davis et al. (2012) estimated that approximately 400,000 blueback herring are consumed annually by striped bass in the Connecticut River spring migration. In this study, striped bass were found in the rivers during the spring spawning migrations of blueback herring and had generally left the system by mid-June (Davis et al. 2012). Many blueback herring in the Connecticut River are thought to be consumed prior to ascending the river on their spawning migration. Therefore, they are removed from the system before spawning. Alternatively, Ferry and Mather (2012) discuss the results of a similar study conducted in Massachusetts watersheds with drastically different findings for striped bass predation. Striped bass were collected and stomach contents analyzed during three seasons from May through October (Ferry and Mather, 2012). The stomach contents of striped bass from the survey were examined and less than 5% of the clupeid category (from 12 categories identified to summarize prey) consisted of anadromous alosines (Ferry and Mather 2012). Overall, the Ferry and Mather (2012) study observed few anadromous alosines in the striped bass stomach contents during the study period. These two recent studies echo similar contradictory findings from previous studies showing a wide variation in predation by striped bass with spatial and temporal effects.

Recent studies provide information on absolute abundance for river herring and key predators such as striped bass in several mid-Atlantic river systems (Harris and Hightower 2017, Hughes and Hightower 2015, McCargo 2018). A higher abundance of striped bass than alewife and blueback herring in these Maryland and North Carolina rivers suggests the potential for predation impacts, which could influence the growth of river herring in this system. In the case of Atlantic cod in the Southern Gulf of St. Lawrence, it has been suggested that such grey seal predator-driven Allee effects are influencing the lack of population growth (Neuenhoff et al. 2019). Research is needed to determine the level of threat posed by predation by key predators on river herring where the abundance estimates for river herring are considerably lower than the predators.

The diets of other predators, including other fish (e.g., bluefish, spiny dogfish), along with marine mammals (e.g., seals) and birds (e.g., double-crested cormorant), have not been quantified nearly as extensively, making it more difficult to assess the importance of river herring in the freshwater and marine food webs. As a result, some models predict a significant negative effect from predation (Hartman 2003, Heimbuch 2008), while other studies did not find an effect (Tuomikoski et al. 2008, Dalton et al. 2009).

In addition to predators native to the Atlantic coast, river herring are vulnerable to invasive species such as the blue catfish (*Ictalurus furcatus*) and the flathead catfish (*Pylodictis olivaris*). These catfish are large, opportunistic predators native to the Mississippi River drainage that were introduced into rivers on the Atlantic coast. They consume a wide range of species, including alosines, and ecological modeling on flathead catfish suggests they may have a large impact on their prey species (Pine 2003, Schloesser et al. 2011). In August 2011, ASMFC approved a resolution calling for efforts to reduce the population size and ecological impacts of invasive species and named blue and flathead catfish as species of concern due to their increasing abundance and potential impacts on native anadromous species. Non-native species are a particular concern because of the lack of native predators, parasites, and competitors to keep their populations in check.

4.4 Evaluation of the Inadequacy of Existing Regulatory Mechanisms

The ESA requires an evaluation of existing regulatory mechanisms to determine whether they may be inadequate to address threats to river herring. As wide-ranging anadromous species, alewife and blueback herring are subject to numerous federal (U.S. and Canadian), state and provincial, tribal, and inter-jurisdictional laws, regulations, and agency activities. Below is a description and evaluation of current domestic and international regulatory measures that affect the species.

4.4.1 International

The Canadian Department of Fisheries and Oceans (DFO) manages alewife and blueback herring fisheries that occur in the rivers of the Canadian Maritimes under the Fisheries Act (R.S.C., 1985, c. F-14). The Maritime Provinces Fishery Regulations include requirements when fishing for or catching and retaining river herring in recreational and commercial fisheries (DFO, 2006)

Commercial and recreational river herring fisheries in the Canadian Maritimes are regulated by license, fishing gear, season and/or other measures (DFO 2001). Since 1993, DFO has issued few new licenses for river herring (DFO 2001). River herring are harvested by various gear types (e.g., gillnet, dip nets, trap), and the regulations depend upon the river and associated location (DFO 2001). The primary management measures are weekly closed periods and limiting the total number of licenses (DFO 2001). Logbooks are issued to commercial anglers in some areas as a condition of the license, and pilot programs are being considered in other areas (DFO 2001). The management objective is to maintain harvest near long-term mean levels when no specific biological and fisheries information is available (DFO 2001).

DFO (2001) stated that additional management measures may be required if increased effort occurs in response to stock conditions or favorable markets. There has been concern as fishery exploitation rates have been above reference levels and fewer licenses are fished than have been issued (DFO 2001). In 2001, DFO reported that in some rivers river herring were being harvested at or above reference levels (e.g., Miramichi River), while in other rivers river herring were harvested at or below the reference point (e.g., St. John River at Mactaquac Dam). The DFO (2001) believes precautionary management involving no increase or decrease in exploitation is important for Maritime river herring fisheries, given that biological and harvest data are not widely available. Additionally, DFO (2001) added that river-specific management plans based on stock assessments should be prioritized over general management initiatives.

Eastern New Brunswick is currently the only area in the Canadian Maritimes with a river herring integrated fishery management plan (DFO 2012). The DFO uses Integrated Fisheries Management Plans (IFMPs) to guide the conservation and sustainable use of marine resources (DFO 2010). An IFMP manages a fishery in a given region by combining the best available science on the species with industry data on capacity and methods for harvesting (DFO 2010). The 6-year management plan (2007-2012) for river herring for Eastern New Brunswick is implemented in conjunction with annual updates to specific fishery management measures (e.g., seasons). However, it appears that this management plan has been updated.

4.4.2 Federal

4.4.2.1 *ASMFC and Enabling Legislation*

Authorized under the terms of the Atlantic States Marine Fisheries Compact, as amended (Public Law 81-721), the purpose of the ASMFC is to promote the better utilization of the fisheries (marine, shell, and anadromous) of the Atlantic seaboard “by the development of a joint program for the promotion and protection of such fisheries, and by the prevention of the physical waste of the fisheries from any cause.” The ASMFC manages 27 nearshore species. The ASMFC’s decision-making occurs through the Interstate Fisheries Management Program, where specific management boards determine management strategies that the states implement through fishing regulations. The boards consider and approve the development and implementation of interstate Fishery Management Plans (ISFMPs). If the ASMFC finds that a state is not in compliance with a coastal FMP, it must notify the Secretaries of Commerce and Interior. If the Secretaries find the state is not in compliance with the management plan, the Secretaries must declare a moratorium on the fishery in question.

The ASMFC adopted Amendment 2 to the ISFMP for American Shad and River Herring in 2009. Amendment 2 establishes the foundation for river herring management. It was developed to address concerns that many stocks of river herring species were declining and/or remain depressed at sustainable levels, and that the ability to accurately assess the status of river herring stocks is complicated by a lack of fishery independent data.

Amendment 2 requires states to close their waters to recreational and commercial river herring harvest, unless they have an approved sustainable management plan in place. To be approved, a state’s plan must clearly meet the Amendment’s standard of a sustainable fishery defined as “a commercial and/or recreational fishery that will not diminish the potential future stock reproduction and recruitment." The plans must meet the definition of sustainability by developing and maintaining sustainability targets. States without an approved plan were required to close their respective river herring fisheries as of January 1, 2012, until such a plan has been submitted and approved by the ASMFC's Shad and River Herring Management Board. Proposals to re-open closed fisheries may be submitted annually as part of a state's annual compliance report. Currently, Maine, New Hampshire, Rhode Island, New York, North Carolina, and South Carolina have approved river herring management plans.

In addition to the state sustainability plan mandate, Amendment 2 makes recommendations to states for the conservation, restoration, and protection of critical river herring habitat. The Amendment also requires states to implement fisheries-dependent and independent monitoring programs to provide critical data for use in future river herring stock assessments. While these measures address problems to the river herring populations in coastal areas, incidental catch in small mesh fisheries, such as those for Atlantic herring, occurs outside state jurisdiction and remains a substantial source of fishing mortality (ASMFC 2017a). Consequently, the ASMFC has requested that the New England and Mid-Atlantic Fishery Management Councils (NEFMC and MAFMC, respectively) increase efforts to monitor river herring incidental catch in small-mesh fisheries.

4.4.2.2 *Atlantic Coastal Fisheries Cooperative Management Act*

River herring stocks are managed under the authority of section 803(b) of the Atlantic Coastal Fisheries Cooperative Management Act (Atlantic Coastal Act, 16 U.S.C 5101 et seq.), which states, in the absence of an approved and implemented FMP under the Magnuson-Stevens Act (MSA, 16 U.S.C. 1801 et seq.) and, after consultation with the appropriate Fishery Management Council(s), the Secretary of Commerce may implement regulations to govern fishing in the Exclusive Economic Zone (EEZ), i.e., from 3 to 200 nautical mi (nm) offshore. The regulations must be: (1) compatible with the effective implementation of an ISFMP American Shad and River Herring developed by the ASMFC; and (2) consistent with the national standards set forth in section 301 of the MSA.

4.4.2.3 *Magnuson-Stevens Fishery Conservation and Management Act (MSA)*

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) is the primary law governing marine fisheries management in federal waters. The MSA was first enacted in 1976 and amended in 1996 and 2007. Most notably, the MSA aided in the development of the domestic fishing industry by phasing out foreign fishing. To manage the fisheries and promote conservation, the MSA created eight regional fishery management councils. The 1996 amendment focused on rebuilding overfished fisheries, protecting essential fish habitat and reducing bycatch. The 2007 amendment mandated the use of annual catch limits and accountability measures to end overfishing, provided for widespread market-based fishery management through limited access privilege programs, and called for increased international cooperation.

The MSA requires that federal FMPs contain conservation and management measures that are consistent with the ten National Standards. National Standard 9 states that conservation and management measures shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch. The MSA defines bycatch as fish that are harvested in a fishery, but which are not sold or kept for personal use. This includes economic discards and regulatory discards. River herring are encountered as both bycatch and incidental catch in federal fisheries. While there is no directed fishery for river herring in federal waters, river herring co-occur with other species that have directed fisheries (Atlantic mackerel, Atlantic herring, whiting) and are either discarded or retained in those fisheries.

Commercial fisheries which incidentally catch river herring in Federal waters are managed by the NEFSC, MAFMC, and NMFS. Several management measures intended to reduce commercial fisheries interactions with river herring and shad in Federal waters are currently in place. These management measures have been developed by the NEFMC, the MAFMC, the Greater Atlantic Regional Fisheries Office of the NMFS, and the NEFSC and promulgated through Federal fishery management plans (FMP) for Atlantic Herring and Atlantic Mackerel, Squid, and Butterfish.

Vessels fishing for Atlantic mackerel and Atlantic herring can encounter river herring and shad. The MAFMC and NEFMC recommended river herring and shad catch caps for these fisheries and NMFS implemented catch caps for these fisheries beginning in 2014. Managers don't currently have enough data to determine biologically based river herring and shad catch caps or to assess the potential effects of such catch caps on river herring and shad populations coastwide. However, the Councils and NMFS believe river herring and shad catch caps provide a strong incentive for the mackerel and herring fleets to continue avoiding river herring and shad. These catch caps are intended to allow for the full harvest of the mackerel and herring annual catch limits while reducing river herring and shad incidental catch.

In December 2014, NMFS implemented river herring and shad catch caps for the Atlantic herring fishery for 2014-2015, and allowed the NEFMC to set river herring and shad catch caps and associated measures in future years though specifications or frameworks, as appropriate (79 FR 71960, December 4, 2014). Catch of river herring and shad on fishing trips that landed more than 3 mt (6,600 lbs) of Atlantic herring counted towards the caps. Caps were area- and gear-specific. Upon a NMFS determination that 95 percent of a river herring and shad cap has been harvested, a 2,000-lb Atlantic herring possession limit for that area and gear would become effective for the remainder of the fishing year. This possession limit has been imposed twice due to river herring and shad catch caps (both for midwater trawl vessels in 2018) since the rule was implemented in 2014. The river herring and shad catch caps for the Atlantic herring fishery for 2019 (set in the 2019 Adjustment to the Atlantic Herring Specifications; 84 FR 2760, February 8, 2019) are as follows:

- A midwater trawl cap for the Gulf of Maine Catch Cap Area (76.7 mt) (169,094 lbs);
- A midwater trawl cap for Cape Cod Catch Cap Area (32.4 mt) (71,430 lbs);
- A midwater trawl cap for Southern New England Mid-Atlantic Catch Cap Area (129.6 mt) (285,719 lbs); and
- A bottom trawl cap for Southern New England Catch Cap Area (122.3 mt) (269,625 lbs).

The river herring and shad catch cap for the mackerel fishery is set through annual specifications. NMFS set the 2018 river herring and shad cap for the mackerel fishery at 82 mt (180,779 lbs) as part of a final rule to implement the 2016 through 2018 Atlantic mackerel specifications (81 FR 24504, April 4, 2016). The 2018 Atlantic mackerel specifications, including the river herring and shad catch cap, apply to 2019 until Framework 13 to the Atlantic mackerel, squid, and butterfish FMP is finalized (84 FR 26634, June 7, 2019). Catch of river herring and shad on fishing trips that land greater than 20,000 lbs of mackerel count towards the cap. If NMFS determines that 95 percent of the river herring and shad cap has been harvested, a 20,000-lb mackerel possession limit will become effective for the remainder of the fishing year. In 2019, the river herring and shad cap was met in March, and the Atlantic mackerel possession limit was reduced starting on March 12, 2019 (84 FR 8999; March 13, 2019). The 2019 river herring and shad catch cap will be adjusted in the final rule implementing Framework Adjustment 13 to the Atlantic Mackerel, Squid, and Butterfish Fishery Management Plan. Framework 13 proposes an initial 89-mt (196,211 lbs) catch cap. The cap could be increased to 129 mt (284,396 lbs) if commercial mackerel landings exceed 10,000 mt (22,046,200 lbs). The increased cap reflects a proportional increase to the proposed increase in the Atlantic mackerel commercial landings limit. Framework 13 will be in place by fall of 2019.

Under the MSA, there is a requirement to describe and identify Essential Fish Habitat (EFH) in each federal FMP. EFH is defined as "...those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The rules promulgated by the NMFS in 1997 and 2002 further clarify EFH with the following definitions: (1) waters - aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; (2) substrate - sediment, hard bottom, structures underlying the waters, and associated biological communities; (3) necessary - the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and (4) spawning, breeding, feeding, or growth to maturity - stages representing a species' full life cycle.

EFH has not been designated for alewife or blueback herring, though EFH has been designated for numerous other species in the Northwest Atlantic. Measures to improve habitats and reduce impacts resulting from those EFH designations may directly or indirectly benefit river herring. Conservation measures implemented in response to the designation of Atlantic salmon EFH and Atlantic herring EFH likely provide the most conservation benefit to river herring over any other EFH designation. Habitat features used for spawning, breeding, feeding, growth and maturity by these two species encompasses many of the habitat features necessary by river herring to carry out their life history. The geographic range in which river herring may benefit from the designation of Atlantic salmon EFH extends from Connecticut to the Maine/Canada border. The geographic range in which river herring may benefit from the designation of Atlantic herring EFH designation extends from the Maine/Canada border to Cape Hatteras.

The Atlantic salmon EFH includes most freshwater, estuary and bay habitats historically accessible to Atlantic salmon from Connecticut to the Maine/Canada border (NEFMC 2006). Many of the estuary, bay and freshwater habitats within the current and historical range of Atlantic salmon incorporate habitats used by river herring for spawning, migration and juvenile rearing. Among Atlantic herring EFHs are the pelagic waters in the Gulf of Maine, Georges

Bank, Southern New England, and mid-Atlantic south to Cape Hatteras out to the offshore U.S. boundary of the EEZ (NEFMC 1998). These areas incorporate nearly all of the U.S. marine areas most frequently used by river herring for growth and maturity. Accordingly,, conservation measures aimed at improving or minimizing impacts to habitats in these areas for the benefit of Atlantic salmon or Atlantic herring may provide similar benefits to river herring.

4.4.2.4 *Federal Power Act (FPA) (16 U.S.C. 791-828) and Amendments*

The FPA, as amended, provides for protecting, mitigating damages to and enhancing fish and wildlife resources (including anadromous fish) impacted by hydroelectric facilities regulated by the Federal Energy and Regulatory Commission (FERC). Applicants must consult with state and federal resource agencies who review proposed hydroelectric projects and make recommendations to FERC concerning fish and wildlife and their habitat, e.g., including spawning habitat, wetlands, instream flows (timing, quality, quantity), reservoir establishment and regulation, project construction and operation, fish entrainment and mortality, and recreational access. Section 10(j) of the FPA provides that licenses issued by FERC may contain conditions to protect, mitigate damages to and enhance fish and wildlife based on recommendations received from state and Federal agencies during the licensing process. Section 18 of the FPA requires a FERC licensee to construct, maintain, and operate fishways prescribed by the Secretary of the Interior or the Secretary of Commerce. Under the FPA, others may review proposed projects and make timely recommendations to FERC to represent additional interests.

While the construction of hydroelectric dams contributed to some historical losses of river herring spawning habitat, only a few new dams have been constructed in the range of these species in the last 50 years. In some areas, successful fish passage has been created; thus, restoring access to large amounts of habitat once blocked. Thus, river herring may often benefit from FPA fishway requirements when prescriptions are made to address anadromous fish passage and during the re-licensing of existing hydroelectric dams when anadromous species are considered.

4.4.2.5 *Anadromous Fish Conservation Act (16 U.S.C. 757a-757f) as Amended*

This law authorizes the Secretaries of Interior and Commerce to enter into cost sharing with states and other non-federal interests for the conservation, development, and enhancement of the nation’s anadromous fish. Investigations, engineering, biological surveys, and research, as well as the construction, maintenance, and operations of hatcheries, are authorized.

4.4.2.6 *Fish and Wildlife Coordination Act (FWCA) (16 U.S.C. 661-666)*

The FWCA is the primary law providing for consideration of fish and wildlife habitat values in conjunction with federal water development activities. Under this law, the Secretaries of Interior and Commerce may investigate and advise on the effects of federal water development projects on fish and wildlife habitat. Such reports and recommendations, which require concurrence of the state fish and wildlife agency(ies) involved, must accompany the construction agency's request for congressional authorization, although the construction agency is not bound by the recommendations.

The FWCA also applies to water-related activities proposed by non-federal entities for which a federal permit or license is required. The most significant permits or licenses required are Section 404 and discharge permits under the Clean Water Act and Section 10 permits under the Rivers and Harbors Act. The USFWS and NMFS may review the proposed permit action and make recommendations to the permitting agencies to avoid or mitigate any potential adverse effects on fish and wildlife habitat. These recommendations must be given full consideration by the permitting agency, but are not binding.

4.4.2.7 *Federal Water Pollution Control Act, and amendments (FWPCA) (33 U.S.C. 1251-1376)*

Commonly known as the "Clean Water Act," the FWPCA mandates federal protection of water quality. The law also provides for assessment of injury, destruction, or loss of natural resources caused by discharge of pollutants. Of major significance is Section 404 of the FWPCA, which prohibits the discharge of dredged or fill material into navigable waters without a permit. Navigable waters are defined under the FWPCA to include all waters of the United States, including the territorial seas and wetlands adjacent to such waters. The permit program is administered by the Army Corps of Engineers (ACOE). The Environmental Protection Agency (EPA) may approve delegation of Section 404 permit authority for certain waters (not including traditional navigable waters) to a state agency; however, the EPA retains the authority to prohibit or deny a proposed discharge under Section 404 of the FWPCA.

The FWPCA (Section 401) also authorizes programs to remove or limit the entry of various types of pollutants into the nation's waters. A point source permit system was established by the EPA and is now being administered at the state level in most states. This system, referred to as the National Pollutant Discharge Elimination System (NPDES), sets specific limits on discharge of various types of pollutants from point source outfalls. A non-point source control program focuses primarily on the reduction of agricultural siltation and chemical pollution resulting from rain runoff into the nation's streams. This effort currently relies on the use of land management practices to reduce surface runoff through programs administered primarily by the Department of Agriculture.

Like the Fish and Wildlife Coordination and Rivers and Harbors Acts, Sections 401 and 404 of the FWPCA have played a role in reducing discharges of pollutants, restricting the timing and location of dredge and fill operations, and affecting other changes that have improved river herring habitat in many rivers and estuaries over the last several decades.

4.4.2.8 *Rivers and Harbors Act of 1899*

Section 10 of the Rivers and Harbors Act requires a permit from the ACOE to place structures in navigable waters of the United States or modify a navigable stream by excavation or filling activities. The Rivers and Habors Act governs most dredging and in-water work that affect river herring habitat.

4.4.2.9 *National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321-4347)*

The NEPA requires an environmental review process of all federal actions. This includes preparation of an environmental impact statement for major federal actions that may affect the quality of the human environment. Less rigorous environmental assessments are reviewed for most other actions, while some actions are categorically excluded from formal review. These reviews provide an opportunity for the agency and the public to comment on projects that may affect fish and wildlife habitat including impacts to river herring.

4.4.2.10 *Coastal Zone Management Act (16 U.S.C. 1451-1464) and Estuarine Areas Act*

Congress passed policy on values of estuaries and coastal areas through these Acts. Comprehensive planning programs, to be carried out at the state level, were established to enhance, protect, and utilize coastal resources. Federal activities must comply with the individual state programs. Habitat may be protected by planning and regulating development that could cause damage to sensitive coastal habitats. These state programs provide protection to individual, river-specific populations of river herring.

4.4.2.11 *Federal Land Management and Other Protective Designations*

Protection and good stewardship of lands and waters managed by federal agencies, such as the Departments of Defense, Interior, and Energy (as well as state-protected park, wildlife and other natural areas), contributes to the health of nearby aquatic systems that support important river herring spawning and nursery habitats. Relevant examples include the Great Bay, Rachel Carson's and ACE Basin National Estuarine Research Reserves, Department of Defense properties in the Chesapeake Bay, and many National Wildlife Refuges.

4.4.2.12 *Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA), Titles I and III and the Shore Protection Act of 1988 (SPA)*

The MPRSA protects fish habitat through establishment and maintenance of marine sanctuaries. The MPRSA and the SPA regulate ocean transportation and dumping of dredge materials, sewage sludge, and other materials. Criteria that the ACOE uses for issuing permits include considering the effects dumping has on the marine environment, ecological systems, and fisheries resources, which include river herring.

4.4.2.13 *Endangered Species Act (1973, as amended) (ESA)*

The Endangered Species Act provides for the conservation of species that are endangered or threatened throughout all or in a significant portion of their range, and the conservation of the ecosystems on which they depend.

In 2009, the Gulf of Maine (GOM) Distinct Population Segment (DPS) of Atlantic salmon was listed as endangered under the ESA (74 FR 29344) and critical habitat was designated. The GOM DPS includes all anadromous Atlantic salmon whose freshwater range occurs in the watersheds from the Androscoggin River northward along the Maine coast to the Dennys River. Concurrently in 2009, critical habitat was designated for the Atlantic salmon GOM DPS pursuant to section 4(b)(2) of the ESA (74 FR 29300; August 10, 2009). The critical habitat designation includes 45 specific areas occupied by Atlantic salmon at the time of listing, and includes approximately 12,160 miles (19,600 km) of perennial river, stream, and estuary habitat and 308 square miles (495 sq km) of lake habitat within the range of the GOM DPS in the State of Maine.

Measures to improve habitats and reduce impacts to Atlantic salmon because of the ESA listing may directly or indirectly benefit river herring. Atlantic salmon are anadromous and spend a portion of their life in freshwater and the remaining portion in the marine environment. River herring occupy many of the same habitats as listed Atlantic salmon for spawning, breeding, feeding, growth and maturity. Therefore, protection measures such as improved fish passage or reduced discharge permits may benefit river herring.

The critical habitat designation provides additional protections beyond classifying a species as endangered by preserving the physical and biological features essential for the conservation of the species in designated waters in Maine. One of the biological features identified in the critical habitat designation for Atlantic salmon was freshwater and estuary migration sites with abundant, diverse native fish communities to serve as a protective buffer against predation. Co-evolved diadromous fish species such as alewives and blueback herring are included in this native fish community. Because the ESA also requires that any federal agency that funds, authorizes, or carries out an action ensure that the action does not adversely modify or destroy designated critical habitat, the impacts to alewife and blueback herring populations may be be considered during consultation with NMFS to ensure that Atlantic salmon critical habitat is not adversely affected by a federal action.

On February 6, 2012, five distinct population segments of Atlantic sturgeon were listed under the ESA (77 FR 5914; 77 FR 5880). The Chesapeake Bay, New York Bight, Carolina, and South Atlantic DPSs of Atlantic sturgeon are listed as endangered, while the Gulf of Maine DPS is listed as threatened. On August 17, 2017, critical habitat was designated for the five DPSs (82 FR 39160).

Measures to improve habitats and reduce impacts to Atlantic sturgeon may directly or indirectly benefit river herring. Atlantic sturgeon are anadromous; adults spawn in freshwater in the spring and early summer and migrate into estuarine and marine waters where they spend most of their lives. As with Atlantic salmon, many of the habitats that Atlantic sturgeon occupy are also habitats that river herring use for spawning, migration and juvenile rearing. The geographic range in which river herring may benefit from Atlantic sturgeon ESA protections extends from the Maine/Canada border to Florida. Therefore, any protection measures within this range such as improved fish passage or a reduction of water withdrawals may also provide a benefit to river herring.

4.4.3 State Regulations

A historical review of state regulations was compiled and published in Volume I of the stock assessment.

Excerpted from ASMFC (2012, 2017b):

> <u>Maine</u>
>
> In Maine, the Department of Marine Resources (DMR), along with municipalities granted the rights to harvest river herring resources, cooperatively manage municipal fisheries. Each town must submit an annual harvesting plan to DMR for approval that includes a 3-day per week escapement period or biological equivalent to ensure 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, as required under Amendment 2, are closed. Each run and harvest location is unique, either in seasonality, fish composition, or harvesting limitations. Some runs have specific management plans that require continuous escapement and are more restrictive than the 3-day closed period. Others have closed periods shorter than the 3-day requirement, but require an escapement number, irrespective of the number harvested during the season. Most towns operate a weir at one location on each stream and prohibit 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 permitted twenty-two municipalities to fish for river herring in 2017. The river specific management plans required the remaining municipalities to close their runs for conservation and not harvest. There are several reasons for the state/municipal restrictions imposed on these fisheries. 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 and some suffer from lack of good upstream or downstream fish passage. The commercial fishery does not exploit the estimated 1.5 – 2.0 million river herring that return to the East Machias River or the millions of fish in the main stem of Maine’s nine largest rivers (ASMFC 2017b).

Maine's directed commercial fisheries are self-sustaining and all operate under sustainable fisheries management plans cooperatively developed between the municipalities that own rights to harvest the river herring resource and the State of Maine, as required under ASMFC Amendment 2 to the Shad and River Herring FMP (ASMFC 2017b).

Recreational anglers 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 anglers may not fish in waters, or in waters upstream, of a municipality that owns fishing rights. Recreational anglers are not required to report their catch. The MRFSS and MRIP programs do sample some of these anglers based on results queried from the database. Recreational fishing for river herring in Maine is limited and landings are low.

New Hampshire

The current general regulations are: (1) no person shall take river herring, alewives and blueback herring, from the waters of the state, by any method, between sunrise Wednesday and sunrise Thursday of any week; (2) any trap or weir used during a specified time period, shall be constructed so as to allow total escapement of all river herring; and (3) any river herring taken by any method during the specified time period shall be immediately released back into the waters from which it was taken. Specific river regulations are:

- Taylor River - from the railroad bridge to the head of tide dam in Hampton shall be closed to the taking of river herring by netting of any method;
- Squamscott River - 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 is open to the taking of river herring by netting of any method only on Saturdays and Mondays, the daily limit shall be one tote per person ("tote" means a fish box or container measuring 31.5 in (80.01cm) x 18 in (45.72 cm) x 11.5 in (29.21cm)) and the tote shall have the harvester's coastal harvest permit number plainly visible on the outside of the tote;
- Oyster River - the Oyster River and its tributaries shall be closed to the taking of river herring by any method from the head-of-tide dam at Mill Pond in Durham, 43°07'51.23"N, 70°55'08.20"W and 43°07'50.31"N, 70°55'08.04"W, downstream to the river mouth at Wagon Hill Farm and Durham Point, a line extending from 43°07'31.87"N, 70°52'17.67"W to 43°07'20.18"N, 70°52'19.16"W. (ASMFC 2017).

These regulations have been approved through a sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River Herring FMP.

Massachusetts

As of January 1, 2012, commercial and recreational harvest of river herring was prohibited in Massachusetts, as required by ASMFC Amendment 2 to the Shad and River Herring FMP. Currently, the Commonwealth of Massachusetts is in the 12^{th} year of a harvest moratorium for river herring (ASMFC 2017b). The following regulations on the harvest, possession and sale of river herring in the Commonwealth are currently in place (322-CMR Section 6:17):

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

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.

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. 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. (updated and current)

Rhode Island

Currently there is a moratorium on harvest of river herring (alewives and bluebacks) in Rhode Island’s fresh and marine waters (RIDFW Reg; RIMF Reg.). Due to drastic declines in spawning stock size beginning in 2001, Rhode Island passed regulations in March 2006 for the complete closure. The marine and freshwater closure continued through 2015 and is planned for 2017 (ASMFC 2017b).

The Rhode Island Division of Fish and Wildlife (RIDFW) will implement a 5% bycatch allowance for federal vessels fishing in the Atlantic herring fishery in federal waters. RIDFW will also implement a mandatory permitting process that will require vessels wanting to fish in the Rhode Island waters Atlantic herring fishery to, amongst other requirements, integrate in to the University of Massachusetts Dartmouth, School for Marine Science and Technology, river herring bycatch monitoring program to ensure monitoring of the fishery and minimize bycatch.

Connecticut

Since April 2002 to present, there has been a statewide moratorium on commercial and recreational take of anadromous blueback herring and alewife from all marine waters and most inland waters. 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. This prohibition is determined on an annual basis (ASMFC 2017b).

New York

Current regulations allow for a restricted river herring commercial and recreational fishery in the Hudson River and tributaries, while all other state waters prohibit river herring fisheries. In response to Amendment 2, New York State proposed, and ASMFC approved, the 2012 Sustainable Fishery Management Plan (SFMP) for New York River Herring Stocks (Hattala et al. 2011a). This SFMP included an experimental five-year restricted fishery in the Hudson River, a partial fishery closure in tributaries, a moratorium for all non-Hudson waters, and annual stock monitoring in the Hudson River (ASMFC 2017b). Monitoring included young of year indices, and for adults: age and length characteristics, mortality estimators, and commercial fishing catch per unit effort (CPUE). The sustainability target for both species was set using the young-of-year indices. The sustainability target value was defined as the 25th percentile of the time series, such that three consecutive years with index values below this target would trigger management action. From 2012-2016, the indices did not fall below the target for three consecutive years for either species (ASMFC 2017b). In 2017, New York State submitted a an update to the 2012 SFMP (Hattala et al. 2011a), which proposed a continuation of the moratorium in non-Hudson waters, a restricted fishery in the Hudson River, annual stock monitoring, and sustainability target described in the original SFMP. The ASMFC Management Board approved this update in February 2017 (ASMFC 2017b).

New Jersey/Delaware

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. As of January 1, 2012, commercial and recreational harvest of river herring was prohibited in New Jersey and Delaware, as required by ASMFC Amendment 2 to the Shad and River Herring FMP (ASMFC 2017b).

Maryland

As of January 1, 2012, commercial and recreational harvest of river herring was prohibited in Maryland, as required by ASMFC Amendment 2 to the Shad and River Herring FMP (ASMFC 2017b).

Potomac River Fisheries Commission (PRFC) / District of Columbia

The PRFC regulates only the mainstem of the Potomac River, while the tributaries on either side are under Maryland and Virginia jurisdiction. The District of Columbia's Department of the Environment (DDOE) has authority for the Potomac River to the Virginia shore and other waters within District of Columbia. In 2012, all directed fisheries were closed to the taking and/or possession of river herring. The PRFC now has no directed commercial or recreational fisheries for river herring. As of January 1, 2010, harvest of river herring was prohibited in the Potomac River, with a minimal bycatch provision of 50 lb (22 kg) per licensee per day for pound nets. These regulations have been approved through a sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River Herring FMP (ASMFC 2017b).

Virginia

Virginia's Department of Game and Inland Fisheries (VDGIF) is responsible for the management of fishery resources in the state's inland waters. As of January 1, 2008, possession of alewives and blueback herring was prohibited on rivers draining into North Carolina (4 VAC 15-320-25). The Virginia Marine Resources Commission (VMRC) is responsible for management of fishery resources within the state's marine waters. As of January 1, 2012, commercial and recreational harvest of river herring was prohibited in all waters of Virginia, as required by ASMFC Amendment 2 to the Shad and River Herring FMP (ASMFC 2017). Additionally, it is unlawful for any person to possess river herring aboard a vessel on Virginia tidal waters, or to land any river herring in Virginia (4 VAC 20-1260-30).

North Carolina

A no harvest provision for river herring, commercial and recreational, within North Carolina was approved in 2007. A limited research set aside of 7,500 lb (3.4 mt) was established, and to implement this harvest, 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. Sale of harvested river herring had to be to a licensed and permitted River Herring Dealer. Each permit holder was allocated 125-250 lb (56-113 kg) for the 4-day season during Easter weekend. These regulations were approved through a sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River Herring FMP. The North Carolina Wildlife

Resources Commission has authority over the inland waters of the state. Since July 1, 2006, harvest of river herring, greater than 6 inches (15.24 cm) has been prohibited in the inland waters of North Carolina's coastal systems (ASMFC 2017b).

South Carolina

In South Carolina, the South Carolina Department of Natural Resources (SCDNR) manages commercial herring fisheries using a combination of seasons, gear restrictions, and catch limits. Today, the commercial fishery for blueback herring has a 10-bushel daily limit (500 lb (226 kg)) per boat in the Cooper and Santee Rivers and the Santee-Cooper Rediversion Canal and a 250-lb-per-boat (113 kg) limit in the Santee-Cooper lakes. Seasons generally span the spawning season. All licensed anglers have been required to report their daily catch and effort to the SCDNR since 1998. The recreational fishery has a 1-bushel (49 lb (22.7 kg)) fish aggregate daily creel for blueback herring in all rivers; however, very few recreational anglers target blueback herring. These regulations have been approved through a sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River Herring FMP (ASMFC 2017b).

Georgia

The take of blueback herring is illegal in freshwater in Georgia. As of January 1, 2012, harvest of river herring was prohibited in all waters of Georgia, as required by ASMFC Amendment 2 to the Shad and River Herring FMP (ASMFC 2017b).

Florida

The St. Johns River, Florida, harbors the southernmost spawning run of blueback herring. As of January 1, 2012, harvest of river herring was prohibited, as required by ASMFC Amendment 2 to the Shad and River Herring FMP. There is no directed fishery (commercial or recreational) in Florida (ASMFC 2017b).

4.5 Other Natural or Manmade Factors Affecting the Species' Continued Existence

4.5.1 Artificial Propagation and Stocking

Genetics data have shown that stocking alewife and blueback herring within and out of basin in Maine has had an impact on the genetic groupings within Maine (McBride et al. 2014); however, the extent to which this poses a threat to river herring locally or coast-wide is unknown. Stocking river herring directly impacts a specific river/ watershed system for river herring in that it can result in passing fish above barriers into suitable spawning and rearing habitat, expanding populations into other watersheds, and introducing fish to newly accessible spawning habitat.

The alewife restoration program in Merrymeeting Bay, Maine, focuses on stocking lakes and ponds in the Sebasticook River watershed and Seven Mile Stream drainage. The highest number of stocked fish was 2,211,658 in 2009 in the Sebasticook River and 93,775 in 2008 in the Kennebec River. The annual stocking goal of the restoration projects range from 120,000 to 500,000 fish, with most fish stocked in the Androscoggin and Sebasticook watersheds. The Union River fishery in Ellsworth, Maine, is sustained through the stocking of adult alewives above the hydropower dam at the head-of-tide. Fish passage is not currently required at this dam, but fish are transported around the dam to spawning habitat in two lakes. The annual adult stocking rate (from 2015 forward) is 315,000 fish. Adult river herring are trapped at commercial harvest sites below the dam and trucked to waters upstream of the dam. The highest number of stocked fish in the Union River was 1,238,790 in 1986. In the Penobscot River watershed, over 48,000 adult fish were stocked into lakes in 2012, using fish collected from the Kennebec (39,650) and Union Rivers (8,998).

In New Hampshire, from 1984 to 2015, approximately 55,600 adult river herring have been stocked in coastal rivers (Cocheco, Winnicut, Exeter, Lamprey and Salmon Falls) (ASMFC 2017b). The transfers that occurred were either in-basin transfers to previously unoccupied habitat or out-of-basin transfers to help supplement spawning runs in rivers with lower return numbers. Fish were stocked from various rivers including the Connecticut, Cocheco, Lamprey, Kennebec, and Androscoggin Rivers.

The Massachussetts Division of Marine Fisheries (DMF) conducts a trap and transport stocking program for alewife and blueback herring in Massachusetts. 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 in 2012 the program transported between 30,000 and 50,000 fish per year into 10-15 different systems. Since the moratorium, a DMF stocking protocol was developed and implemented in 2013 that provided criteria for stocking decisions and a focus to allow remnant populations present at restoration sites to naturally re-colonize habitat prior to the introduction of donor stock genetics. The protocol has reduced stocking activity with most recent efforts occurring within drainage, moving fish upstream past multiple obstructions to the headwater spawning habitat (ASMFC 2017b).

Rhode Island’s Department of Environmental Management (DEM) conducts trap and transport utilizing out-of-state and in-state broodstock sources to supplement existing runs or restore extirpated systems where habitats 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 River 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 River and Nonquit Rivers 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. In 2015, the following locations were stocked: Kickemuit, Turner Reservoir, Woonsquatucket, Potowamut, and Watchaug with 1,000 fish each, and Pawtucket River was stocked with 2,000 fish.

The Edenton National Fish Hatchery (NFH) in North Carolina and the Harrison Lake NFH in

Virginia have propagated blueback herring for restoration purposes. Edenton NFH is currently rearing blueback herring for stocking in Indian Creek and Bennett's Creek in the Chowan River watershed in Virginia.

4.5.2 Competition

Intra- and inter-specific competition were considered as potential natural threats to alewife and blueback herring. The earlier spawning time of alewife may lead to differences in prey selection from blueback herring, given that they become more omnivorous with increasing size (Klauda et al. 1991a). This could lead to differences in prey selection given that juvenile alewife would achieve a greater age and size earlier than blueback herring. Juvenile American shad are reported to focus on different prey than blueback herring (Klauda et al. 1991b). However, Smith and Link (2010) found few differences between American shad and blueback herring diets across geographic areas and size categories; therefore, competition between these two species may be occurring. Cannibalism has been observed (rarely) in landlocked systems with alewife. Additionally, evidence of hybridization exists between alewife and blueback herring, but the implications of this are unknown. Competition for habitat or resources has not been documented with alewife/ blueback herring hybrids, as there is little documentation of hybridization in published literature, but given the unknowns about their life history, it is possible that competition between non-hybrids and hybrids could be occurring.

4.5.3 Hybrids

Genetic studies indicate that interbreeding among alewife and blueback herring (hybridization) may be occurring in some instances where populations overlap (see for example, NMFS 2012a). Though interbreeding among closely related species is uncommon, it does occasionally occur (Levin 2002) and has been reported at rates of 1.8 to 2.4% (Hasselman et al. 2014, Hasselman et al. 2016, Kan et al. 2017). Most often, different reproductive strategies, home ranges, and habitat differences of closely related species prevent interbreeding or keep interbreeding at very low levels. In circumstances where interbreeding does occur, natural selection often keeps hybrids in check because hybrids are less fit in terms of survival or their ability to breed successfully (Levin 2002). Other times, environmental conditions can provide an environment where hybrids can thrive. When hybrids breed with the member of the parent species, this can lead to ''mongrelization'' of one or both parent species; a process referred to as introgressive hybridization (Arnold 1997). Introgressive hybridization can also occur as a result of introductions of closely related species, or man-made or natural disturbances that create environments more suitable for the hybrid offspring than for the parents (e.g., the introduction of mallards has led to the decline of the American black duck through hybridization and introgression) (Anderson 1949; Rhymer 2008). McBride et al. (2014) documented F1 hybrids and Hasselman et al. (2014) documented F2 generation hybrids breeding with parent species While hybridization is likely occurring between alewife and blueback herring, there is not enough evidence to conclude whether or not hybridization poses a threat to one or both species of river herring.

4.5.4 Landlocked Populations

Alewives and blueback herring maintain two life history variants; anadromous and landlocked. It is believed that they diverged relatively recently (300 to 5,000 years ago) and are now discrete from each other. Landlocked alewife populations occur in many freshwater lakes and ponds from Canada to North Carolina as well as the Great Lakes (Rothschild 1966, Boaze and Lackey 1974). Landlocked blueback herring occur mostly in the southeastern United States and the Hudson River drainage. At this time, there is no substantive information that would suggest that landlocked populations can or would revert to an anadromous life history if they had the opportunity to do so.

The discrete life history and morphological differences between the two life history variants provide substantial evidence that upon becoming landlocked, landlocked herring populations become largely independent and separate from anadromous populations. Landlocked populations and anadromous populations occupy largely separate ecological niches, especially in respect to their contribution to freshwater, estuary and marine food webs (Palkovacs and Post 2008). Thus, the existence of landlocked life forms does not appear to pose a significant threat to the anadromous forms.

5 ASSESSMENT OF EXTINCTION RISK FOR THE ALEWIFE AND BLUEBACK HERRING

5.1 INTRODUCTION

In many previous NMFS status reviews, a SRT of experts has been convened in order to compile the best available information on the species and conduct a risk assessment through evaluation of the demographic risks, threats, and extinction risk facing the species or distinct population segment (DPS). This information is ultimately used by NMFS, after consideration of the legal and policy dimensions of the ESA standards and benefits of ongoing conservation efforts, to make a listing determination. For purposes of this risk assessment, NMFS organized a Status Review Team (SRT) in 2018 composed of fishery biologists and managers. Because the petition requested that NMFS list alewife and blueback herring as threatened throughout all or a significant portion of their ranges, or in the alternative, designate and assess the risk to DPSs for these species, the SRT was tasked with multiple assessments. First, the SRT was asked to review the best available information in the Status Review document and to assess the overall risk of extinction facing alewife and blueback herring rangewide now and in the foreseeable future. Second, the SRT was tasked with identifying any DPSs within these populations and asked to assess the risk of extinction facing each identified DPS of alewife and blueback herring now and in the foreseeable future.

As the available information for the biology and the threats do not always differ between the rangewide analysis and the DPS analyses, this section of the report first discusses the SRT's identification of DPSs' for both species and then presents a summary of the SRT's assessment of the extinction risk for the rangewide and DPSs of each species.

5.2 DISTINCT POPULATION SEGMENT ANALYSIS

5.2.1 Criteria for Identification of Distinct Population Segments

As part of the status review, the SRT considered whether any petitioned populations qualify as DPSs within the species. The joint policy of the USFWS and NMFS provides guidelines for defining DPSs below the taxonomic level of species (61 FR 4722; February 7, 1996). The policy identifies two elements to consider in a decision regarding whether a population qualifies as a DPS: discreteness and significance of the population segment to the species.

Discreteness

A population segment is considered discrete if it is markedly separate from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors, or if it is delimited by international governmental boundaries. Genetic or morphological differences between the population segments being considered may be used to provide evidence of this separation.

Significance

If a population segment is considered discrete, its biological and ecological significance must then be evaluated. Significance is evaluated in terms of the importance of the population segment to the overall welfare of the species. Some of the considerations that can be used to determine a discrete population segment's significance to the taxon as a whole include:

1) Persistence of the population segment in an unusual or unique ecological setting;

2) Evidence that loss of the population segment would result in a significant gap in the range of the taxon; and

3) Evidence that the population segment differs markedly from other populations of the species in its genetic characteristics.

5.2.2 Distinct Population Segment Analysis

5.2.2.1 *Proposed Alewife DPSs by Petitioners*

NMFS received a petition from the Natural Resources Defense Council ("Petitioner") requesting that NMFS list alewife (*Alosa psuedoharengus)* as threatened throughout all or a significant portion of its range under the Endangered Species Act. In the alternative, they requested that NMFS designate DPSs of alewives for Central New England, Long Island Sound, Chesapeake Bay, and Carolina. The petitioner described these populations in each of these DPSs (and in those identified for blueback) as behaviorally and physiologically discrete from other members of their respective taxon because they return to their natal rivers in their specific DPS to spawn, which leads to separation by river. The petition noted that geographic distances and differences between habitats in these four areas serve to isolate and differentiate these populations. These four DPSs of alewife were described as significant because of the unique ecological settings where they are found, which align with ecoregions identified by the Nature Conservancy and used to distinguish populations of Atlantic Sturgeon in 2010. The petition also noted that the persistence of these four DPSs were important for maintaining genetic diversity.

5.2.2.2 *Evaluation of Potential Alewife DPSs*

To be comprehensive, NMFS is evaluating whether or not any DPSs, not just the DPSs outlined in the petition, exist throughout the entire range of the alewife. As discussed in the Status Review section on **Population Structure**, tagging and genetics data, as well as fisheries management information, are available with which to make determinations about potential DPSs.

5.2.2.2.1 Discreteness

The SRT initially considered the DPS boundaries presented by the petitioner (Central New England, Long Island Sound, Chesapeake Bay and Carolina), but found that these groupings were not supported by the best available information.

Excerpt from NRDC (2011):

> The alewife populations and the blueback herring populations in each of these DPSs are behaviorally and physiologically discrete from other members of their respective taxon because they return to their natal rivers in their specific DPS to spawn, which leads to separation by river. As discussed supra, evidence indicating that alewives maintain fidelity to their natal rivers and do not stray to adjacent rivers during their spawning runs supports reproductive isolation among alewife and blueback herring populations according to their natal rivers (Messieh 1977; NOAA 2009).

The most recent genetic data (e.g., Palkovacs et al. 2013, McBride et al. 2014, Hasselman et al. 2016, Ogburn et al. 2017, Reid et al. 2018) suggest a nearest neighbor pattern of genetic continuity along the coast and that river herring do indeed exhibit straying behavior (see also Straying section). However, Reid et al. (2018), indicates regional differentiation using SNPs for alewife and describes the following regional stock complexes (see *Genetics* section):

- Aw-Canada- Garnish River, Newfoundland to Saint John River, New Brunswick
- Aw-Northern New England- St. Croix River, ME to Merrimack River, NH
- Aw-Southern New England- Parker River, MA to Carll's River, NY
- Aw-Mid Atlantic- Hudson River, NY to Alligator River, NC

As highlighted in the DPS Policy, quantitative measures of morphological discontinuity or differentiation can serve as evidence of marked separation of populations. This new information suggests that the population's genetic structure is different from the delineation presented by the petition and that the maintenance of genetic diversity, noted as important in the petition, requires consideration of boundaries that more accurately reflect genetic separation within the population.

The SRT found that the four regional groupings (Figure 19) outlined in Reid et al. (2018) demonstrate the best available information regarding genetic separation within this population. Although there is a high degree of admixture (mixture of two or more genetically differentiated populations) at the boundaries of each of these stock complexes, self-assignment tests (ranging from 86-92%) indicate that there is regional separation occurring. Still the SRT noted that the delineations between these groupings may not be precise because of high admixture at the borders and spatial gaps where samples were not obtained and tested (e.g., between the Aw-Southern New England and Aw-Mid Atlantic stock complexes). This admixture at the borders, however, is expected with a species such as alewife that exhibits straying.

Additionally, the SRT noted that there is some uncertainty surrounding these groupings due to the methodology used by Reid et al. (2018) in the rangewide analysis where STRUCTURE was

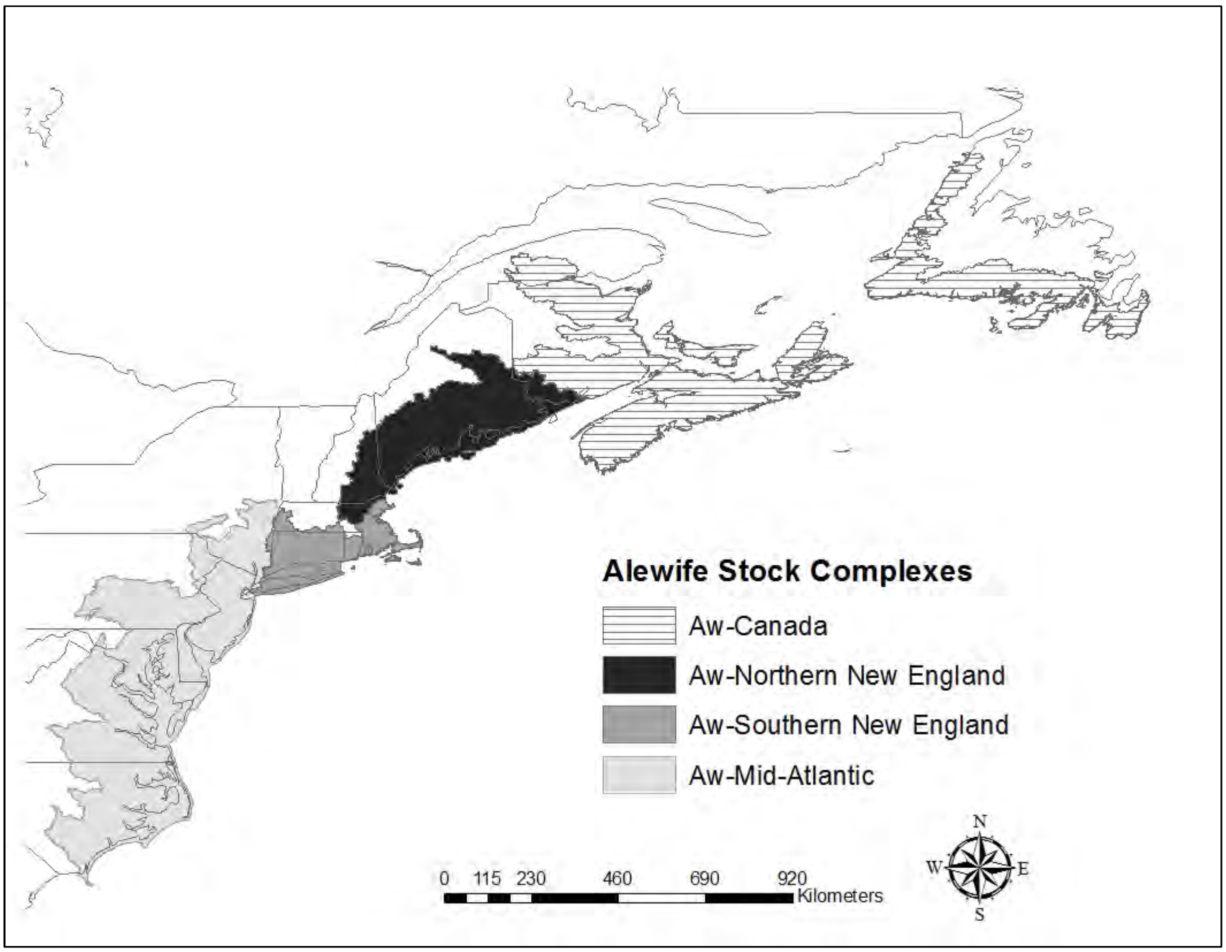


Figure 19. Map of Alewife regional stock complexes: Aw-Canada; Aw-Northern New England; Aw-Southern New England; and Aw-Mid-Atlantic.

run on collection sites without binning into larger spawning habitats. For example, Black Creek was considered separate from the Hudson in the analysis even though this river shares an estuary. Additionally, a number of small tributaries of the Connecticut River (e.g. Wethersfield Cove, Mill Creek and Mill Brook) were considered as separate independent populations. An analysis that lumped tributary systems into larger rivers may have been more informative to the DPS process for the SRT.

5.2.2.2.2 Significance

The DPS policy instructs that significance is evaluated in terms of the ecological and biological importance of the population segment to the species. The SRT considered the significance of each of the four regional groupings (i.e., stock complexes) found to be discrete.

The SRT first considered unique ecological setting, including the terrestrial ecoregions identified by The Nature Conservancy (Anderson 2003). The SRT reviewed each of the terrestrial ecoregions where alewife are present along the east coast (e.g., Northern Appalachian Boreal Forest, Lower New England/Northern Piedmont, North Atlantic Coast, Chesapeake Lowland, Mid-Atlantic Coastal Plain). When comparing the predominant terrestrial habitats of the stock complexes, SRT members provided evidence of duplicate ecological settings within two or more of the stock complexes. For example, the Northern Appalachian/Acadian terrestrial ecoregion extends throughout both the Aw-Northern New England and Aw-Canada stock complexes. Additionally, both the Northern Piedmont and North Atlantic coast ecoregions extend throughout the Aw-Northern New England, Aw-Southern New England and Aw-Mid-Atlantic stock complexes. There were also instances such as the Chesapeake Bay Lowlands, which existed entirely within one stock complex (Mid-Atlantic). However the Mid-Atlantic stock complex also contains a portion of the North Atlantic coast ecoregion (which spans three stock complexes). The majority of the TNC ecoregions spanned multiple stock complexes and did not demonstrate that the four discrete groupings existed in a unique or unusual ecological setting. The SRT also considered whether other ecological factors such as ocean currents or thermal regimes existed within the boundaries of these complexes that might point to persistence in a unique ecological setting. However, the SRT did not find that any of these stock complexes persist in a unique terrestrial ecoregions or other “ecological settings,” instead they noted that some of these stock complexes may share marine environments where oceanic features appear unique and that the terrestrial ecoregions do not align with the four discrete stock complex boundaries.

Next, the SRT considered whether the loss of the population segments would result in significant gaps in the range of the taxa. The SRT agreed that the length of coastline or overall size of the habitat that the discrete grouping inhabited would be the greatest factor in determining whether a gap, or loss in the range, was significant to a taxon as a whole. Specifically, large gaps in the range across widespread watersheds might be difficult for either species to refill naturally (i.e., through straying) and would be extremely difficult to fill through management efforts (e.g., stocking).

Large gaps in the range may interfere with connectivity between populations, resulting in isolated populations that are more vulnerable to the impacts of large threats or catastrophic events (e.g., storms, regional drought). Connectivity, population resilience and diversity are important when determining what constitutes a significant portion of the species' range (Waples *et al.* 2007). Maintaining connectivity between genetic groups supports proper metapopulation function, in this case, anadromy. Ensuring that river herring populations are well represented across diverse habitats helps to maintain and enhance genetic variability and population resilience (McElhany *et al.* 2000). Additionally, ensuring wide geographic distribution across diverse climate and geographic regions helps to minimize risk from catastrophes (e.g., droughts, floods, hurricanes, etc.; McElhany *et al.* 2000). Furthermore, preventing isolation of genetic groups protects against population divergence (Allendorf and Luikart, 2007). Further, a large gap on the periphery of the range would limit the distribution of the species, similarly reducing resiliency. For example, wide distributions may provide a diversity of habitats and buffer species against widespread threats such as changing temperatures by providing more opportunities for habitat refugia. Although there is no evidence currently available to suggest that genetic differences between these stock complexes represent adaptive traits (only neutral genetic markers have been used in the current population structure analyses), the SRT also noted that significant gaps could represent a loss of genetic adaptation if these regional groupings are also linked to adaptive traits.

Alewife that originate from other discrete stock complexes could potentially re-colonize spatial gaps in the range. Genetic studies provide evidence of straying (see **Straying** section) and suggest transition zones between populations. The SRT noted that gaps in the population would most likely be filled in a step-wise fashion with fish moving in from the borders of the nearest stock complexes, but that some straying may occur mid-range as well. Because river herring exhibit straying both from nearby rivers and over larger distances (Gardner *et al.* 2011, Hogg 2012, sensu Reid *et al.* 2018), the SRT noted that the significance of any particular gap will primarily be a factor of both the geographic scope (i.e., size of the gap) and how quickly straying populations are likely to naturally repopulate gaps in the range.

The SRT noted that it would be difficult to determine the exact time-frame over which gaps might remain, but that available habitat would be variable over longer periods of time (e.g greater than 60 years). For the purposes of assessing the loss of each discrete stock complex, the SRT defined a significant gap to be an area (considering the length of coastline or size of the watershed) that was unlikely to be recolonized with self-sustaining populations within at least 10 generations (40-60 years). Straying increases the likelihood of a population rebuilding naturally after reductions or extirpations. The SRT also noted that low straying numbers of fish found in rivers should not constitute a gap being filled, and they agreed that when considering the plausibility of any particular gap being filled that they should consider whether it was likely that a small but self-sustaining population could exist within an area after the given timeframe. There is debate in the literature regarding the application of assigning a general number to represent when populations are sufficiently large enough to maintain genetic variation (Allendorf and Luikart 2007). The SRT settled on a self-sustaining population of around 1,000 spawning fish annually in currently occupied rivers within the area; a number close to the population of some smaller river systems where populations are able to maintain returns (e.g. Little River, MA). This metric of 1,000 fish is close to, but greater than the "500 rule" introduced by Franklin (1980) in guidance for indicating when a population may be at risk of losing genetic variability.

Aw-Canada

When considering if the loss of the Aw-Canada stock complex would result in a significant gap in the range, the SRT considered the geopgraphic extent of this discrete population and whether this complex might be able to repopulate all currently occupied rivers with 1,000 fish within 40-60 years. An extensive area would be without alewives if the Aw-Canada stock complex was lost. Over 169,000 sq. kilometers, 15,200 km of coastline, and 7.5 degrees of latitude that are currently occupied would have no spawning population of the species. The range of alewife in the Aw-Canada stock complex ranges through the provinces of New Brunswick, Nova Scotia, Prince Edward Island, Quebec, and Newfounland and covers all of the estuary and nearshore areas of Bay of Fundy, Scotian Shelf, and Gulf of St. Lawrence. In addition, the Aw-Canada stock complex is located at the northern-most extent of the range.

The nearest neighboring stock complex to Aw-Canada is Aw-Northern New England, which the SRT determined would be mostly likely to colonize in a step-wise fashion moving from south to north in the Aw-Canada stock complex. The SRT also acknowledged that strays may colonize from any stock complex, but this scenario was less likely than strays colonizing from the closest stock complex. Given the estimated straying rates of alewives and the large spatial area of the Canadian stock complex, the SRT concluded that the entirety of the Aw-Canada stock complex (over 35 percent of the rangewide watershed area) was unlikely to be recolonized at self-sustaining levels within 40-60 years and that loss of the area would result in curtailment of the range of the species as a whole.

- ➢ Conclusion: The SRT determined that the loss of the Aw-Canada stock complex would likely result in a significant gap in the range of the taxon.

Aw-Northern New England

Next, the SRT considered whether loss of the Aw-Northern New England stock complex would result in a significant gap. The SRT considered the geographic extent of this discrete area and due to straying found in alewife, whether this complex might be able to repopulate all currently occupied rivers with 1,000 fish within 40-60 years. An extensive area would be without alewives if the Aw-Northern New England stock complex was lost. Over 74,000 sq. kilometers, 5,800 km of coastline, and 2.5 degrees of latitude that are currently occupied would have no spawning population of the species. The range of alewife in the Aw-Northern New England stock complex ranges through New Hampshire, Maine and a portion of New Brunswick and covers more than 50% of the estuary and nearshore areas of the Gulf of Maine.

The nearest neighboring stock complexes to Aw-Northern New England stock complex is the Canadian stock complex (north) and Aw-Southern New England stock complex (south). The SRT determined that recolonization would most likely be in step-wise fashion from fish moving south from the Canadian stock complex and fish moving north from the Aw-Southern New England Stock complex. The SRT also acknowledged that strays may colonize from any stock complex, but this scenario was less likely than strays colonizing from the closest stock complex. Given the estimated straying rates of alewives and the large spatial area of the Aw-Northern New England stock complex, the SRT concluded that the entirety of the Aw-Northern New England stock complex (over 15 percent of the rangewide watershed area) was unlikely to be recolonized at self-sustaining levels within 40-60 years and that loss of the area would result in curtailment of the range of the species as a whole

- Conclusion: The SRT determined that the loss of the Aw-Northern New England stock complex would likely result in a significant gap in the range of the taxon.

Aw-Southern New England

Next, the SRT considered whether loss of the Aw-Southern New England stock complex would result in a significant gap. The SRT considered the geographic extent of this discrete area, and due to straying found in alewife, whether this complex might be able to repopulate all currently occupied rivers with 1,000 fish within 40-60 years. An extensive area would be without alewives if the Aw-Southern New England stock complex was lost. Over 35,500 sq. kilometers, 7,400 kilometers of coastline, and 2.5 degrees of latitude that are currently occupied would have no spawning population of the species. The range of alewife in the Aw-Southern New England stock complex ranges through Massachusetts, Rhode Island, Connecticut and a portion of New York and the estuary and nearshore areas of Long Island Sound and a portion of the Gulf of Maine.

The nearest neighboring stock complexes to Aw-Southern New England stock complex are the Aw-Northern New England stock complex (north) and Aw-Mid-Atlantic stock complex (south). The SRT determined that recolonization would most likely be in step-wise fashion from fish moving south from the Aw-Northern New England stock complex and fish moving north from the Mid-Atlantic stock complex. The SRT also acknowledged that strays may colonize from any stock complex, but this scenario was less likely than stray fish colonizing from the closest stock complex. Given the estimated straying rates of alewives and the large spatial area of the Aw-Southern New England stock complex, the SRT concluded that the entirety of the Aw-Southern New England stock complex (over 7 percent of the rangewide watershed area) was unlikely to be recolonized at self-sustaining levels within 40-60 years and that loss of the area would result in curtailment of the range of the species as a whole.

- Conclusion: The SRT determined that the loss of the Aw-Southern New England stock complex would likely result in a significant gap in the range of the taxon.

Aw-Mid-Atlantic

Next, the SRT considered whether loss of the Aw-Mid-Atlantic stock complex would result in a significant gap. The SRT considered the geographic extent of this discrete area, and due to straying found in alewife, whether this complex might be able to repopulate all currently occupied rivers with 1,000 fish within 40-60 years. An extensive area would be without alewives if the Aw-Mid-Atlantic stock complex was lost. Over 211,500 sq. kilometers, 19,600 kilometers of coastline, and 9 degrees of latitude that are currently occupied would have no spawning population of the species. The range of alewife in the Aw-Mid-Atlantic stock complex ranges through portions of New York, Pennsylvania, New Jersey, Maryland, Virginia, and North Carolina and the estuary and nearshore areas of the New York Bight, Delaware Bay and Chesapeake Bay. In addition, the Aw-Mid-Atlantic stock complex is located at the southern-most extent of the range.

The nearest neighboring stock complexes to Aw-Mid-Atlantic stock complex is the Aw-Southern New England stock complex (north), as it the southernmost population. The SRT determined that recolonization would be in step-wise fashion from fish moving south from the Aw-Southern New England stock complex. The SRT also acknowledged that strays may colonize from any stock complex, but this scenario was less likely than strays colonizing from the closest stock complex. Given the estimated straying rates of alewives and the large spatial area of the Aw-Mid-Atlantic stock complex, the SRT concluded that the entirety of the Aw-Mid-Atlantic stock complex (over 43 percent of the rangewide watershed area) was not likely to be recolonized at self-sustaining levels within 40-60 years.

- ➢ Conclusion: The SRT determined that the loss of the Aw-Mid-Atlantic stock complex would likely result in a significant gap in the range of the taxon.

All SRT members agreed that the loss of any of the four regional stock complexes of alewife would result in a significant gap in the range- defined as the inability to recolonize to self-sustaining levels within 40-60 years.

Finally, the SRT considered evidence to determine whether any of the discrete population segments differ markedly from other populations of the species (i.e., the other three stock complexes) in its genetic characteristics. The SRT discussed the methodology in the Reid et al. (2018) paper and inquired with one of the lead authors if the paper presented information on genetic diversity (e.g. heterozygosity among stock complexes). The SNP markers in the Reid et al. (2018) paper used neutral genetic markers which do not convey adaptive traits, so the SRT was unable to find whether evidence of genetic diversity (e.g heterozygosity among stock complexes) from this study.

The SRT also considered spawning timing, which has been shown to be heritable in steelhead and presumably could be heritable in other anadromous fish, including alewife. After discussion of rangewide spawning strategies, the SRT was not aware of diverse life history strategies such as winter and fall spawning timing in the species (as exhibited in steelhead). Alewives use thermal cues for spawning timing; however this appears to be due to clinal patterns, with rivers in the southern portion of the range beginning spawning earlier in the year and the rivers at highest latitudes spawning latest in the year. Overall, the SRT did not find existing evidence to support heritable spawning timing in alosines.

After reviewing the significance criteria, the SRT did not find that these four discrete stock complexes persist in a unique ecological setting or that there is available evidence that they differ markedly from one another in their genetic characteristics. However, the SRT did find evidence that loss of the population segment would result in a significant gap in the range of the taxon for all four discrete stock complexes: Aw-Canada; Aw-Northern New England; Aw-Southern New England, and; Mid-Atlantic (Table 6). The SRT relied on the best available information throughout this analysis; but, noted that future information on behavior, ecology, and genetic diversity may reveal significant differences, showing fish to be uniquely adapted to each stock complex.

Because the stock complexes meet both the discreteness and significance prongs, the SRT identified the following DPSs for alewife (Figure 20):

- Aw-Canada DPS- Garnish River, Newfoundland to Saint John River, New Brunswick
- Aw-Northern New England DPS- St. Croix River, ME to Merrimack River, NH
- Aw-Southern New England DPS- Parker River, MA to Carll's River, NY
- Aw-Mid Atlantic DPS- Hudson River, NY to Alligator River, NC

Table 6. Summary of Significant Gap Discussion for Alewife Stock Complexes.

Discrete Stock Complex	**Estimates of Geographic Scope of the Stock Complex (watershed size (square kilometers (km^2) (square miles mi^2)); coastline distance (km) (mi); degrees latitude; percent of rangewide watershed area)**	**Likelihood of Recolonization**	**Loss of the Stock Complex would result in a Significant Gap (Yes or No)**
Alewife Canada	169,000 km^2 (65,251 mi^2); 15,200 km (9,444 mi); 7.5 degrees latitude; 35 percent	Recolonization is unlikely due to the large size of the gap and with only one neighboring complex to the south	Yes
Alewife Northern New England	74,000 km^2 (28,572 mi^2) ; 5,800 km (3,604 mi); 2.5 degrees latitude,15 percent	Recolonization across this range is unlikely due to the large size of the gap despite having neighboring complexes to the south and north beginning to recolonize bordering areas	Yes
Alewife Southern New England	35,500 km^2 (13,707 mi^2); 7400 km (4,598 mi); 2.5 degrees latitude; 7 percent	Recolonization is unlikely due to the large size of the gap and with only one neighboring complex to the north	Yes
Alewife Mid-Atlantic	211,500 km^2 (81,661 mi^2); 19,600 km (12,179 mi); 9 degrees latitude; 43 percent	Recolonization is unlikely due to the large size of the gap and with only one neighboring complex to the north.	Yes

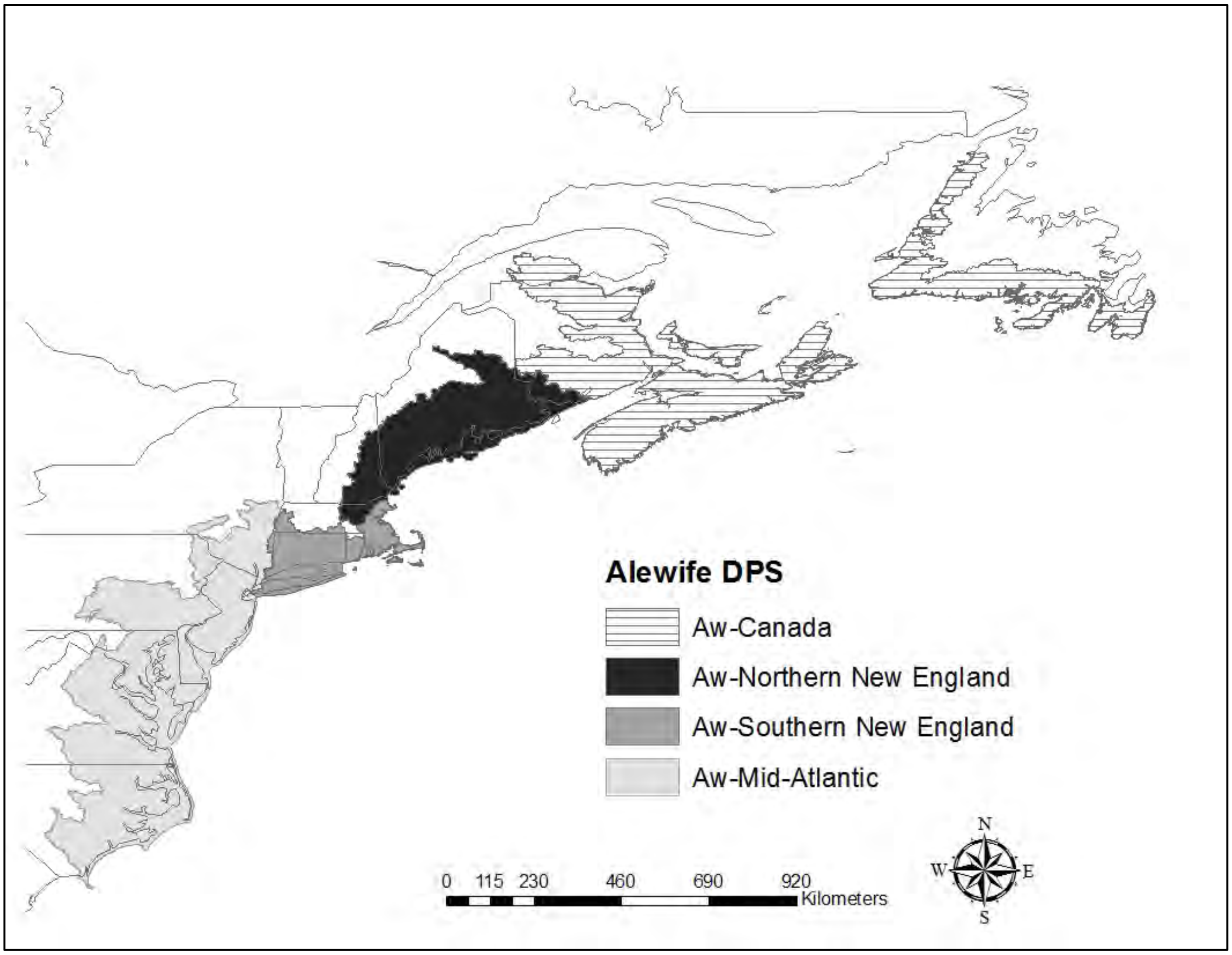


Figure 20. Map of Alewife Distinct Populations Segments (DPS): Aw-Canada DPS, Aw-Northern New England DPS, Aw-Southern New England DPS, and Aw-Mid-Atlantic DPS.

5.2.2.3 *Evaluation of Potential Blueback Herring DPSs*

To be comprehensive, NMFS is evaluating whether or not any DPSs, not just the DPSs outlined in the petition, exist throughout the entire range of the blueback herring. As discussed in the Status Review section on **Population Structure**, tagging and genetics data, as well as fisheries management information, are available with which to make determinations about potential DPSs.

5.2.2.3.1 Proposed Blueback Herring DPSs by Petitioners

NMFS received a petition from the Natural Resources Defense Council requesting that NMFS list blueback herring (*Alosa aestivalis)* as threatened throughout all or a significant portion of its range under the Endangered Species Act. In the alternative, they requested that NMFS designate DPSs of blueback herring for Central New England, Long Island Sound and Chesapeake Bay. As noted earlier in the alewife description, the petitioner described these populations as behaviorally and physiologically discrete and noted the importance of maintaining the genetic diversity of the species by maintaining these populations.

5.2.2.3.2 Discreteness

The SRT considered the DPS boundaries presented by the petitioner. However as noted earlier, the boundaries outlined by NRDC do not align with the most recent genetic data as outlined by several recent papers (e.g., Palkovacs et al. 2013, McBride et al. 2014, Hasselman et al. 2016, Ogburn et al. 2017, Reid et al. 2018). This new information suggests that the population's genetic structure is different from the delineation presented by the petition and that the maintenance of genetic diversity, noted as important in the petition, requires consideration of boundaries that more accurately reflect genetic separation within the population. Therefore, the SRT did not further consider the Central New England, Long Island Sound, and Chesapeake Bay delineations suggested in the 2011 petition.

The best available genetic information for blueback herring, Reid et al. (2018) indicates the following regional genetic groupings using SNPs for blueback herring:

- Bb-Canada/Northern New England- Margaree River, Nova Scotia to Kennebec River, ME
- Bb-Mid New England- Oyster River, NH to Parker River, MA
- Bb-Southern New England- Mystic River, MA to Gilbert-Stuart Pond, RI
- Bb-Mid Atlantic- Connecticut River, CT to Neuse River, NC
- Bb-Southern Atlantic- Cape Fear River, NC to St. Johns River, FL

As highlighted in the DPS Policy, quantitative measures of morphological discontinuity or differentiation can serve as evidence of marked separation of populations. The SRT considered the STRUCTURE analysis and the self-assignment tests (76-95%) for blueback herring groupings outlined in Reid et al. (2018) and found these groupings indicate that there is regional separation occurring. Therefore, the group found the five regional groupings (Bb-Canada/Northern New England, Bb-Mid New England, Bb-Southern New England, Bb-Mid Atlantic and Bb-Southern Atlantic; Figure 21) met the definition of discreteness under the ESA. Still the SRT noted that the delineations between these groupings may not be precise because of high admixture at the borders and spatial gaps where samples were not obtained and tested (e.g., between the Bb-Southern New England and Bb-Mid Atlantic stock complexes). This admixture at the borders, however, is expected with a species such as blueback herring that exhibit straying.

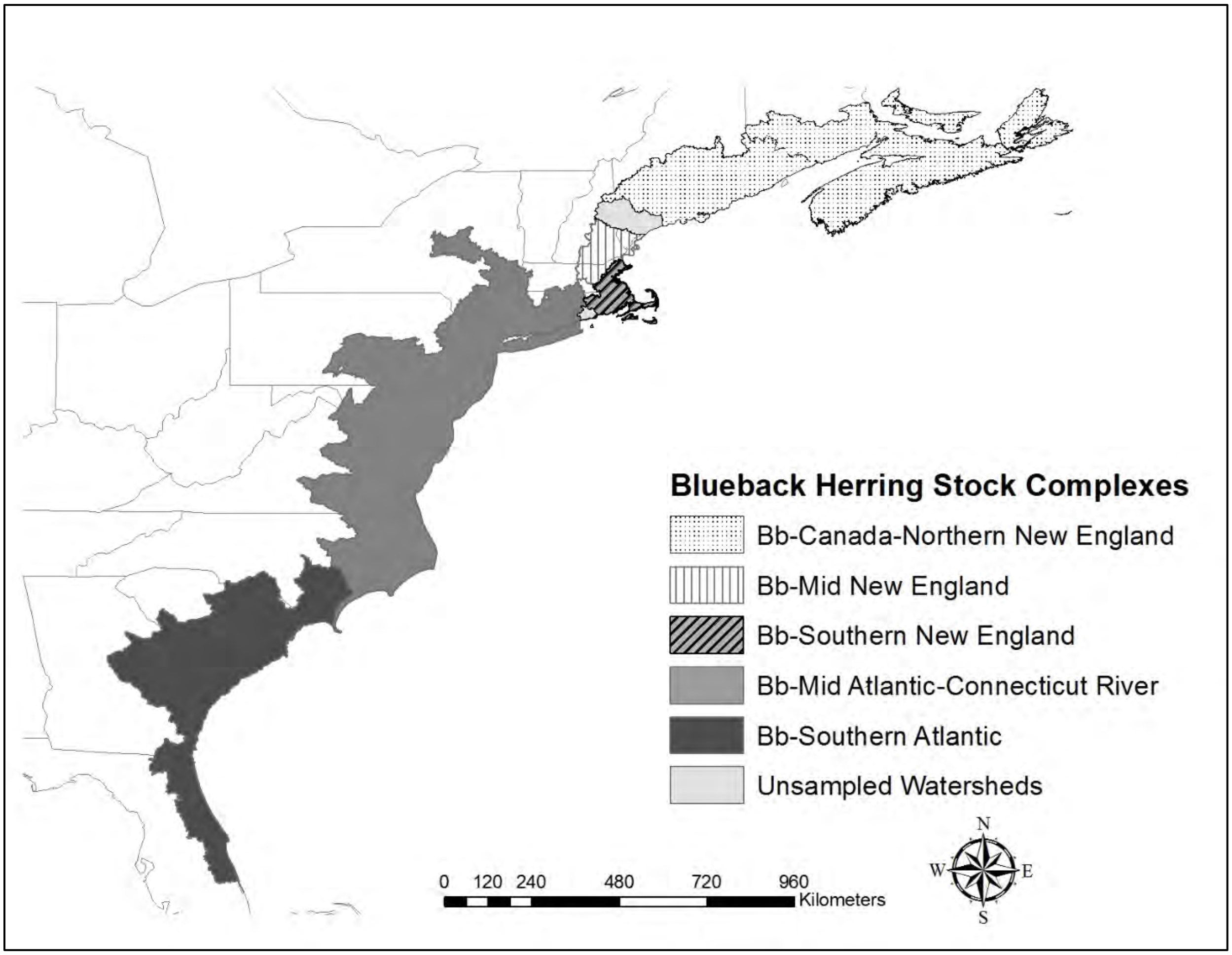


Figure 21. Map of Blueback herring regional stock complexes: Bb-Canada/Northern New England, Bb-Mid-New England, Bb-Southern New England, Bb-Mid-Atlantic; and, Bb-Southern Atlantic.

5.2.2.3.3 Significance

The DPS policy instructs that significance is evaluated in terms of the biological and ecological importance of the population segment to the species as a whole. The SRT considered the significance of each of the five regional groupings found to be discrete. The SRT first considered whether these complexes persist in a unique ecological setting, including reviewing the the TNC ecoregion map The SRT reviewed each of the ecoregions where blueback herring were present along the east coast (e.g., Northern Appalachian Boreal Forest, Lower New England/Northern Piedmont, North Atlantic Coast, Chesapeake Lowland, Mid-Atlantic Coastal Plain, and South Atlantic Coastal Plain, Florida Peninsula). Similar to alewives, the SRT did not find consistent evidence to support unique ecological setting because TNC's terrestrial ecoregions do not align with the blueback herring stock complexes. When comparing regional stock complexes with ecoregions there are several examples of duplicate ecological settings within two or more of the stock complexes. For example, the Northern Piedmont and North Atlantic Coastal ecoregions extended through the Bb-Mid-New England, Bb-Southern New England and into the Bb-Mid-Atlantic stock complex. Additionally the Mid-Atlantic Coastal Plain eco-region extends through both the Bb-Mid-Atlantic and Bb-Southern Atlantic stock complexes and is not unique to only one discrete stock complex. The SRT did acknowledge that there were cases where a TNC ecoregion was wholly within a stock complex such as: the Chesapeake Bay lowlands exists completely within the Bb- Mid-Atlantic stock complex and the Northern Appalachian/Acadian ecoregion exists within the Bb-Canada/Northern New England stock complex. However, these stock complexes also contained other TNC terrestrial ecoregions and did not demonstrate that any particular discrete grouping persists within a single unique ecological setting.

The SRT also considered whether other ecological factors such as ocean currents or thermal regimes existed within the boundaries of these complexes that might point to persistence in a unique ecological setting for any of the discrete groupings. One example that was considered and mentioned in the petition as a boundary between stock complexes was the unique thermal regimes both above and below Cape Cod due to Gulf of Maine and George's Bank currents. The Bb-Southern New England stock complex stretches across these waters both to the north (up to the Ipswich River) and to the south (up to Narragansett Bay), and as such the thermal regime outlined by the petitioners does not appear to act as a boundary for any particular grouping. While this thermal regime may be unique to this area, the SRT noted that several stock complexes may share this marine environment at various points in the life cycle and did not find persuasive evidence for persistence in a unique ecological setting due to the influence of this thermal regime.

Next, the SRT considered whether the loss of the population segments would result in a significant gap in the range of the taxon. The SRT agreed that the length of coastline or overall size of the habitat would be the greatest factor in determining whether a gap, or loss in the range, was significant to the range of the taxon. Specifically, large gaps in the range might be difficult for the species to refill naturally (i.e., through straying) and would be extremely difficult to fill through management efforts (e.g., stocking). Large gaps in the range become significant to the taxon as a whole, because it increases the vulnerability of the species to large or catastrophic events (e.g., storms, regional drought). Significant gaps represent a loss of resiliency to the taxon (e.g. fewer available habitat types, potential loss of genetic adaptation) Blueback herring that originate from other discrete stock complexes could potentially re-colonize spatial gaps in the range. Genetic studies provide evidence of straying (see **Straying** section) and suggest transition zones between populations. The SRT noted that gaps in the population would most likely be filled in a step-wise fashion with fish moving in from the borders of the nearest stock complexes. Because blueback herring exhibit straying both from nearby rivers and over larger distances (citation), the SRT noted that the significance of any particular gap will be a factor of both the geographic scope and how quickly straying populations are likely to naturally repopulate gaps in the range.

The SRT noted that it would be difficult to determine the exact time-frame over which gaps might remain, but that available habitat might alter significantly over longer periods of time (e.g greater than 60 years). For the purposes of assessing the loss of each discrete stock complex, the SRT defined a significant gap to be an area (considering the length of coastline or size of the watershed) that was unlikely to be recolonized with self-sustaining populations within at least 10 generations (40-60 years).

Straying increases the likelihood of a population rebuilding naturally after reductions or extirpations, The SRT also noted that small straying numbers of fish found in rivers should not constitute a gap being filled, and they agreed that when considering the plausibility of any particular gap being filled that they should consider whether it was likely that a small but self-sustaining population could exist within an area after the given timeframe. There is debate in the literature regarding the application of assigning a general number to represent when populations are sufficiently large enough to maintain genetic variation (Allendorf and Luikart 2007). The SRT settled on a self-sustaining population of around 1,000 spawning fish annually in currently occupied rivers within the area; a number close to the population of some smaller river systems where populations are able to maintain returns (e.g. Little River, MA). This metric of 1,000 fish is close to, but greater than the "500 rule" introduced by Franklin (1980) guidance for indicating when a population may be at risk of losing genetic variability.

Bb-Canada/Northern New England

First, the SRT considered if the loss of the Bb-Canada/Northern New England stock complex would result in a significant gap in the range. The SRT considered the geographic extent of this discrete area and whether this complex might be able to repopulate all currently occupied rivers with 1,000 fish within 40-60 years. An extensive area would be without blueback herring if the Bb-Canada/Northern New England stock complex was lost. Over 137,000 sq. kilometers, 11,100 kilometers of coastline, and 4 degrees of latitude that are currently occupied would have no spawning population of the species. The range of blueback herring in the Bb-Canada/Northern New England stock complex extends through the provinces of New Brunswick, Nova Scotia, Prince Edward Island, Quebec, and the state of Maine. It also covers all of the estuary and nearshore areas of Bay of Fundy, Scotian Shelf, Gulf of St. Lawrence and the Gulf of Maine. In addition, the Bb-Canada stock complex is located at the northern-most extent of the range.

The nearest neighboring stock complex to Bb-Canada/Northern New England is the Bb-Mid-New England stock complex. Colonization would likely happen in a step-wise fashion moving from south to north in the Bb-Canada/Northern New England stock complex. The SRT also acknowledged that strays may colonize from other stock complexes, but this scenario was less likely than strays colonizing from the closest stock complex. The SRT discussed the level of straying exhibited by blueback herring as documented in Reid et al. (2018) that showed genetic continuity along the coast. Given the estimated straying rates of blueback herring and the large spatial area of the Bb-Canada/Northern New England stock complex, over representing 26% of blueback herring's rangewide watershed area, the SRT concluded that the entirety of the Bb-Canada/New England stock complex was unlikely to be recolonized at self-sustaining levels within 40-60 years.

- ➢ Conclusion: The SRT determined that the loss of the Bb-Canada/Northern New England stock complex would likely result in a significant gap in the range of the taxon.

Bb-Mid-New England

Next, the SRT considered if the loss of the Bb-Mid-New England stock complex would result in a significant gap in the range. The SRT considered the geographic extent of this discrete area, and whether this complex might be able to repopulate all currently occupied rivers with 1,000 fish within 40-60 years. Over 12,000 sq. kilometers, 311 kilometers of coastline, and 0.5 degrees of latitude that are currently occupied would have no spawning population of the species. The range of blueback herring in the Mid-New England stock complex extends through portions of New Hampshire and Maine. It also covers all of the estuary and nearshore areas of the Great Bay Estuary and Isle of Shoals.

The nearest neighboring stock complexes to this discrete grouping are the Bb-Southern New England stock complex to the south and the Bb-Canada/Northern New England stock complex to the north. The SRT determined that recolonization would most likely come from the northern and southern respective edges of these stock complexes. The Bb-Mid-New England stock complex contains approximately 311 km of coastline and less than approximately 3% of the estimated total watershed area of blueback herring rangewide. Because recolonization was likely to occur on both borders of the range and the discrete grouping only spans a relatively short coastline distance, the SRT noted that area would likely be recolonized to self-sustaining levels within the 40-60 year period. Additionally, isolation by distance evidence from Palkovacs et al. (2014) and McBride et al. (2015), suggest that genetic exchange (straying) currently happens over such distances as 100-200 km.

- ➢ Conclusion: The SRT determined that the loss of the Bb-Mid-New England stock complex was unlikely to constitute a significant gap in the range of the taxon.

Bb-Southern New England

Next, the SRT considered if the loss of the Bb-Southern New England stock complex would result in a significant gap in the range. The SRT considered the geographic extent of this discrete area, and whether this complex might be able to repopulate all currently occupied rivers with 1,000 fish within 40-60 years. The loss of the Bb-Southern New England stock complex represents over 9,000 sq. kilometers, 2,900 kilometers of coastline, and 1.5 degrees of latitude that are currently occupied would have no spawning population of the species. The range of blueback herring in the Bb-Mid-New England stock complex extends through portions of Massachusetts and Rhode Island. It also covers all of the estuary and nearshore areas of Massachusetts Bay, Cape Cod Bay, Nantucket Sound and Buzzards Bay.

The nearest neighboring stock complexes for this discrete area are the Bb-Mid-Atlantic stock complex to the south and the Bb-Mid-New England stock complex to the north. The SRT determined that recolonization would most likely come from the northern and southern respective edges of these stock complexes. Additionally, the SRT noted the proximity of this stock complex to known river herring overwintering grounds and suspected that some recolonization might come from this area. The Bb-Southern New England stock complex contains less than approximately 2% of the estimated total watershed area of blueback herring rangewide. Because recolonization was likely to occur on both borders of the range and the discrete grouping only spans a small coastline (~300 km), the SRT determined that the area could likely be recolonized to self-sustaining levels within the 40-60 year period. Therefore, loss of the Bb-Southern New England stock complex did not constitute a significant gap.

- ➢ Conclusion: The SRT determined that the loss of the Bb-Southern New England stock complex was unlikely to constitute a significant gap in the range of the taxon.

Bb-Mid-Atlantic

Next, the SRT considered if the loss of the Bb-Mid-Atlantic stock complex would result in a significant gap in the range. The SRT considered the geographic extent of this discrete area and whether this complex might be able to repopulate all currently occupied rivers with 1,000 fish within 40-60 years. An extensive area would be without blueback herring if the Bb-Mid-Atlantic stock complex was lost. Over 211,000 sq. kilometers, 24,800 kilometers of coastline, and 9 degrees of latitude that are currently occupied would have no spawning population of the species. The range of blueback herring in the Bb-Mid-Atlantic stock complex extends through Connecticut, New York, New Jersey, Pennsylvania, Delaware, Virginia, and North Carolina. It also covers all of the estuary and nearshore areas of Long Island Sound, the New York Bight, Delaware Bay and Chesapeake Bay.

The nearest neighboring stock complexes for this discrete grouping are the Bb-Southern New England stock complex to the north and the Bb-Southern Atlantic stock complex to the south. The SRT determined that recolonization would most likely come from the edges of these bordering stock complexes. Given the estimated straying rates of blueback herring and the large spatial area of the Bb-Mid-Atlantic stock complex (over 40% of the estimated total watershed area of blueback herring rangewide), the SRT concluded that the entirety of the Bb-Mid-Atlantic stock complex was unlikely to be recolonized at self-sustaining levels within 40-60 years.

- ➢ Conclusion: The SRT determined that the loss of the Bb-Mid-Atlantic stock complex would likely result in a significant gap in the range of the taxon.

Bb-Southern Atlantic

Finally, the SRT considered if the loss of the Bb-Southern Atlantic stock complex would result in a significant gap in the range. The SRT considered the geographic extent of this discrete area and whether this complex might be able to repopulate all currently occupied rivers with 1,000 fish within 40-60 years. An extensive area would be without blueback herring if the Bb-Southern Atlantic stock complex was lost. Over 140,000 sq. kilometers, 18,300 kilometers of coastline, and 7 degrees of latitude that are currently occupied would have no spawning population of the species. The range of blueback herring in the Bb-Southern Atlantic stock complex extends through North Carolina, South Carolina, Georgia, and Florida. It also covers estuary and nearshore areas of Blake Basin and the Southeast U.S. Atlantic coast. Additionally, this stock complex represents the southern-most extent of the blueback herring range.

The nearest neighboring stock complexes for this discrete grouping is the Bb-Mid-Atlantic stock complex to the north. The SRT determined recolonization would likely come from the Mid-Atlantic stock complex. Given the estimated straying rates of blueback herring and the large spatial area of the Southern stock complex (26 % of the estimated total watershed area of blueback herring rangewide), the SRT concluded that the entirety of the Bb-Southern Atlantic stock complex was unlikely to be recolonized at self-sustaining levels within 40-60 years.

➢ Conclusion: The SRT determined that the loss of the Bb-Southern Atlantic stock complex would likely result in a significant gap in the range of the taxon.

After considering whether the loss of any discrete grouping might result in a significant gap in the range of the taxon, SRT members agreed that the loss of the Bb-Canada/Northern New England, Bb-Mid-Atlantic, or Bb-Southern Atlantic stock complex would likely result in a significant gap in the range. However, due to the small size of the Bb-Mid-New England and Bb-Southern New England stock complexes and because these complexes were likely to be recolonized by stock complexes to the north and to the south, the loss of one of these complexes did not represent a significant gap in the range of the taxon.

Finally, the SRT considered evidence as to whether any of the population segments differ markedly from other populations of the species in its genetic characteristics. Similar to alewife, the SRT discussed the methodology in the Reid et al. (2018) paper and inquired with one of the lead authors if the paper presented information on genetic diversity (e.g. heterozygosity among stock complexes) to assess this question. The SNP markers in the Reid et al. (2018) paper used neutral genetic markers which do not necessarily convey adaptive traits, so the group was unable to find evidence of genetic diversity from this particular study. The SRT also considered spawning timing, which has been shown to be heritable with steelhead (Abadia-Cardoso et al. 2013). After discussion of rangewide spawning strategies, the SRT was not aware of diverse life history strategies such as winter and fall spawning timing in the species (as exhibited in steelhead). Blueback herring use thermal cues for spawning timing; however this appears to be due to clinal patterns, with rivers in the southern portion of the range beginning spawning earlier in the year and the rivers at highest latitudes spawning latest in the year. Overall, the SRT did not find existing evidence to support heritable spawning timing in alosines.

After reviewing the significance criteria, the SRT did not find that any of these four discrete stock complexes persist in a unique ecological setting or that they differ markedly from one another in their genetic characteristics. However, the SRT did find evidence that that the loss of Bb-Canada/Northern New England, Bb-Mid-Atlantic or Bb-Southern Atlantic stock complexes would result in a significant gap in the range of the taxon (Table 7). Therefore, the Bb-Canada/Northern New England, Bb-Mid-Atlantic or Bb-Southern Atlantic stock complexes meet the significance prong of the DPS policy (Figure 22). The SRT relied on the best available information throughout this analysis; but, noted that future information on behavior, ecology, and genetic diversity may reveal significant differences, showing fish to be uniquely adapted to each stock complex.

Because the three stock complexes meet both the discreteness and significance prongs, the SRT recommends the following distinct population segments for blueback herring:

- Bb-Canada/Northern New England DPS- Margaree River, Nova Scotia to Kennebec River, ME
- Bb-Mid Atlantic DPS- Connecticut River, CT to Neuse River, NC
- Bb-Southern Atlantic DPS- Cape Fear River, NC to St. Johns River, FL

Table 7. Summary of Significant Gap Discussion for blueback herring stock complexes.

Discrete Stock Complex	**Estimates of Geographic Scope of the Stock Complex (watershed size (square kilometers (km^2) (square miles mi^2)); coastline distance (km) (mi); degrees latitude; percent of rangewide watershed area)**	**Likelihood of Recolonization**	**Loss of the Stock Complex would result in a Significant Gap (Yes or No)**
Blueback Herring Canada/Northern New England	137,000 km^2 (52,896 mi^2); 11,100 km (6,897 mi); 4 degrees of latitude; 26 percent	Recolonization is unlikely due to the large size of the gap and with only one neighboring complex to the south.	Yes
Blueback Herring Mid New England	12,000 km^2 (4,633 mi^2); 311 km (193 mi); 0.5 degrees of latitude; <3 percent	Recolonization across this range is likely given the small size of the gap and because neighboring complexes can recolonize step-wise from the south and north.	No
Blueback Herring Southern New England	9,000 km^2 (3,475 mi^2); 2900 km (1,802 mi); 1.5 degrees of latitude;< 2 percent	Recolonization across this range is likely given the small size of the gap and because neighboring complexes can recolonize step-wise from the south and north. Additionally, proximity to known river herring overwintering grounds might support further recolonization.	No
Blueback Herring Mid Atlantic	211,000 km^2(81,468 mi^2); 24,800 km (15,410 mi); 9 degrees of latitude; 40 percent	Recolonization across this range is unlikely due to the large size of the gap despite neighboring complexes to the south and north beginning to recolonize bordering areas.	Yes
Blueback Herring Southern Atlantic	140,000 km^2 (54,054 mi^2); 18,300 km (11,371 mi); 7 degrees of latitude, 26 percent	Recolonization is unlikely due to the large size of the gap and with only one neighboring complex to the north.	Yes

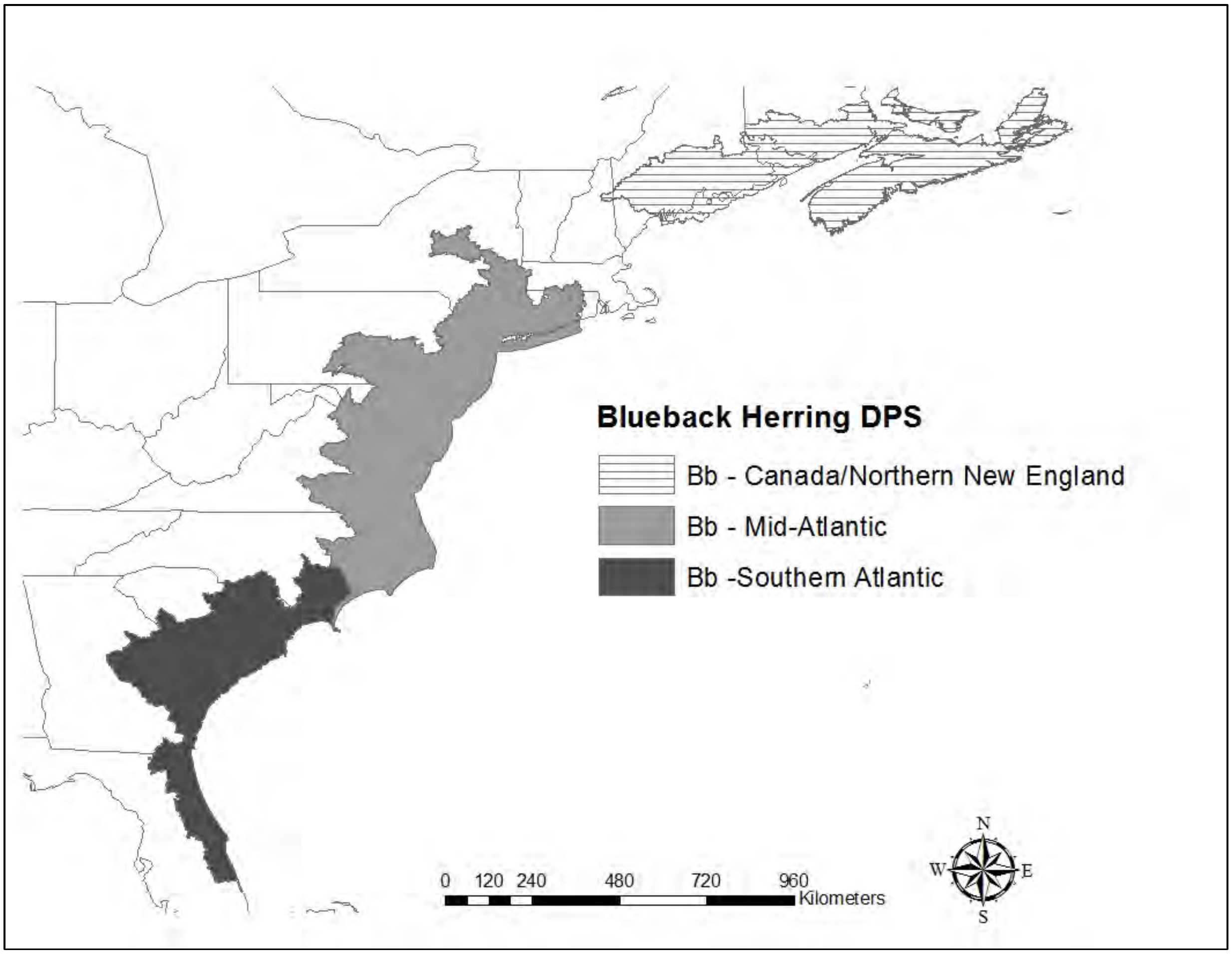


Figure 22. Map of Blueback herring Distinct Populations Segments (DPS): Bb-Canada/Northern New England DPS, Bb-Mid-Atlantic DPS, and, Bb-Southern Atlantic DPS.

6 EXTINCTION RISK ANALYSIS

Often the ability to measure or document risk factors is limited, and information is not quantitative and very often lacking altogether. Therefore, in assessing risk, it is important to include both qualitative and quantitative information. In previous NMFS status reviews, SRTs have used a risk matrix method to organize and summarize the professional judgment of a panel of knowledgeable scientists. This approach is described in detail by Wainright and Kope (1999) and has been used in a number of status reviews (see http://www.nmfs.noaa.gov/pr/species/ for links to these reviews). In the risk matrix approach, the condition of the species is summarized according to four demographic risk criteria: abundance, growth rate/productivity, spatial structure/connectivity, and diversity. These viability criteria, outlined in McElhany et al. (2000), reflect concepts that are well-founded in conservation biology and that individually and collectively provide strong indicators of extinction risk. Using these concepts, the SRT estimated the extinction risk of the alewife and blueback herring (rangewide and for each DPS) after conducting a demographic risks analyses. Likewise, the SRT performed a threats assessment for the species by scoring the severity of current threats to the species (rangewide and for each

DPS). The summary of the demographic risks and threats obtained by this approach was then considered by the SRT in determining the species' (rangewide and for each DPS) overall level of extinction risk. Specifics on each analysis are provided below.

6.1 Methods

6.1.1 Foreseeable Future

The ESA defines an endangered species as any species which is in danger of extinction throughout all or a significant portion of its range and a threatened species as any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range (16 U.S.C. 1532(6) and (20)). The term "foreseeable future" is not further defined or described within the ESA. However, consistent with our past practice, we describe the "foreseeable future" on a case-by-case basis, using the best available data for the particular species, and taking into consideration factors such as the species' life history characteristics, threat projection time frames, and environmental variability. We interpret the foreseeable future as extending only so far into the future as we can reasonably determine that both the threats and the particular species' responses to those threats are likely. Because a species may be susceptible to a variety of threats for which different data are available, or which operate across different time scales, the foreseeable future is not necessarily reducible to a particular number of years.

Highly productive species with short generation times (e.g., river herring) are more resilient than less productive, long-lived species, as they are quickly able to take advantage of available habitats for reproduction (Mace *et al*. 2002). Species with shorter generation times, such as river herring (4 to 6 years), experience greater population variability than species with long generation times, because they maintain the capacity to replenish themselves more quickly following a period of low survival (Mace *et al.* 2002). Consequently, given the high population variability among clupeids, projecting out further than a few generations could lead to considerable uncertainty in predicting the response to threats for each species.

As described below, the SRT determined that dams, water withdrawal, poor water quality, incidental catch, inadequacy of regulations, and climate change vulnerability are the main threats to both species. The SRT determined, and we agree, the foreseeable future is best defined by a 12 to 18 year time frame (i.e., out to 2030–2036), or a three-generation time period, for each species for both alewife and blueback herring. This is a period in which impacts of present threats to the species could be realized in the form of noticeable population declines, as demonstrated in the available survey and fisheries data. This timeframe would allow for reliable predictions regarding the impact of current levels of mortality on the biological status of the two species.

- ➢ Conclusion: The SRT decided a 12 to 18 year timeframe (e.g., 2030–2036), or a three-generation time period, for each species was appropriate for use as the foreseeable future for both alewife and blueback herring.

6.1.2 Demographic Risk Analysis

All relevant biological and commercial information for the species was reviewed, including: current abundance of the species in relation to historical abundance and trends in abundance based on indices such as catch statistics; the species growth rate/productivity in relation to other species and its potential effect on survival rates; its spatial and temporal distribution; natural and human-influenced factors that cause variability in survival and abundance; and possible threats to genetic integrity. This information is reflected in the **Life History and Ecology** and **Distribution and Abundance** section. Then, the SRT assigned risk scores to each of the four demographic criteria (abundance, growth rate/productivity, spatial structure/connectivity, diversity). Risks for each demographic criterion were ranked on a scale of 1 (no or very low risk) to 5 (very high risk). Below are the definitions that the SRT used for each ranking:

Table 8. Definitions for demographic criterion for qualitative rankings.

Criterion	Definitions
(1) Very Low Risk	It is unlikely that this descriptor contributes significantly to risk of extinction, either by itself or in combination with other VP descriptors.
(2) Low Risk	It is unlikely that this descriptor contributes significantly to long-term or near future risk of extinction by itself, but there is some concern that it may, in combination with other VP descriptors.
(3) Moderate Risk	This descriptor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future.
(4) High Risk	This descriptor contributes significantly to long-term risk of extinction and is likely to contribute to short-term risk of extinction in the near future.
(5) Very High Risk	This descriptor by itself indicates danger of extinction in the near future.

The SRT members were given a template (Table 9) to fill out and asked to rank the risk of the demographic criteria. Preliminary scores were discussed during the Extinction Risk Workshop in March 2018 and then provided back to the SRT for consideration and review. During the workshop, the SRT discussed the range of perspectives for each of the demographic risks including considerations outlined in McElhany *et al*. (2000) and the supporting data on which it was based. Summary labels were assigned by rounding to the up/down to the nearest whole number and labeled as follows: Very Low (1 to <1.5), Low (≥ 1.5 to <2.5), Moderate (≥ 2.5 to <3.5), High (≥ 3.5 to <4.5), Very High (≥ 4.5 to 5.0).

Table 9. Template for the risk matrix used in SRT deliberations. The matrix is divided into four sections that correspond to the parameters for assessing population viability (McElhany *et al*. 2000).

Viable Population Descriptor	**Name**	**Risk Score (1-5)**	**Group Discussion Notes**	**Individual reviewer Justification-** *(Provide narrative for your decision making process, including any citations that were relevant to your decision). Also include a narrative of uncertainties you considered with your score.*
Abundance				
Growth Rate				
Spatial Structure				
Diversity				

6.1.3 Threats Assessment

Section 4(a)(1) of the ESA requires the agency to determine whether the species is endangered or threatened because of any of the following factors:

1) destruction or modification of habitat;

2) overutilization for commercial, recreational, scientific, or educational purposes;

3) disease or predation;

4) inadequacy of existing regulatory mechanisms; or

5) other natural or human factors.

SRT members conducted a qualitative ranking of the severity of each of the 21 identified threats to alewife and blueback herring (see Section 3).

SRT members ranked the threats for alewife and blueback herring at a range-wide scale. The SRT adopted the “likelihood point” (FEMAT) method to allow individuals to express uncertainty in determining the contribution to extinction risk of each threat to the species. Each SRT member was allotted five likelihood points to rank each threat. SRT members ranked the severity of each threat through the allocation of these five likelihood points across five ranking criteria ranging from a score of “very low contribution” to “very high contribution.” Below are the specific definitions of the threat effect levels:

Table 10. Definitions for ranking criteria for threats.

Ranking	Definition
(1) Very Low Contribution	It is unlikely that this threat contributes significantly to risk of extinction, either by itself or in combination with other threats.
(2) Low Contribution	It is unlikely that this threat contributes significantly to long-term or near future risk of extinction by itself, but there is some concern that it may, in combination with other threats.
(3) Medium Contribution	This threat contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future.
(4) High Contribution	This threat contributes significantly to long-term risk of extinction and is likely to contribute to short-term risk of extinction in the near future.
(5) Very High Contribution	This threat by itself indicates danger of extinction in the near future.

SRT members were given a template (Figure 23) to fill out and asked to rank the effect that the threat was currently having on the extinction risk of the species. Each SRT member could allocate all five likelihood points to one ranking criterion or distribute the likelihood points across several ranking criteria to account for any uncertainty. Each individual SRT member distributed the likelihood points as she/he deemed appropriate with the condition that all five likelihood points had to be used for each threat. SRT members also had the option of ranking the threat as “0” to indicate that in their opinion there was insufficient data to assign a score, or “N/A” if, in their opinion, the threat was not relevant to the species either throughout its range or for individual stock complexes. When a SRT member chose either N/A (Not Applicable) or 0 (Unknown) for a threat, all 5 likelihood points had to be assigned to that category only.

Listing Factor		Not Applicable	Unknown	Very Low contribution to extintion risk	Low Contribution to extinction risk	Moderate contribution to extinction risk	High contribution to extinction risk	Very High Contribution to extinction risk
		N/A	0	1	2	3	4	5
A) The present or threatened destruction, modification, or curtailment of habitat or range	Climate Change* (see climate guidance)			1	2	2		
	Other manmade non-fishing habitat impacts (e.g. drilling, windfarms)					1	3	1
	Bottom fishing Impacts			5				

Figure 23. Example of qualitative threats assessment worksheet and how likelihood points could be assigned to account for uncertainty (*this example does not represent real data*).

During the group discussion, the SRT members were asked to identify other threat(s) or demographic factor(s) that were interacting with river herring life history to increase the species' extinction risk. As preliminary scores were provided by individual SRT members, the SRT discussed the range of perspectives for each of the threats, and the supporting data on which it was based. After the initial scoring, individual reviewers were instructed to review their individual scores and provide written individual justification. Summary labels were assigned by rounding to the up/down to the nearest whole number and labeled as follows: Very Low (1 to <1.5), Low (≥1.5 to <2.5), Medium (≥2.5 to <3.5), High (≥3.5 to <4.5), Very High (≥4.5 to 5.0).

6.1.4 Overall Level of Extinction Risk Analysis

Guided by the results from the demographics risk analysis as well as threats assessment, the SRT members used their informed professional judgment to make an overall extinction risk determination for each species now and in the foreseeable future. For these analyses, the SRT used three levels of extinction risk defined as:

Table 11. Definitions for extinction risk rankings.

Rank	Definitions
(1) Low Risk	A species or DPS is at low risk of extinction if it is not at moderate or high level of extinction risk (see "Moderate risk" and "High risk" above). A species or DPS may be at low risk of extinction if it is not facing threats that result in declining trends in abundance, productivity, spatial structure, or diversity. A species or DPS at low risk of extinction is likely to show stable or increasing trends in abundance and productivity with connected, diverse populations.

Rank	Definitions
(2) Moderate Risk	A species or DPS is at moderate risk of extinction if it is on a trajectory that puts it at a high level of extinction risk in the foreseeable future (see description of “High risk” above). A species or DPS may be at moderate risk of extinction due to projected threats or declining trends in abundance, productivity, spatial structure, or diversity. The appropriate time horizon for evaluating whether a species or DPS will be at high risk in the foreseeable future depends on various case- and species-specific factors. For example, the time horizon may reflect certain life history characteristics (e.g., long generation time or late age-at-maturity) and may also reflect the time frame or rate over which identified threats are likely to impact the biological status of the species or DPS (e.g., the rate of disease spread). (The appropriate time horizon is not limited to the period that status can be quantitatively modeled or predicted within predetermined limits of statistical confidence. The biologist (or SRT) should, to the extent possible, clearly specify the time horizon over which it has confidence in evaluating moderate risk.)
(3) High Risk	A species or DPS with a high risk of extinction is at or near a level of abundance, productivity, spatial structure, and/or diversity that places its continued persistence in question. The demographics of a species or DPS at such a high level of risk may be highly uncertain and strongly influenced by stochastic or depensatory processes. Similarly, a species or DPS may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; or disease epidemic) that are likely to create imminent and substantial demographic risks.

The SRT adopted the “likelihood point” (FEMAT) method to allow individuals to express uncertainty in determining the overall level of extinction risk facing the species (Table 11). Each SRT member was given the following instructions in their ranking templates: “Distribute 10 likelihood points per person among the three defined levels of extinction risk. In the absence of any information at all about a species or threats to a species, the ‘null hypothesis’ is one where all likelihood points are in the ‘low risk’ category. Uncertainty is expressed by assigning points to different risk categories. For example, a SRT member would assign all 10 points to the ‘low risk’ category if he/she was certain that the definition for ‘low risk’ was met. However, he/she might assign a small number of points to the ‘moderate risk’ category and the majority to the ‘low risk’ category if there was a low level of uncertainty regarding the risk level. The more points assigned to one particular category, the higher the level of certainty. This approach has been used in previous NMFS status reviews (*e.g.*, Pacific salmon, Southern Resident killer whale, Puget Sound rockfish, Pacific herring, black abalone, and common thresher shark) to structure the SRT members’ thinking and express levels of uncertainty when assigning risk categories. Although this process helps to integrate and summarize a large amount of diverse information, there is no simple way to translate the risk matrix scores directly into a determination of overall extinction risk. The SRT members’ scores were tallied, discussed, for the alewife and blueback herring rangewide and then by DPS.

Finally, The SRT did not make recommendations as to whether the species should be listed as threatened or endangered. Rather, the SRT members drew scientific conclusions about the overall risk of extinction faced by alewife and blueback herring under present conditions and in the foreseeable future (as noted above, defined as 12-18 years) based on his/her evaluation of the species’ demographic risks and assessment of threats.

Table 12. Template for the overall level of extinction risk analysis used in status review deliberations. Likelihood points were distributed amongst each of the categories based upon each SRT member's expert judgment.

Overall Extinction Risk	Low Risk	Moderate Risk	High Risk
	1	2	3
Reviewer name			

6.2 Extinction Risk Results for Alewife

6.2.1 Evaluation of Demographic Risks for Alewife

The compiled results of the SRT's alewife demographic assessments are shown in Table 13 - Table 17.

Table 13. Assessment of demographic risks for alewife rangewide.

Demographic Factor	**Mean**	**Range**	**SD**	**Risk**
Abundance	2.0	2	0.0	Low
Growth Rate	2.1	1-3	0.6	Low
Diversity	3.0	3	0.0	Moderate
Spatial Structure	2.6	2-3	0.5	Moderate

Table 14. Assessment of demographic risks for the Aw-Canada DPS.

Demographic Factor	**Mean**	**Range**	**SD**	**Risk**
Abundance	2.0	2	0.0	Low
Growth Rate	2.0	2	0.0	Low
Diversity	2.9	2-3	0.4	Moderate
Spatial Structure	2.7	2-3	0.5	Moderate

Table 15. Assessment of demographic risks for the Aw-Northern New England DPS.

Demographic Factor	**Mean**	**Range**	**SD**	**Risk**
Abundance	2.0	2	0.0	Low
Growth Rate	2.0	2	0	Low
Diversity	3.0	3	0.0	Moderate
Spatial Structure	2.7	2-3	0.5	Moderate

Table 16. Assessment of demographic risks for the Aw-Southern New England DPS.

Demographic Factor	Mean	Range	SD	Risk
Abundance	2.1	2-3	0.4	Low
Growth Rate	2.1	2-3	0.4	Low
Diversity	3.0	3	0.0	Moderate
Spatial Structure	2.9	2-3	0.4	Moderate

Table 17. Assessment of demographic risks for the Aw-Mid-Atlantic DPS.

Demographic Factor	Mean	Range	SD	Risk
Abundance	2.7	2-3	0.5	Moderate
Growth Rate	2.3	2-3	0.5	Low
Diversity	3.0	3	0.0	Moderate
Spatial Structure	2.9	2-3	0.4	Moderate

6.2.1.1 *Abundance*

The SRT individually evaluated the available alewife abundance information, which is summarized in the **Description of Population Abundance and Trends** section of the status review. SRT members noted that the available information indicated alewife abundance had declined significantly from historical levels throughout its range. Definitive estimates of abundance prior to the past few decades are sparse, but recent research (Hall et al. 2012, Mattocks et al. 2017) examined potential biomass of anadromous alewife based upon habitat loss since the colonial era and concluded that current biomass north of the Hudson is between 0-17% of historical potential. In Massachusetts, data from as recently as the early 1960s shows that harvest on many populations was far greater than current population estimates. Given the lengthy and persistent declines in alewife abundance, the species is a model for shifting baseline syndrome effects (Pauly 1995), as the unimpacted ecological capacity and importance of the species is difficult to assess.

Given the available data that indicate alewife abundance to be strongest in the northern extent of the range, the SRT concluded that alewife abundance would likely be resilient to climate related perturbations. There do not appear to be depensatory processes rangewide that result in low densities such that may be insufficient to support mate choice, sex-ratios, fertilization and recruitment success, reproductive or courting behaviors, foraging success, and predator avoidance behaviors. The SRT reviewed available abundance indices for each DPS. The mean score calculated based on the SRT's scores for the rangewide, Aw-Canada, and Aw-Northern New England DPSs correspond to a *Low* ranking, as this factor is unlikely to contribute significantly to the risk of alewife extinction.

The Mid-Atlantic DPS abundance mean score was 2.7 corresponding to a *Moderate* ranking, slightly higher than the mean scores for the other DPSs. SRT members noted uncertainty about abundance in the Mid-Atlantic DPS, due to minimal available abundance information (with the exception of the Hudson, several rivers in Chesapeake Bay, and a few ASMFC time series).

However, early results from the Chesapeake (Ogburn unpublished data) appear favorable, with abundance estimates in surveyed rivers in the 100,000s of fish. SRT members also noted short to moderate distances between populations should allow natural connectivity and metapopulation dynamics in this DPS.

6.2.1.2 *Growth rate/productivity*

The SRT evaluated the available life history traits information for alewife as they relate to this factor, as summarized in the **Reproduction, Growth, and Demography** section in the status review. SRT members noted that there were declining trends in both repeat spawning percentage and mean lengths at age. However, data are limited on growth rate/productivity and some SRT members noted that there is little effort to systematically collect and standardize this type of data in most of the range of the species. For this status review, MARSS models from 2013 were updated to estimate population growth rates for each species range-wide; these growth rates were used to inform SRT member qualitative rankings. The 2018 MARSS modeling results estimated the rangewide alewife population growth rates to be 0.038 ±0.032. The 2013 MARRS alewife rangewide estimate was 0.032±0.006 (NEFSC 2013).

The mean score calculated based on SRT members' scores corresponds to a *Low* ranking rangewide, as this factor is unlikely to contribute significantly to the risk of extinction for alewife. The mean scores for DPS specific growth rate ranged 2.0-2.3 (Aw-Canada and Aw-Northern New England DPS and the Aw-Mid-Atlantic DPS, respectively). SRT members noted that trends in demographic and reproductive rates are largely stable or negative (ASMFC 2017a), which could indicate stress on populations and a greater risk for extinction over the long term, especially in data-poor regions of the range.

6.2.1.3 *Diversity*

The SRT evaluated the available information on alewife diversity summarized in the **Population Structure** section in the status review. The available genetics studies indicate that there are a minimum of four genetic stock complexes rangewide and there is reproductive connectivity along a continuum rangewide. SRT members noted that due to declines in abundance over the last several hundred years; the species has likely lost genetic diversity and therefore has lost adaptive potential. This loss of diversity affects resilience, especially in the face of climate change. Additionally, SRT members determined that human activities of stocking and propagation have also contributed to reduced genetic diversity. Coupled with habitat alterations and reduced access to spawning and nursery habitat, the phenotypic responses of the species have likely been limited and have even perhaps selected for characteristics conducive to survival in modified and dammed river systems.

The mean score calculated based on SRT members' scores corresponds to a *Moderate* ranking rangewide and for the Aw-Northern New England, Aw-Southern New England and Mid-Atlantic DPSs, as this descriptor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future. The Aw-Canada DPS had a slightly lower score for risk of diversity with a mean score of 2.9. SRT members noted that this DPS has a very large range and the species has access to a wide variety of stream size and temperature regimes. Additionally, the SRT noted this DPS likely experiences less active stocking which could negatively affect genetic diversity.

6.2.1.4 *Spatial structure/connectivity*

The SRT evaluated the available information on alewife spatial structure (tagging and genetics information) summarized in the **Population Structure** section 2.5. Alewife range from North Carolina to Newfoundland, Canada. While the species exhibits homing, rates of straying and therefore dispersal help to buffer the species from threats related to loss of habitat and loss of spatial connectivity. The mean score calculated based on SRT members' scores corresponds to a *Moderate* ranking rangewide and for all DPSs as this factor is unlikely to contribute significantly to the alewife's risk of extinction. SRT members noted that habitat degradation and destruction threats related to population growth will presumably continue to increase and the cumulative effects influence the species range wide. Reduced, restricted, and impacted spawning and nursery habitat will likely remain a limiting factor to population growth in many river systems.

6.2.2 Threats Assessment for Alewife

SRT members identified several threats in the *Low* and *Medium* risk categories for contribution to extinction risk including: climate change variability, climate change vulnerability, water quality, incidental catch, and inadequacy of existing international, federal and state regulations (Table 18-22). Dams and other barriers and water withdrawal received the highest overall mean likelihood point score with a threat ranking of *Moderate*. Water withdrawal and incidental catch were the only two factors that received any likelihood points in the *Very High* contribution to extinction risk category. No threats considered by the SRT were given an overall average score to classify as a *High* or *Very High* contribution to extinction risk to alewife. All SRT members gave point allocations in the *Very Low* contribution to extinction risk from the following threats: scientific research and education, hybrids, and landlocked populations.

A summary of the SRT's finding regarding each threat is detailed below and where relevant, additional information is provided for specific geographic threats outlined for each DPS.

Table 18. Qualitative ranking of threats for alewife *range-wide*. Threats were scored using 5 likelihood points distributed in the following bins: 1- very low, 2-low, 3- medium, 4-high, 5-very high. Mean represents the overall workshop participants' average, SD represents the standard deviation based on overall likelihood point allocation given by workshop participants, and range represents the distributions of likelihood points allocated for each threat by workshop participants.

Listing Factor	Threat	Mean	SD	Range	N
A) The present or threatened destruction, modification, or curtailment of habitat or range	Climate Variability	2.4	0.6	1-3	8
	Climate Vulnerability	2.6	0.6	2-4	8
	Dams/Other Barriers	2.9	0.8	1-4	8
	Dredging/Channelization	1.5	0.6	1-3	8
	Water Quality	2.8	0.6	2-4	8
	Water Withdrawal	3.2	0.7	2-5	8
B) Overutilization for commercial, recreational, scientific, or educational purposes	Directed Commercial Harvest	1.7	0.7	1-3	8
	Incidental catch	2.5	0.9	1-5	8
	Recreational Harvest	1.5	0.6	1-3	8
	Scientific Research	1.0	0.0	1	8
	Educational	1.0	0.0	1	8
C) Disease or predation	Disease	1.5	0.6	1-3	8
	Predation	1.8	0.6	1-3	8
D) Inadequacy of existing regulatory mechanisms	International Regulations	2.1	0.7	1-4	7
	Federal Regulations	2.6	0.7	2-4	8
	State Regulations	2.5	0.8	1-4	8
E) Other Natural or man-made factors	Competition	1.4	0.6	1-3	7
	Artificial Propagation	1.2	0.4	1-2	8
	Hybrids	1.1	0.2	1-2	7
	Landlocked populations	1.0	0.2	1-2	6

Table 19. Qualitative ranking of threats for the Aw-*Canada DPS*. Threats were scored using 5 likelihood points distributed in the following bins: 1- very low, 2-low, 3- medium, 4-high, 5-very high. Mean represents the overall workshop participants' average, SD represents the standard deviation based on overall likelihood point allocation given by workshop participants, and range represents the distributions of likelihood points allocated for each threat by workshop participants.

Listing Factor	Threat	Mean	SD	Range	N
A) The present or threatened destruction, modification, or curtailment of habitat or range	Climate Variability	2.5	0.5	1-3	7
	Climate Vulnerability	2.7	0.6	2-4	7
	Dams/Other Barriers	3.2	0.8	1-4	7
	Dredging/Channelization	1.7	0.6	1-3	7
	Water Quality	2.7	0.6	2-4	7
	Water Withdrawal	2.8	0.7	2-5	7
B) Overutilization for commercial, recreational, scientific, or educational purposes	Directed Commercial Harvest	2.1	0.7	1-3	7
	Incidental catch	2.7	1.0	1-5	6
	Recreational Harvest	2.1	1.0	1-3	7
	Scientific Research	1.0	0.0	1	7
	Educational	1.0	0.0	1	7
C) Disease or predation	Disease	1.5	0.7	1-3	7
	Predation	1.7	0.7	1-3	7
D) Inadequacy of existing regulatory mechanisms	International Regulations	2.7	0.8	1-4	7
	Federal Regulations	2.3	0.6	2-4	7
	State Regulations	1.6	0.7	1-4	7
E) Other Natural or man-made factors	Competition	1.4	0.5	1-3	7
	Artificial Propagation	1.2	0.4	1-2	7
	Hybrids	1.1	0.2	1-2	7
	Landlocked populations	1.0	0.2	1-2	6

Table 20**.** Qualitative ranking of threats for the *Aw-Northern New England DPS*. Threats were scored using 5 likelihood points distributed in the following bins: 1- very low, 2-low, 3- medium, 4- high, 5- very high. Mean represents the overall workshop participants' average, SD represents the standard deviation based on overall likelihood point allocation given by workshop participants, and range represents the distributions of likelihood points allocated for each threat by workshop participants.

Listing Factor	Threat	Mean	SD	Range	N
A) The present or threatened destruction, modification, or curtailment of habitat or range	Climate Variability	2.5	0.5	1-3	7
	Climate Vulnerability	2.7	0.6	2-4	7
	Dams/Other Barriers	3.3	0.7	1-4	7
	Dredging/Channelization	1.6	0.7	1-3	7
	Water Quality	2.8	0.7	2-4	7
	Water Withdrawal	3.0	0.7	2-5	7
B) Overutilization for commercial, recreational, scientific, or educational purposes	Directed Commercial Harvest	1.7	0.6	1-3	7
	Incidental catch	2.4	0.8	1-5	7
	Recreational Harvest	1.5	0.6	1-3	7
	Scientific Research	1.0	0.0	1	7
	Educational	1.0	0.0	1	7
C) Disease or predation	Disease	1.5	0.7	1-3	7
	Predation	1.7	0.7	1-3	7
D) Inadequacy of existing regulatory mechanisms	International Regulations	2.3	0.6	1-4	7
	Federal Regulations	2.7	0.7	2-4	7
	State Regulations	2.7	0.7	1-4	7
E) Other Natural or man-made factors	Competition	1.4	0.5	1-3	7
	Artificial Propagation	1.7	0.7	1-2	7
	Hybrids	1.1	0.2	1-2	7
	Landlocked populations	1.0	0.2	1-2	6

Table 21. Qualitative ranking of threats for the *Aw-Southern New England DPS*. Threats were scored using 5 likelihood points distributed in the following bins: 1- very low, 2-low, 3- medium, 4- high, 5- very high. Mean represents the overall workshop participants' average, SD represents the standard deviation based on overall likelihood point allocation given by workshop participants, and range represents the distributions of likelihood points allocated for each threat by workshop participants.

Listing Factor	Threat	Mean	SD	Range	N
A) The present or threatened destruction, modification, or curtailment of habitat or range	Climate Variability	2.6	0.5	1-3	7
	Climate Vulnerability	2.7	0.6	2-4	7
	Dams/Other Barriers	3.4	0.6	1-4	7
	Dredging/Channelization	1.6	0.7	1-3	7
	Water Quality	2.9	0.7	2-4	7
	Water Withdrawal	3.3	0.7	2-5	7
B) Overutilization for commercial, recreational, scientific, or educational purposes	Directed Commercial Harvest	1.2	0.4	1-3	7
	Incidental catch	2.7	0.8	1-5	7
	Recreational Harvest	1.3	0.5	1-3	7
	Scientific Research	1.0	0.0	1	7
	Educational	1.0	0.0	1	7
C) Disease or predation	Disease	1.5	0.7	1-3	7
	Predation	1.8	0.6	1-3	7
D) Inadequacy of existing regulatory mechanisms	International Regulations	2.1	0.7	1-4	7
	Federal Regulations	2.8	0.7	2-4	7
	State Regulations	2.7	0.7	1-4	7
E) Other Natural or man-made factors	Competition	1.5	0.6	1-3	7
	Artificial Propagation	1.3	0.5	1-2	7
	Hybrids	1.1	0.2	1-2	7
	Landlocked populations	1.0	0.2	1-2	6

Table 22. Qualitative ranking of threats for the Aw-*Mid-Atlantic DPS*. Threats were scored using 5 likelihood points distributed in the following bins: 1- very low, 2- low, 3- medium, 4- high, 5- very high. Mean represents the overall workshop participants' average, SD represents the standard deviation based on overall likelihood point allocation given by workshop participants, and range represents the distributions of likelihood points allocated for each threat by workshop participants.

Listing Factor	Threat	Mean	SD	Range	N
A) The present or threatened destruction, modification, or curtailment of habitat or range	Climate Variability	2.7	0.6	1-3	7
	Climate Vulnerability	2.8	0.6	2-4	7
	Dams/Other Barriers	3.1	0.7	1-4	7
	Dredging/Channelization	1.7	0.7	1-3	7
	Water Quality	3.2	0.7	2-4	7
	Water Withdrawal	3.2	0.7	2-5	7
B) Overutilization for commercial, recreational, scientific, or educational purposes	Directed Commercial Harvest	1.6	0.6	1-3	7
	Incidental catch	2.5	0.9	1-5	7
	Recreational Harvest	1.5	0.6	1-3	7
	Scientific Research	1.0	0.0	1	7
	Educational	1.0	0.0	1	7
C) Disease or predation	Disease	1.5	0.7	1-3	7
	Predation	1.8	0.6	1-3	7
D) Inadequacy of existing regulatory mechanisms	International Regulations	2.0	0.7	1-4	7
	Federal Regulations	2.7	0.7	2-4	7
	State Regulations	2.7	0.7	1-4	7
E) Other Natural or man-made factors	Competition	1.5	0.6	1-3	7
	Artificial Propagation	1.2	0.5	1-2	7
	Hybrids	1.0	0.2	1-2	7
	Landlocked populations	1.0	0.0	1-2	6

6.2.2.1 *Habitat Destruction, Modification, or Curtailment*

The SRT assessed six different factors that may contribute to habitat destruction, modification or curtailment of alewife: climate change and variability, climate change and vulnerability, dams and other barriers, dredging/channelization, water quality, and water withdrawal. All threats listed in this category scored in the *Medium* contribution to extinction risk categories, except for dredging and channelization which was scored as a *Low* contribution. Dams and other barriers and water withdrawal were the two highest ranked threats overall with scores that concluded that the threats contribute significantly to long-term risk of extinction but do not in themselves constitute a danger of extinction in the near future (see **6.2.2.1.3 Dams and other Barriers and 6.2.2.16 Water Withdrawal**). Climate change variability, climate change vulnerability, and water quality also scored in the *Medium* risk category.

6.2.2.1.1 Climate Change and Variability

SRT members evaluated the available information on climate change and climate variability of alewife summarized in the status review. In general, diadromous species will be heavily impacted by climate change as they have riverine and oceanic life stages. Alewives are habitat generalists in the marine environment; however, they require specialized habitat during the estuary and freshwater portions of their life cycle. Changes to riverine flows and habitat due to extreme events will impact both spawning and early life stages (Tommasi et al. 2015), while migratory patterns and food availability will be two of many impacts of a changing climate on the ocean stages. As water temperatures continue to increase, the alewife coastal range may shrink, shifting northward. A condensing of the range would allow natural or anthropogenic catastrophic events to have a larger impact on species extinction risk. The overall mean score for climate change and vulnerability corresponded to a *Medium* ranking rangewide and in each DPS. The SRT noted uncertainty related to current limitations in predicting the specific changes that will occur within river herring habitat across the range make it difficult to determine the degree to which river herring may be impacted in the foreseeable future.

Aw-Southern New England DPS

The Aw-Southern New England DPS threat score for climate variability was slightly higher than the rangewide score. The large estuary ecosystems within the Aw-Southern New England DPS could be severely impacted by river/ocean warming and sea level rise. Additionally, rivers in this DPS are situated in areas with high population densities and predicted population growth, which will likely decrease the amount of water available for river herring and lead to juveniles being unable to emigrate from nursery habitats. Increased impervious surfaces, as well as anthropogenic responses to rising sea levels are likely to increase flow variability in this DPS.

Aw-Mid-Atlantic DPS

The Aw-Mid-Atlantic DPS threat score for climate variability was slightly higher than other DPSs. The Aw-Mid-Atlantic DPS constitutes the southern edge of the range. It will likely be the first to see extreme riverine temperatures during spawning and juvenile phases. In addition, many of the known runs in this DPS are in larger river systems and spawning success will likely be negatively impacted by the extreme spring flows as well as the increased summertime salt intrusions predicted to occur due to climate change. Finally, rivers in the northern portion of this DPS are situated in areas with high population densities and predicted population growth, which will likely decrease the amount of water available for river herring and lead to juveniles being unable to emigrate from nursery habitats.

6.2.2.1.2 Climate Change and Vulnerability

SRT members evaluated the available information on climate change and vulnerability of alewife summarized in the status review. Overall, alewives are habitat generalists in the marine environment, however, they require specialized habitat during the estuary and freshwater portions of their life cycle. Alewife occur in coastal waters and estuaries during much of the year. They migrate upstream to spawning areas during the spring and require connected habitats with adequate water quality and quantities to complete both their upstream and downstream migrations to and from spawning areas. Additionally, juveniles require freshwater for spawning and early rearing, and require connectivity between rearing habitat (lakes/rivers) to estuaries in addition to adequate water quality and quantities during emigration. Juvenile alewives (ages 1-3) have been reported to overwinter in estuaries (J. Stevens, pers. comm.) which makes the estuary a critical component of the alewife habitat year round. Their unique life history vulnerabilities provide several pinch points where climate change can have negative effects on individual populations. Increasing and irregular water temperature regimes will have large impacts at these stages, especially in the larger river systems, which seem to be more important to alewife. In the ocean, changing currents and thermal clines will affect prey availability as well as growth for juvenile and adult alewife (Hare et al. 2016a, Hare et al. 2016b). The mean rangewide scores for climate change and vulnerability corresponded to a *Medium* ranking rangewide and in each DPS.

Aw-Mid-Atlantic DPS

The mean score for climate change in vulnerability was slightly higher in the Aw-Mid-Atlantic DPS compared to the rangewide score. The SRT predicted that alewives in more southern portions of the range were at a slightly higher risk from climate change and vulnerability due to the reduced timeline of predicted impacts from this threat. The Aw-Mid-Atlantic DPS will likely be the first to see extreme riverine temperatures during spawning and juvenile phases. Additionally, fish at the edges of the range will be most impacted by changes in ocean currents due to climate change, as these fish have the longest ocean migrations to known overwintering areas. Alewife populations could expand northward, however it is unknown if expansion could occur fast enough to preserve genetic integrity of this DPS. This threat is magnified because there will be minimal opportunity to control negative climatic effects as they become more apparent.

6.2.2.1.3 Dams and Other Barriers

Dams prevent access to historical spawning habitat (e.g. Hall et al. 2012, Mattocks et al. 2016), but also alter stream continuity and impair water quality on a number of levels. Dams and other barriers often affect migration rates, influencing both upstream and downstream migration of adults and downstream migration of juveniles. Delayed migration can have serious impacts at both life stages, including timing with forage (zooplankton availability) as well as predator avoidance in juveniles, and preferred spawning temperatures in adults. There is some evidence, that of the two river herring species, alewife are better adapted to navigating fishways (K. Sullivan, pers. comm; B.Gahagan, unpublished). Finally, dams often have detrimental nutrient and temperature impacts on downstream river communities affecting both adult and early life stages.

The passage solutions to get fish above dams can have a wide range of efficacy, and in some instances be quite ineffective. Constructed fish passage also does not restore full riverine continuity or address water quality concerns. Further, both nature-like and technical fishways are engineered and built to function on flows modeled from historical records. Deviations in future flow patterns due to climate change could greatly reduce fishway efficacy. The overall mean score for dams and other barriers corresponded to a *Medium* threat for the rangewide ranking and in each of the DPSs.

Aw-Canada DPS

Specific barrier threats related to the Aw-Canada DPS include head-of-tide dams that block access to freshwater habitat and increased prevalence of dams and tidal barrages in the Bay of Fundy, Minas Basin, and St. Croix. The SRT noted that there were limited data on barriers in this region to be able to assess the threat on alewife. A majority of SRT members spread their threat scores to reflect greater uncertainty.

Aw-Northern New England DPS

The SRT determined that threats posed by dams and other barriers within the range of the Aw-Northern New England DPS are more severe compared to those on a rangewide scale. Specific barrier threats related to this DPS include impacts to habitat quality and passage solutions. The SRT took into account that the region was one of the epicenters of colonial and industrial era dam building and many of these structures remain in this area. According to ASFMC (2017b), dam construction in Maine 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.

Access to much of river herring habitat in Maine is still blocked by dams without upstream fish passage and other impediments (ASFMC 2017b). The SRT determined that dams and other barriers are a more pertinent threat to the species in this DPS because alewife are typically more reliant on habitats upstream of dams for reproductive success. The SRT also noted that the NNE region, like the SNE, has many more dams located closer to the head of tide compared to the other DPSs. As a result, there is limited spawning habitat below these dams and spawning runs are heavily influenced by management practices (e.g. truck and transport, fish lifts, fishway maintenance).

According to ASFMC (2017b), resource agencies in Maine are making progress by installing upstream and downstream fish passage facilities, especially in the Sebasticook River watershed and smaller coastal watersheds. In recent years, rock-ramp or nature-like fishways have become increasingly popular for passing river herring in Maine. In New Hampshire, restoration of diadromous fish populations 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 and the Taylor River in the Hampton-Seabrook Estuary. These fishways re-opened acres of freshwater spawning and nursery habitat for river herring (ASFMC 2017b).

Aw-Southern New England DPS

The SRT determined that threats posed by dams and other barriers within the range of the Aw-Southern New England (SNE) DPS are more severe compared to those on a rangewide scale. The SRT took into account that the SNE region was one of the epicenters of colonial and industrial era dam building and many of these structures remain in this area. According to ASMFC (2017b), there are over 500 dams within the historic range of river herring in

Connecticut. Access to habitat previously blocked has been restored through construction of fishways and dam removal, providing more spawning habitat to increase production. Since 1990, 11 dams have been removed and 53 fishways have been constructed throughout the state with more projects being completed each year.

In Rhode Island, the Division of Fish and Wildlife is partnering with government agencies, NGOs, and private entities on a 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 (ASFMC 2017b). Gilbert Stuart and Nonquit river herring stocks are predominantly alewives. At Gilbert Stuart, the Alaskan steeppass has been the primary survey site for monitoring adult river herring since 1981. Edwards (2015) reported that the fishway passed over 290,000 fish in 2000 and in recent years estimates of one thousand fish per hour have been observed. The Denil fishway at Nonquit has been the primary survey site for monitoring adult river herring since 1999. In 1999, the fishway passed over 230,000 fish (Edwards 2015). Buckeye Brook (RI) is a free-flowing system and river herring migrate to Warwick Pond without obstruction (ASFMC 2017b).

Despite the aforementioned state-run fish passage solutions, the SRT determined that dams and other barriers are a more pertinent threat to the species in this DPS because alewife are typically more reliant on habitats upstream of dams for reproductive success. The SRT noted that the Aw-Southern New England DPS, like the Aw-Northern New England DPS, has many more dams located closer to the head of tide compared to the other DPSs. As a result, there is limited spawning habitat below these dams and spawning runs are heavily influenced by management practices (e.g. truck and transport, fish lifts, fishway maintenance).

Aw-Mid-Atlantic DPS

The average score for dams and other barriers in the Aw-Mid-Atlantic DPS was slightly higher than the rangewide score. Specific barrier threats related to this DPS include the presence of man-made barriers within the historic range of river herring. While dams and other barriers to fish migration are widely distributed throughout this DPS, the SRT noted that the existing dams are generally further upstream, leaving relatively more alewife habitat below the dams. As such, the SRT determined that barrier threats related to the Aw-Mid-Atlantic DPS are similar (and possibly less severe) compared to those considered in the other DPSs.

In New Jersey, restoration programs for river herring have been limited to the installation of fish ladders and occasional minor trap and transport programs or dam removal. Fish ladders have also been installed in Delaware to restore river herring runs. 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.

In addition to fish passage installations, dam removal has been the focus of restoration effort is some states. In May 2016, the first dam upstream of the confluence with the Hudson River was removed from the Wynants Kill, a relatively small tributary in Troy, NY, downstream of the Federal Dam. According to ASMFC (2017b) within days of the removal, hundreds of herring moved past the former dam location into upstream habitat. Subsequent sampling efforts yielded river herring eggs, providing evidence that river herring were actively spawning in the newly available habitat. This dam removal will provide an additional half kilometer of spawning habitat for river herring that has not been available for 85 years (ASMFC 2017b). Similarly, Maryland DNR's Fish Passage program has completed 79 projects, reopening a total 457 miles of upstream spawning habitat in Maryland since 2005.

In Pennsylvania, dam removals along with installation of fish passage have opened up 100 river miles to migratory fish. In 2000 and 2001, river herring were transported to the Conestoga River, a tributary of the Susquehanna River in Pennsylvania. The transported river herring left the Conestoga River, moved up the mainstem Susquehanna River, and were observed at the Safe Harbor Dam. Transports to the Conestoga River included 1,820 alewives in 2000.

Several states within the range of this DPS have implemented restoration programs focused on a range of solutions to fish passage. These solutions include fish passage installation, dam removal, and trap-and-transport initiatives. An abundance of available coastal and estuarine habitat and the presence of long undammed sections of major rivers within the range of this DPS led the SRT to determine that the threat of dams was slightly reduced in this region compared to other DPSs.

6.2.2.1.4 Dredging/Channelization

Similar to dams, dredging has affected historical spawning and nursery habitats. Maintenance dredging continues to reduce available habitat, negatively affect water quality, as well as change river flows. Although regulated through federal and state permitting, dredging and shoreline hardening associated with estuary/coastline development are not likely to decrease in spatial extent or scope through the next century. Both practices reduce wetland and nearshore habitats, impacting nursery habitats for river herring, including the macrophytes and natural streamflow important to nearshore ecosystem health. While widespread, the SRT ranked the threat of dredging/channelization rangewide and in each DPS as *Low*.

Aw-Mid-Atlantic DPS

The SRT ranked the threat of dredging in the Aw-Mid-Atlantic DPS to be at slightly higher risk compared to other DPSs. The increased volume of industrial activity and growing number of dredge projects in the Aw-Mid-Atlantic DPS may pose a greater risk to alewife compared to other regions. This DPS encompasses several hundred miles of dredged river channels, the ports of New York and New Jersey, Baltimore Harbor, the Hudson and Delaware Rivers, as well as the Chesapeake Bay, all of which are subject to regular dredging.

6.2.2.1.5 Water Quality

Water quality is an important threat in some parts of the species' range. While the large scale acute water quality issues that fueled the creation of the EPA and Clean Water Act have, in many areas, been remedied, the wide impacts of increasing urbanization on the eastern coast of the U.S. has led to widespread deleterious conditions (e.g., perennial hypoxic and anoxic areas in estuaries and nurseries, eutrophication of freshwater systems, invasive plants and eutrophication altering spawning habitat). Siltation resulting from erosional land use practices as well as natural disturbances such as hurricanes/flood events, reduces survival of aquatic vegetation and impacts streamflow. Additionally, climate variability may increase sedimentation in natal rivers, contributing to poorer water quality. These types of effects, often from non-point sources, occur over entire landscapes and are often more difficult to detect, measure, test, and remedy. The overall mean score for water quality corresponded to a *Medium* ranking rangewide and in each DPS.

Mid- Atlantic DPS

The threat of water quality was slightly elevated in the Aw-Mid-Atlantic DPS compared to the rangewide ranking. Many of the major estuaries in the Aw-Mid-Atlantic DPS have documented water quality issues. This DPS also has many growing population centers and anthropogenic threats are predicted to increase in the foreseeable future. Similar to climate change and variability, the interactions between anthropogenic change and climate change are likely to severely affect water quality, especially temperature, in regions at the edge of the species' tolerance.

6.2.2.1.6 Water Withdrawal

Water withdrawal facilities impact natural streamflow and result in impingement/ entrainment mortality of alewives. Disrupting streamflow can influence migratory timing as well as water quality below the facility. Additionally, water withdrawal for agriculture or other human activities degrades or destroys habitat for alewives and poses a significant threat to their survival, especially when coupled with other threats. The threat is likely to increase alongside coastal population growth, which in conjunction with climate change effects, will likely result in reduced base flows. Water withdrawals and reduced flows can disrupt connectivity between habitats and cause ontogenetic shifts in life history. For alewives to be successful, adults must be able to immigrate to nursery areas, spawn, and then emigrate. Juveniles should have adequate flow to emigrate volitionally. In this way, withdrawals act much like dams and other barriers but are less visible.

Ocean temperatures are expected to warm along the Atlantic coast. Warming temperatures coupled with changes in ocean composition in marine and freshwater habitats may present a risk to alewives. The SRT concluded that both climate change and climate vulnerability are a moderate threat to alewife rangewide in the foreseeable future. However most climate change effects over the long term will occur outside the foreseeable future window of 12-18 years. As water temperatures continue to increase, the alewife coastal range may shrink, shifting northward. A condensing of the range would allow natural or anthropogenic catastrophic events to have a larger impact on species extinction risk. Early life stage growth/survival and successful spawning events are temperature dependent. Increasing and irregular water temperature regimes will have large impacts at these stages. In the ocean, changing currents and thermal clines will affect prey availability as well as growth for juvenile and adult alewife. Additionally, solutions to climate change may include construction of floodgates, berms around cities, changes in water structures, which may further reduce access to spawning habitat. The overall mean score for water withdrawal corresponded to a *Medium* ranking rangewide and in each DPS.

Aw-Canada DPS

The threat of water withdrawl was slightly reduced in the Aw-Canada DPS compared to the rangewide ranking. Human population density and the resulting anthropogenic effects on water quality (including animal husbandry and agriculture) and the demands for water withdrawals/diversions are likely less of a threat to the species in this DPS compared to rangewide average.

Aw-Northern New England DPS

Because of the lower human population density in the Aw-Northern New England DPS and corresponding demands on water resources, there is a diminished risk related to water withdrawals for the species in this region compared to the rangewide average. However, the presence of numerous head of tide dams where emigration is related to fall flows/water levels from head ponds remains a threat.

Aw-Southern New England DPS

The threat of water withdrawal was slightly elevated in the Aw-Southern New England DPS compared to the rangewide ranking. Water withdrawal may be higher in the Aw-Southern New England DPS than other areas due to high populations density. Water withdrawal can lead to reduced stream flow, and the presence of impoundments can further affect temporal variability of stream flow through their water storage capacities. Similar to populations further north, populations here face an increased risk from artificially manipulated water levels in head ponds where summer and fall emigration is dependent on adequate stream flows. As water transfers/withdrawals increase in the future, this threat will increase greatly.

Aw-Mid-Atlantic DPS

The threat of water withdrawal in the Aw-Mid-Atlantic DPS was similar is to the rangewide score for alewife. The SRT noted predicted high population growth rate in this region. Demand for water and anthropogenic pressures will likely increase, resulting in reduced stream flows which affect juvenile emigration and survival.

6.2.2.2 *Overutilization*

The SRT assessed five different factors that may contribute to the overutilization of alewife: directed commercial harvest, retained and discarded incidental catch (including slippage), recreational harvest, scientific research and educational use. Of the threats considered in the Overutilization category, Retained and discarded incidental catch scored the highest, and was considered a *Medium* contribution to extinction risk rangewide and in all DPSs. Directed commercial harvest and tecreational harvest were ranked as *Low* contributions to extinction risk, while all of the other threats were ranked as *Very Low* contributions.

6.2.2.2.1 Directed Commercial Harvest

Overutilization for commercial purposes was once considered one of the primary threats to alewife populations. Significant declines have been documented throughout much of the alewife’s range due to historic fishing pressure and other threats. Directed harvest does still occur in several states and the fishing occurs during migration to spawning grounds. Amendment 2 to the ASMFC Shad and River Herring Interstate Fishery Management Plan requires states to have a sustainable fishery management plan (SFMP) for each river with a river herring fishery (beginning in 2012). SFMPs must be reviewed by the ASMFC Shad and River Herring Technical Committee for adequate sustainability measures and approved by the ASMFC Management Board. Monitoring is required on all harvested runs in the U.S. Overall, SRT members felt that the current directed harvest was well regulated and occurred only on stocks that have demonstrated sustainability. The overall mean score for directed harvest rangewide corresponded to a *Medium* ranking.

Aw-Canada DPS

The threat ranking for directed commercial harvest was higher in the Aw-Canada DPS compared to the rangewide ranking and other DPSs. SRT members noted increased uncertainty related to directed harvest levels within Canada. Gibson et al. (2017) indicated high annual removal rates where recorded or reported. Additionally, Gibson et al. (2017) indicated that previous reporting and collection methods do not provide consistent and accurate information, increasing concern and uncertainty for this threat. Finally, the Department of Fisheries and Oceans still allows some fishing on mixed stocks in Canadian waters, which makes managing impacts to individual populations more difficult.

Aw-Northern New England DPS

The threat ranking for directed commercial harvest was slightly higher in the Aw-Northern New England DPS compared to the rangewide ranking. Maine and New Hampshire currently have approved ASMFC sustainable fishing management plans within this DPS. The SRT noted uncertainty related to lack of publicly available commercial harvest data for Maine due to confidentiality, therefore the total removals and removal rates by river system are largely unknown.

Aw-Southern New England DPS

The threat ranking for directed commercial harvest was lower in the Aw-Southern New England DPS compared to the rangewide ranking and was ranked as *Very Low*. There is currently no directed commercial harvest conducted within the Aw-Southern New England DPS. The Nemasket River, in southern Massachusetts, has an ASMFC approved SFMP but no harvest has occurred to date, largely due to variability in run strength. SRT members noted uncertainty related to whether further directed harvest of alewife would be permitted within the Aw-Southern New England DPS in the forseeable future.

Aw-Mid-Atlantic DPS

The threat ranking for directed commercial harvest was lower in the Aw-Mid-Atlantic DPS compared to the rangewide ranking and corresponded to and overall ranking of *Low* contribution to extinction risk. New York is the only state to have an approved ASMFC sustainable fishing management plan within this DPS.

6.2.2.2.2 Retained and Discarded Incidental Catch

Retained and discarded incidental catch (including slippage) is likely negatively affecting some alewife populations. The team noted that historical declines in alewife abundance were not likely driven by incidental catch, but because of current depleted abundances incidental catch may impede restoration and recovery efforts. As with all of the threats, the true magnitude of incidental catch remains largely unknown because there is no estimate of rangewide abundance. While some monitoring of incidental catch does occur in the Atlantic herring and mackerel fisheries, it has been estimated that monitored fisheries may only constitute half the discards in a given year (Wigley 2009). Further, the contribution of slippage also remains unknown because it is not currently reported. From 2005-2015, the total annual incidental catch of alewife ranged from 36.5-531.7 metric tons (mt) in New England and 10.9-295.0 mt in the Mid-Atlantic region (ASMFC 2017a).

Because incidental catch occurs in marine waters, and alewife stock complexes overlap in their distribution in the ocean, the retained and discarded incidental catch occurs on a mixed stock complex fishery (that is, there is no “oceanic” stock of alewives, the alewife in the ocean come from all of the stock complexes). Recent studies have also shown that alewife incidentally caught in a number of statistical areas were from several genetic stock complexes (Hasselman et al. 2016, Palkovacs unpublished). This finding increases the probability that alewife are being exploited from populations that do not meet sustainable harvest requirements. The team noted the highest uncertainty around the contribution of incidental catch to extinction (shown variability and range of scores), due to uncertainties around the estimates of exploitation, future monitoring coverage, and future use of bycatch avoidance programs. Based on the best available information, the team concluded that the threat from incidental catch corresponded to a *Medium* contribution to extinction risk.

Aw-Canada DPS

The team concluded that the threat from incidental catch corresponded to a *Medium* contribution to extinction risk, a slightly higher risk compared to the rangewide score. Limited information is available to estimate the impacts of incidental catch in the Aw-Canada DPS. Based on information from Palkovacs (unpublished data) a smaller proportion of fish from this DPS are reported in the Atlantic herring/mackerel mid-water trawl fisheries compared to other alewife DPSs. However, there is uncertainty related to other small mesh fisheries in this region that may incidentally catch river herring.

Aw-Northern New England DPS

The team concluded that the threat from incidental catch corresponded to a *Medium* contribution to extinction risk, with an average score slightly lower compared to the rangewide score. Recent information presented to the team from Palkovacs (unpublished data) suggest that Aw-Northern New England alewife made up a minimal amount indirect catch. Sampling design for this study was limited primarily to incidental catch from Atlantic Herring Management Area 2. The team noted that numerous small mesh fisheries exist in Areas 1 and 2 but a high level of uncertainty exists related to the magnitude and stock compositions of the incidental catch in these fisheries. Information regarding bycatch in those fisheries would be very beneficial to understanding the level of impact on river herring populations in this DPS.

Aw-Southern New England DPS

The threat score for incidental catch in the Aw-Southern New England DPS was elevated compared to the rangewide ranking and corresponded to a *Medium* ranking. Limited data available from Palkovacs (unpublished data) showed large proportions of Aw-Mid-Atlantic and Aw-Southern New England alewife captured by mid-water trawl and small mesh bottom trawl in the Atlantic herring/mackerel fisheries compared to other DPSs. Much of the incidental catch from these fisheries was concentrated around Block Island Sound, which is located closest to this DPS. Team members noted that the results presented by Palkovacs are representative of the bycatch samples in the Atlantic herring and mackerel fisheries, which are concentrated in the Aw-Mid-Atlantic and Northeast. The sampling did not represent other small-mesh coastal fisheries that may occur.

Aw-Mid-Atlantic DPS

The team concluded that the threat from incidental catch corresponded to a *Medium* contribution to extinction risk, with the same average score as the rangewide ranking. Unpublished data from

Palkovacs showed alewife from the Aw-Mid-Atlantic DPS were captured in the Atlantic herring/mackerel fisheries during the period 2012-2015. Hasselman et al. (2016) estimated that incidental catch from rivers south of the Hudson ranged from 400,000 in 2012 to 1.3 million in 2013. However, these previous estimates assumed that the Hudson River grouped with the Aw-Southern New England DPS, rather than the newly designated Aw-Mid-Atlantic DPS, where it is now grouped. Therefore, if the analysis were rerun with the new boundaries, the estimates of incidental catch would be greater for this DPS.

6.2.2.2.3 Recreational Harvest

Recreational harvest has largely been eliminated and where it does exist is well-regulated. Amendment 2 to the ASMFC Shad and River Herring Interstate Fishery Management Plan requires states to have a sustainable fishery management plan for each river with a river herring fishery (beginning in 2012). Plans must be reviewed by the ASMFC S&RH technical committee for adequate sustainability measures and approved by the ASMFC management board. Historical rangewide, recreational catch is largely unknown and the recent ASMFC assessment (2017a) deemed recreational catch estimates unreliable. Based on the best available information the SRT concluded that the threat from recreational harvest corresponded to a *Very Low* contribution to extinction risk rangewide and in all DPSs except for the Aw-Canada DPS which was ranked as a *Low* contribution to extinction risk. However, the SRT noted that illegal and unmonitored recreational harvest could have significant local impacts.

Aw-Canada DPS

The SRT scored the threat of recreational harvest in the Aw-Canada DPS to be a *Low* contribution to extinction risk. The risk score was elevated in this DPS in comparison to the rangewide score due to uncertainty surrounding monitoring and reporting of recreational fisheries in Canada.

6.2.2.2.4 Scientific Research and Educational Harvest

The SRT could find little information linking scientific and educational use to declines in alewife populations. Therefore, based on the best available information, the SRT concluded that neither scientific use nor educational use is contributing to the species' risk of extinction. Both threats ranked in the *Very Low* category.

6.2.2.3 *Disease or Predation*

The SRT could find little information linking disease to declines in alewife populations. Predation also does not appear to be increasing this species' risk of extinction rangewide. Therefore, based on the best available information, the SRT concluded that neither disease nor predation is contributing to the species' risk of extinction. Both threats ranked in the *Low* category.

6.2.2.3.1 Disease

Little information exists on diseases that may affect river herring; however, there are reports of a variety of parasites that have been found in both alewife and blueback herring. The most comprehensive report is that of Landry et al. (1992) in which 13 species of parasites were identified in blueback herring and 12 species in alewives from the Miramichi River, New Brunswick, Canada. SRT members noted disease is of biggest concern at low population levels; however, warmer summer temperatures, changing fish communities, and changing migratory

patterns due to climate change may make alewife populations more susceptible to disease in the future. The SRT concluded that the threat from disease corresponded to a *Low* contribution to extinction risk rangewide and in all DPSs.

6.2.2.3.2 Predation

While alewife are an important forage species, predators on the Northeast U.S. shelf are generally opportunistic (versus specialized) and will consume prey species in relation to their abundance in the environment. At high population levels, predation is likely not an issue; however, as populations decline predation can become a larger threat, especially locally. Recent papers focus on the predation impacts of striped bass; however, the predatory impact by striped bass is likely localized to areas/times of overlap (Davis et al. 2012, Ferry and Mather 2012, Overton et al 2008).

The overall mean score for predation corresponded to a *Low* ranking rangewide and in all DPSs. The SRT noted uncertainty surrounding introduced or invasive piscivores such as snakeheads or blue catfish, which could have larger impacts if they dramatically expand their ranges. Alterations to fish behavior, such as inability to break through predatory gauntlets to’’ access fish passage, were also noted as components of predation that have not been well described in literature to date.

6.2.2.4 *Inadequacy of Existing Regulatory Mechanisms*

The SRT assessed three different factors that may contribute to the inadequacy of existing regulatory mechanisms: international regulations, federal regulations and state regulations. The inadequacy of regulatory mechanisms to control the harvests of alewife was once considered a significant threat to their populations. The best available information indicates that legal protections for alewife vary between outright prohibitions on most directed harvest in the U.S. and limited fishing permitted in Canada, though uncertainties remain about international fishing regulations. Federal regulations and state regulations ranking as a slightly higher contribution to extinction risk than international regulations. SRT members noted uncertainty with expertise related to other global or national environmental regulations in this category.

6.2.2.4.1 International Regulations

The inadequacy of international regulations was ranked in the *Low* contribution to extinction risk category, except in the Aw-Canada DPS, where it was ranked as a *Medium* threat. However, SRT members noted uncertainty with expertise related to global or national environmental regulations in this category.

Aw-Canada DPS

SRT members ranked the threat of International regulations as a slightly higher risk within the Aw-Canada DPS and was ranked as a *Medium* threat. This DPS is located entirely within Canada, therefore international regulations are predicted to directly affect this DPS more than the other DPSs. Canada does not routinely separate river herring species and have less reported monitoring compared to the U.S.

6.2.2.4.2 Federal Regulations

SRT members noted that an adequate regulatory framework to effectively manage and recover both species of river herring currently exists. However, given the minimal commercial value in the present day, the SRT noted the uncertainty that river herring conservation would be prioritized compared to more important or valuable species and uncertainties around estimates of incidental take on the rangewide population. Low economic valuation has negative consequences for alewife in terms of incidental take in profitable fisheries and also, but perhaps less obvious, in relation to current management practices within regional fisheries management commissions and councils. Managers in inter-jurisdictional fisheries may overlook less economically valuable species, such as river herring, which can have negative conservation implications for these species.

The SRT also considered other federal non-fishery regulations such as the Clean Water Act and Federal Power Act. Despite current regulations, habitat alterations, such as dams and culverts, excess nutrient loading and sedimentation due to poor land use practices, dredging, and coastal development continue to affect both marine and freshwater habitats, potentially limiting population growth. In tandem with the predicted effects of climate change, such as increased precipitation and warming ocean temperatures, the importance of federal regulations to alewife recovery will likely increase in the future. The SRT also identified mismatches with the life cycle of alewife and the long regulatory processes (often 20-50 years) that accompany fish passage improvements via the Federal Power Act and relicensing of hydropower facilities through the Federal Energy Regulatory Commission. Federal Regulations were ranked in the *Medium* contributions to extinction risk category, except for the Aw-Canada DPS which was ranked in the *Low* category.

6.2.2.4.3 State Regulations

As with federal regulations, SRT members noted that existing state regulations related to fisheries provided structure for protection of alewives at a state level through ASMFC. However, like federal regulations, state regulations related to habitat loss remain a large concern for the future of the species, especially since spawning and nursery habitats are found in state waters.

Uncertainty around state regulations related to the reliability of enforcement of existing state laws and concerns for non-fishing regulations that regulate modifications to coastal and riverine habitat in the face of increasing populations and coastal development. State regulations were ranked in the *Medium* contributions to extinction risk category for all DPSs, with the exception of the Aw-Canada DPS, where it was ranked as a *Low* contribution to extinction risk.

6.2.2.5 *Other Natural or Manmade Factors*

The SRT assessed four different threats that may contribute to other natural or manmade factors affecting the species continued existence: competition, artificial propagation/stocking, hybrids and landlocked populations. The SRT could find very little information linking any of these threats to declines in abundance of alewife. Therefore, based on the best available information, the SRT concluded that none of the threats in the other natural or man-made factors are contributing to the species' risk of extinction. All threats ranked in the *Very Low* or *Low* categories.

6.2.2.5.1 Competition

Competition among fish species is difficult to determine because it requires demonstration of limiting resource. Given the diet of alewife (and generalist nature), prey are likely not limiting. However, there is some possibility that space could be limiting (e.g. dams, poor fish passage, etc.). Competition ranked in the *Very Low* or *Low* category rangewide and for all DPSs, with slightly higher rankings for the Aw-Southern New England and Aw-Mid-Atlantic DPSs.

6.2.2.5.2 Artificial Propagation/Stocking

Artificial propagation ranked as a *Very Low* or *Low* threat to alewives rangewide. However, SRT members noted that artificial propagation/stocking has detrimental effects on alewife populations. First, hatchery efforts often take focus and importance away from on-the-ground issues with a fish and its habitat, which would be harmful in the long term. Second, artificial propagation would almost certainly lead to a significant loss of genetic diversity, which is already likely substantially lower than most times in the past.

Aw-Northern New England DPS

The SRT ranked the threat of artificial propagation/stocking slightly higher in the Aw-Northern New England DPS compared to the rangewide and other DPS risk scores and corresponded to a *Low* contribution to extinction risk. As noted in the Abundance portion of the Extinction Risk Assessment, the persistence of many populations in Maine are reliant on active management strategies (e.g. truck and transport, fish lifts, fishway maintenance) rather than volitional passage. Therefore, a change in management strategy, especially related to stocking/truck and transport would have dramatic impacts on these runs. In addition, the intensive stocking in this region has likely reduced genetic variability in the U.S. portion of this DPS.

6.2.2.5.3 Hybrids

Hybrids have likely been a natural occurrence throughout the history of alewife and blueback herring. In most cases they occur at low to very low rates in natural and impacted systems (McBride et al. 2014, Hasselman et al. 2014). Further, no research to date has even attempted to show any loss of viability or function in hybrids and hybrids have been shown to be completely viable and reproductively successful (Hasselman et al. 2014). Hybrids ranked in the *Very Low* category rangewide and for all DPSs.

6.2.2.5.4 Landlocked Populations

Landlocked alewives are discrete from anadromous alewives, with differing morphological features and occupy different ecological niches. The SRT ranked landlocked populations as *Very Low* contribution to extinction risk rangewide and for all DPSs.

6.2.3 Overall Risk Summary for Alewife

SRT members ranked the overall risk of extinction for alewife rangewide and for the Aw-Canada, Aw-Northern New England, Aw-Southern New England, and Aw-Mid-Atlantic DPSs (Figure 24, 25). The mean overall risk scores for alewife rangewide correspond to a 75% likelihood of a Low risk of extinction, currently or in the foreseeable future (defined by the SRT as 12-18 years). The distributions of likelihood points used in the Overall Extinction Risk Analysis are summarized below.

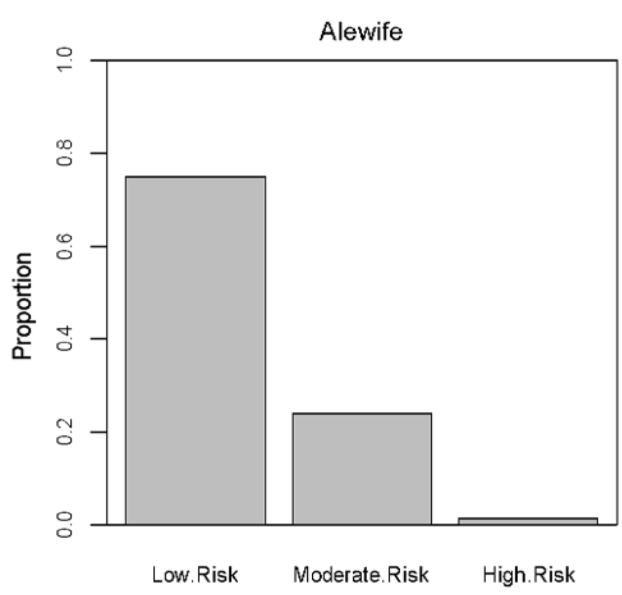


Figure 24. Overall level of extinction risk for alewife rangewide. Likelihood points were distributed amongst each of the categories based upon each SRT member’s (n=8) expert judgment.

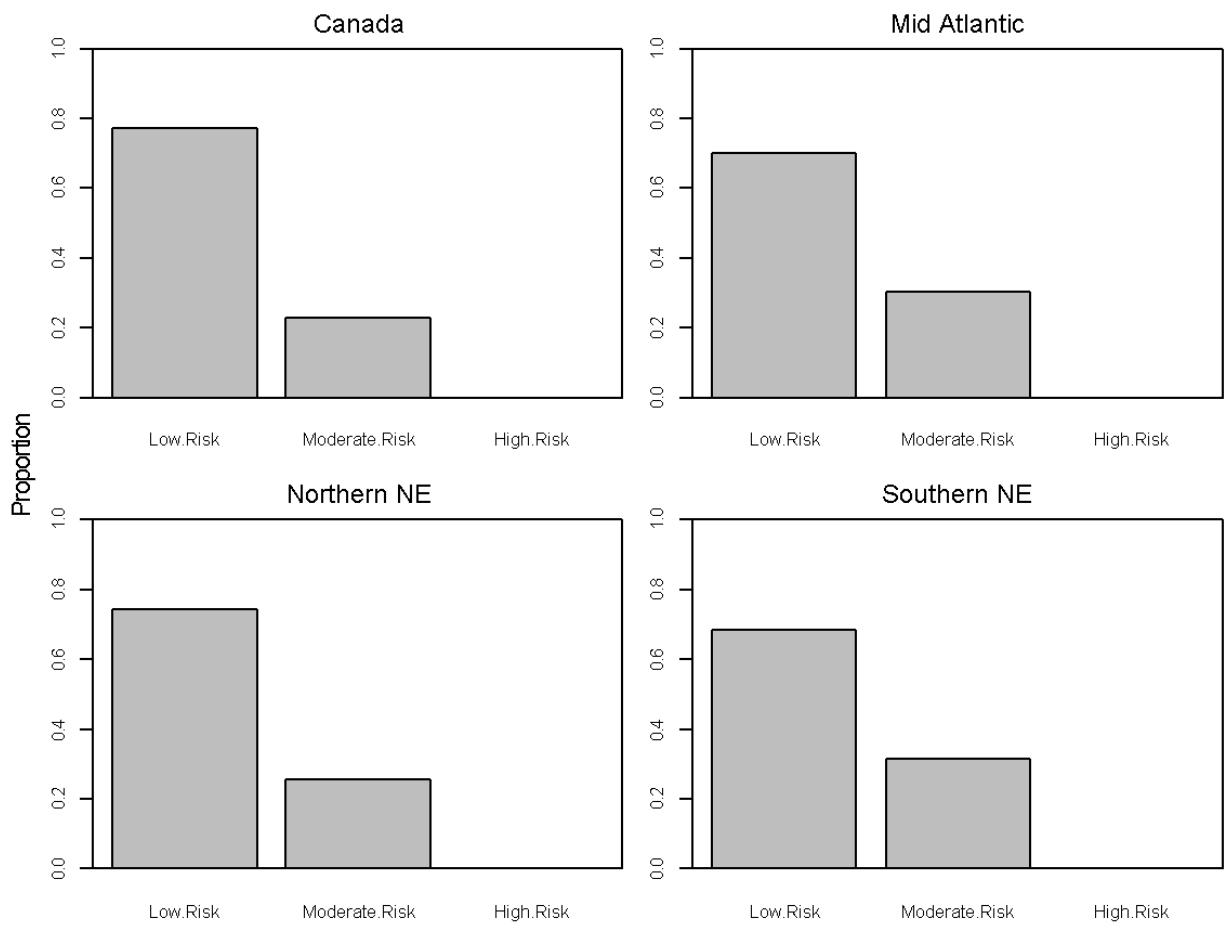


Figure 25. Overall level of extinction risk for alewife by DPS (Aw-Canada, Aw-Northern New England, Aw-Southern New England and Aw-Mid-Atlantic). Likelihood points were distributed amongst each of the categories based upon each SRT member's (n=7) expert judgment.

SRT members indicated that there was a 75% low risk, 22% moderate risk of extinction and a 3% high risk of extinction for alewife rangewide. SRT members attributed elevated risks to the complex anadromous fish life history, uncertainty in climate change and vulnerability, incidental catch, potential habitat modification (e.g. increased coastal development and water use), and concern about the adequacy of current and future regulatory mechanisms, including fisheries rangewide.

The mean overall risk scores for alewife in the Aw-Canada DPS correspond to a 77% likelihood of a Low risk and 23% moderate risk of extinction. The mean overall risk scores for alewife in the Aw-Northern New England DPS correspond to a 74% likelihood of a Low risk and 26% moderate risk of extinction. The mean overall risk scores for alewife in the Aw-Southern New England DPS correspond to a 69% likelihood of a Low risk and 31% moderate risk of extinction. The mean overall risk scores for alewife in the Aw-Mid-Atlantic DPS correspond to a 70% likelihood of a Low risk and 30% moderate risk of extinction.

To conclude, alewives have been subjected to habitat impacts for centuries and considerable fishing pressure for many decades. The SRT acknowledged that they are at historical low levels, but noted that improved fisheries management efforts in recent years have reduced fishing mortality rates on alewife stocks and hundreds of habitat improvement projects have been completed in the past 20 years. Many relatively robust populations of alewife exist and genetic data show connectivity among populations (genetic continuum along the coastline) despite regional groupings. Demographic risks are mostly low and significant threats have been reduced. Based upon the available information summarized here and the SRT's individual expert opinions, considered as a mean score, alewife have a low risk of extinction rangewide and in all DPSs, assuming the dominant threats to their populations continue to be managed.

6.3 Extinction Risk Results for Blueback Herring

6.3.1 Evaluation of Demographic Risks for Blueback Herring

The compiled results of the SRT's blueback herring demographic assessment are shown in Table 22-26.

Table 23. Assessment of demographic risks for blueback herring rangewide.

Demographic Factor	Mean	Range	SD	Risk
Abundance	3.00	3	0.00	Moderate
Growth Rate	2.75	2-4	0.64	Moderate
Spatial Structure	2.87	2-3	0.35	Moderate
Diversity	3.10	3-4	0.35	Moderate

Table 24. Assessment of demographic risks for blueback herring in the Bb-Canada/Northern New England DPS.

Demographic Factor	Mean	Range	SD	Risk
Abundance	3.00	3	0.00	Moderate
Growth Rate	2.75	2-4	0.68	Moderate
Spatial Structure	2.86	2-3	0.38	Moderate
Diversity	3.14	3-4	0.38	Moderate

Table 25. Assessment of demographic risks for blueback herring in the Bb-Mid-Atlantic DPS.

Demographic Factor	Mean	Range	SD	Risk
Abundance	3.00	3	0.00	Moderate
Growth Rate	2.88	2-4	0.49	Moderate
Spatial Structure	2.88	2-3	0.38	Moderate
Diversity	3.00	3	0	Moderate

Table 26. Assessment of demographic risks for blueback herring in the Bb-Southern Atlantic DPS.

Demographic Factor	Mean	Range	SD	Risk
Abundance	3.00	3	0.00	Moderate
Growth Rate	3.00	2-4	0.58	Moderate
Spatial Structure	2.71	2-3	0.49	Moderate
Diversity	3.14	3-4	0.38	Moderate

6.3.1.1 *Abundance*

The SRT individually evaluated the available blueback herring abundance information. SRT members noted that the available information indicated blueback herring abundance had declined significantly from historical levels throughout its range. The SRT reviewed the recent ASMFC stock assessment update and available abundance indices for each. Blueback herring abundance estimates were lower than available estimates for alewife, but recent run count estimates documented hundreds of thousands of fish in the Chowan River, Chesapeake Bay (Ogburn unpublished data), Connecticut River, various Massachusetts rivers, and rivers in Maine (ASMFC 2017b) and New Brunswick (Gibson *et al.* 2017). The mean score calculated based on the SRT's scores corresponds to a *Moderate* ranking rangewide (3.0) and in each DPS (Bb-Canada/Northern New England (3.0), Bb-Mid-Atlantic (3.0), and Bb-Southern Atlantic (3.0) DPSs), as this factor is contributing significantly to the blueback herring's risk of extinction, but does not in itself constitute a danger of extinction in the near future.

The SRT reviewed the best available data on blueback herring in the Bb-Canada/Northern New England DPS. The SRT noted that blueback herring in the St. John River, New Brunswick are managed using a fixed escapement policy of 200,000 blueback herring moved above the dam each year; this number is not indicative of abundance, but can be viewed as a minimum when escapement targets are met. The Mactaquac time series (1999 to 2017) ranged from 192,000 to 515,000, with over 489,000 blueback herring passed upstream in 2017. Escapement estimates for the Tusket River in Nova Scotia during the period of 2014 to 2015 ranged from 200,000 to 600,000 blueback herring. As noted above for alewife, the ASMFC Stock Assessment reports trends from select rivers along the Atlantic Coast (see Table 1 of ASMFC 2017a); depending on sampling methods these may be reported by species or in combination (i.e. reported as just river herring). There is little stock specific information on blueback herring in Maine. Within the U.S portion of the Bb-Canada/Northern New England DPS, the ASMFC (2017a) reported trends over 2006 - 2015 as increasing for river herring in the Kennebec and Sebasticook Rivers. Data reported from rivers throughout this range were also reviewed, and numbers varied widely from year to year, as expected for this species. According to the most recent stock assessment report (ASMFC 2017b), blueback herring estimates for the Kennebec and Sebasticook Rivers in Maine were over 1 million fish (reported as combined species). The state of Maine conducts an annual young-of-the-year survey for six Maine rivers (1979 to 2015). Relative abundance was near zero from 1979 to 1991, and increased gradually through 2004 before declining in recent years (ASMFC 2017a).

The SRT reviewed available abundance data for the blueback herring-Bb-Mid-Atlantic DPS, which ranges from Connecticut to North Carolina. The ASMFC (2017a) reported increasing blueback herring trends for the Mianus and Rappahannock Rivers; stable trends for the Connecticut River, Shetucket River, and Chowan River; no trends for the Delaware and Nanticoke Rivers; and unknown trends for the Farmington, Naugatuck, Potomac, James, York, Alligator, Scuppernog, and St. Johns Rivers. Additionally, trends for river herring were reported as increasing in the Hudson (ASMFC 2017a). Data reported from rivers throughout this range were also reviewed, and numbers varied widely from year to year as expected for this species. The SRT noted blueback herring abundance estimates ranging from 500,000-700,000 during 2013-2016 in the Choptank River; 18,000-54,000 during 2016-2017 in the Patapsco River; and 500,000-950,000 during 2013-2014 in the Marshyhope River (Ogburn unpublished data). Additionally, absolute abundance estimates of blueback herring in the Roanoake River using hydroacoustics ranged from 100,000-478,000 (Waine 2010, Hughes and Hightower 2015, McCargo 2018) across studies conducted in 2008, 2009, 2010, 2011, and 2015, with the high reported in 2015. Total blueback herring population estimates (for age 3+) in the Chowan River time series (1972 to 2015) ranged from a high of 157 million (1976) to a low of 593,693 (2007; ASMFC 2017b). The most recent estimate of blueback herring abundance in the Chowan River was 5,160,983 (2015). Commercial CPUE estimates for blueback herring in the Chowan River have declined since the 1980s.

The ASMFC (2017a) reported no trend for blueback herring in the Santee Cooper River and unknown trends for the St. Johns River. Due to limited trend information, the SRT reviewed available abundance data for the Bb-Southern Atlantic DPS, including young-of-the-year push trawl estimates from Florida (2007 to 2016); CPUE estimates from Santee-Cooper River (1969 to 2015), and minimum population size estimates from the Santee-Cooper River (1990 to 2015) (ASMFC 2017b). Minimum population size estimates from the Santee Cooper River ranged from 8,503 (1990) to 3.4 million (1996); the minimum population size was estimated at 410,000 in 2015. The SRT noted increased uncertainty for Bb-Southern Atlantic abundance risk due to the small number of available indices.

6.3.1.2 *Growth rate/productivity*

The SRT evaluated the available data for blueback herring as they relate to this factor, as summarized in the Reproduction, Growth, and Demography section (2.0). Data are limited on growth rate/productivity, and there has been limited effort to systematically collect and standardize this type of data in most of the range of the species. For this status review, MARSS models from 2013 were updated to estimate population growth rates for each species range-wide; these growth rates were used to inform SRT member qualitative rankings.

SRT members noted that in some populations the maximum age appears to be trending upward, and blueback herring maximum age data indicate most runs had stable ages (ASMFC 2017a). On a rangewide basis, the 2018 MARSS model showed blueback herring population growth rate point estimate of 0. 066 (±0.078) The rangewide blueback herring population growth estimates calculated in 2013 were 0.039 (±0.040). While recent abundance trends have indicated positive growth rates, trends in demographic (maximum age) and reproductive rates (repeat spawners) are largely negative or stable; the combination of these two trends is an indicator of a potentially declining growth rate, given the paucity of high accuracy abundance data for blueback herring.

The mean score calculated based on SRT member's scores corresponds to a *Moderate* ranking rangewide (2.8) and in all DPSs (Bb-Canada/Northern New England DPS (2.8), Bb-Mid-Atlantic DPS (2.9) and Bb-Southern Atlantic DPS (3.0)) as this factor is contributing significantly to the blueback herring's risk of extinction, but does not in itself constitute a danger of extinction in the near future. The lack of available data contributed to higher uncertainty around the growth rate for blueback herring.

6.3.1.3 *Spatial structure/connectivity*

The SRT evaluated the available information on blueback herring spatial structure (tagging and genetics information) summarized in the **Population Structure** section in the status review. Blueback herring range from Florida to Nova Scotia. While the species exhibits homing, rates of straying and therefore dispersal help to buffer the species from threats related to loss of habitat and loss of spatial connectivity. The SRT noted however, that blueback herring likely have longer distances between populations (AMFC 2017a,b), which could result in less resiliency as a spatially connected rangewide population. Additionally, depending on natal river, some blueback herring have longer migratory distances from overwintering areas, thereby exposing them to a longer duration of threats in the marine environment.

In some areas, habitat patches are destroyed faster than they are naturally created but the reverse is likely true in other areas. Dams, habitat alterations and water quality have had a substantial impact on the amount of accessible/suitable spawning/nursery habitats in some river systems and a lack of these habitats impede recovery. Human population growth and development in coastal areas of the eastern United States has continued unabated for decades and the cumulative effects of this growth have large impacts across most of the species' range. These issues are complicated by habitat constraints that include site fidelity and ontogenetic shifts in habitat.

The mean score calculated based on SRT member's scores rangewide and in each DPS correspond to a *Moderate* ranking rangewide, as this factor is unlikely to contribute significantly to the blueback herring's risk of extinction by itself, but there is some concern that it may, in combination with other threats.

6.3.1.4 *Diversity*

The SRT evaluated the available information on blueback herring diversity summarized in the **Population Structure** section in the status review. The available genetics studies indicate that there are a minimum of five genetic stock complexes rangewide and there is evidence of reproductive connectivity along a continuum rangewide. However, blueback herring exhibit larger distances between populations when compared to alewives (ASMFC 2017a,b), which will reduce their ability to harness genetic diversity in the face of extinction risks. The SRT noted that due to declines in abundance over the last several hundred years, the species has likely lost genetic diversity and therefore has lost some amount of adaptive potential. This loss of diversity affects resiliency, especially in the face of climate change. Additionally, SRT members noted that human activities of stocking and propagation have also contributed to reduced genetic diversity. The mean score calculated based on SRT member's scores correspond to a *Moderate* ranking rangewide and in each DPS, as this descriptor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future.

6.3.2 Threats Assessment for Blueback herring

SRT members identified several threats in the *Low to Moderate* category for contribution to extinction risk including: climate change variability, climate change vulnerability, dredging, water quality, water withdrawal, incidental catch, inadequacy of existing international, federal and state regulations (Table 27 -30). Dams and other barriers (see Section 6.3.2.3) received the highest overall mean likelihood point score with a threat ranking of *Moderate*. No threats considered by the SRT were given an overall average score to classify as a *High or Very High* contribution to extinction risk to blueback herring, however water withdrawal and incidental catch received likelihood points in the *Very High* contribution to extinction risk category. All SRT members gave point allocations in the *Very Low* contribution to extinction risk from the following threats: scientific research, education, hybrids, and landlockeds.

Each threat is detailed below and where relevant, specific geographic threats outlined for each DPS.

Table 27. Qualitative ranking of threats for the blueback herring rangewide. Threats were scored using 5 likelihood points distributed in the following bins: 1- very low, 2-low, 3- medium, 4-high, 5-very high. Mean represents the overall workshop participants' average, SD represents the standard deviation based on overall likelihood point allocation given by workshop participants, and range represents the distributions of likelihood points allocated for each threat by workshop participants.

Listing Factor	Threat	Mean	SD	Range	N
A) The present or threatened destruction, modification, or curtailment of habitat or range	Climate Variability	2.1	0.7	1-3	8
	Climate Vulnerability	2.5	0.8	2-4	8
	Dams/Other Barriers	3.1	0.7	1-4	8
	Dredging/Channelization	2.2	0.9	1-3	8
	Water Quality	2.9	0.6	2-4	8
	Water Withdrawal	2.9	0.7	2-5	8
B) Overutilization for commercial, recreational, scientific, or educational purposes	Directed Commercial Harvest	1.8	0.6	1-3	8
	Incidental catch	2.4	0.8	1-5	8
	Recreational Harvest	1.5	0.6	1-3	8
	Scientific Research	1.0	0.0	1	8
	Educational	1.0	0.0	1	8
C) Disease or predation	Disease	1.7	0.7	1-3	8
	Predation	1.8	0.7	1-3	8
D) Inadequacy of existing regulatory mechanisms	International Regulations	2.0	0.7	1-4	7
	Federal Regulations	2.6	0.7	2-4	8
	State Regulations	2.7	0.7	1-4	8
E) Other Natural or man-made factors	Competition	1.5	0.6	1-3	7
	Artificial Propagation	1.3	0.5	1-2	8
	Hybrids	1.0	0.0	1-2	7
	Landlocked populations	1.0	0.0	1-2	7

Table 28. Qualitative ranking of threats for the blueback herring in the Bb-Canada/Northern New England DPS. Threats were scored using 5 likelihood points distributed in the following bins: 1- very low, 2-low, 3- medium, 4-high, 5-very high. Mean represents the overall workshop participants' average, SD represents the standard deviation based on overall likelihood point allocation given by workshop participants, and range represents the distributions of likelihood points allocated for each threat by workshop participants.

Listing Factor	Threat	Mean	SD	Range	N
A) The present or threatened destruction, modification, or curtailment of habitat or range	Climate Variability	2.2	0.7	1-3	7
	Climate Vulnerability	2.5	0.8	2-4	7
	Dams/Other Barriers	3.3	0.6	1-4	7
	Dredging/Channelization	2.0	0.7	1-3	7
	Water Quality	2.9	0.6	2-4	7
	Water Withdrawal	2.8	0.6	2-5	7
B) Overutilization for commercial, recreational, scientific, or educational purposes	Directed Commercial Harvest	1.9	0.7	1-3	7
	Incidental catch	2.6	0.8	1-5	7
	Recreational Harvest	1.8	0.7	1-3	7
	Scientific Research	1.0	0.0	1	7
	Educational	1.0	0.0	1	7
C) Disease or predation	Disease	1.7	0.7	1-3	7
	Predation	1.9	0.7	1-3	7
D) Inadequacy of existing regulatory mechanisms	International Regulations	2.3	0.7	1-4	7
	Federal Regulations	2.7	0.7	2-4	7
	State Regulations	2.7	0.7	1-4	7
E) Other Natural or man-made factors	Competition	1.5	0.6	1-3	7
	Artificial Propagation	1.8	0.7	1-2	7
	Hybrids	1.0	0.0	1-2	7
	Landlocked populations	1.0	0.0	1-2	6

Table 29**.** Qualitative ranking of threats for the blueback herring in the Bb-Mid-Atlantic DPS. Threats were scored using 5 likelihood points distributed in the following bins: 1- very low, 2-low, 3- medium, 4-high, 5-very high. Mean represents the overall workshop participants' average, SD represents the standard deviation based on overall likelihood point allocation given by workshop participants, and range represents the distributions of likelihood points allocated for each threat by workshop participants.

Listing Factor	Threat	Mean	SD	Range	N
A) The present or threatened destruction, modification, or curtailment of habitat or range	Climate Variability	2.1	0.7	1-3	7
	Climate Vulnerability	2.6	0.8	2-4	7
	Dams/Other Barriers	3.0	0.7	1-4	7
	Dredging/Channelization	2.3	0.9	1-3	7
	Water Quality	3.2	0.7	2-4	7
	Water Withdrawal	2.9	0.7	2-5	7
B) Overutilization for commercial, recreational, scientific, or educational purposes	Directed Commercial Harvest	1.6	0.6	1-3	7
	Incidental catch	2.6	0.8	1-5	7
	Recreational Harvest	1.6	0.6	1-3	7
	Scientific Research	1.0	0.0	1	7
	Educational	1.0	0.0	1	7
C) Disease or predation	Disease	1.7	0.7	1-3	7
	Predation	2.0	0.7	1-3	7
D) Inadequacy of existing regulatory mechanisms	International Regulations	2.0	0.7	1-4	7
	Federal Regulations	2.7	0.7	2-4	7
	State Regulations	2.7	0.7	1-4	7
E) Other Natural or man-made factors	Competition	1.6	0.7	1-3	7
	Artificial Propagation	1.2	0.4	1-2	7
	Hybrids	1.0	0.0	1-2	7
	Landlocked populations	1.0	0.0	1-2	6

Table 30. Qualitative ranking of threats for the blueback herring in the Bb-Southern Atlantic DPS. Threats were scored using 5 likelihood points distributed in the following bins: 1- very low, 2-low, 3- medium, 4-high, 5-very high. Mean represents the overall workshop participants' average, SD represents the standard deviation based on overall likelihood point allocation given by workshop participants, and range represents the distributions of likelihood points allocated for each threat by workshop participants.

Listing Factor	Threat	Mean	SD	Range	N
A) The present or threatened destruction, modification, or curtailment of habitat or range	Climate Variability	2.6	0.7	1-3	7
	Climate Vulnerability	2.9	0.7	2-4	7
	Dams/Other Barriers	2.6	0.6	1-4	7
	Dredging/Channelization	2.0	0.7	1-3	7
	Water Quality	2.9	0.6	2-4	7
	Water Withdrawal	2.9	0.7	2-5	7
B) Overutilization for commercial, recreational, scientific, or educational purposes	Directed Commercial Harvest	1.5	0.6	1-3	7
	Incidental catch	1.7	0.7	1-5	7
	Recreational Harvest	1.3	0.5	1-3	7
	Scientific Research	1.0	0.0	1	7
	Educational	1.0	0.0	1	7
C) Disease or predation	Disease	1.7	0.7	1-3	7
	Predation	1.8	0.7	1-3	7
D) Inadequacy of existing regulatory mechanisms	International Regulations	1.3	0.4	1-4	7
	Federal Regulations	2.7	0.7	2-4	7
	State Regulations	2.5	0.9	1-4	7
E) Other Natural or man-made factors	Competition	1.4	0.6	1-3	7
	Artificial Propagation	1.2	0.4	1-2	7
	Hybrids	1.0	0.0	1-2	7
	Landlocked populations	1.0	0.0	1-2	6

6.3.2.1 *Habitat Destruction, Modification, or Curtailment*

The SRT assessed six different factors that may contribute to habitat destruction, modification or curtailment of blueback herring: climate change and variability, climate change and vulnerability, dams and other barriers, dredging/channelization, water quality, and water withdrawal. All threats listed in this category scored in the *Low* or *Moderate* contribution to extinction risk categories. Climate vulnerability, dams and other barriers, water quality, and water withdrawal were the highest ranked threats overall with scores that concluded that the threats contribute significantly to long-term risk of extinction but do not in themselves constitute a danger of extinction in the near future.

6.3.2.1.1 Climate Change and Variability

SRT members evaluated the available information on climate change and climate variability of blueback herring summarized in the status review. In general, diadromous species will be heavily impacted by climate change as they have riverine and oceanic life stages. Blueback herring are habitat generalists in the marine environment, however, they require specialized habitat during the estuary and freshwater portions of their life cycle. Changes to riverine flows and habitat alteration due to extreme events will impact both spawning and early life stages (Tommasi et al. 2015), while migratory patterns and food availability will be two of many impacts of a changing climate on the ocean stages. As water temperatures continue to increase, the blueback herring coastal range may shrink, shifting northward. A condensing of the range would allow natural or anthropogenic catastrophic events to have a larger impact on the species' extinction risk. The overall mean score for climate change and variability corresponded to a *Low* ranking rangewide and in each DPS, except for the Bb-Southern Atlantic DPS, which was ranked as *Moderate* contribution.

Bb-Southern Atlantic DPS

The scores for climate change and variability in Bb-Southern Atlantic DPS were slightly higher because the DPS constitutes the southern edge of the range and will be the first to experience extreme riverine temperatures during spawning and juvenile phases. In addition, many of the known runs in this DPS are in larger river systems and spawning success will likely be negatively impacted by the extreme spring flows as well as the increased summertime salt intrusions predicted to occur due to climate change. The interacting effects of climate change with anthropogenic changes, especially in relation to temperature and flow, carries a potentially significant threat.

6.3.2.1.2 Climate Change and Vulnerability

SRT members evaluated the available information on climate change and vulnerability of blueback herring summarized in the status review. Overall, blueback herring are habitat generalists in the marine environment, however, they require specialized habitat during the estuary and freshwater portions of their life cycle. Blueback herring occur in coastal waters and estuaries during much of the year. They migrate upstream to spawning areas during the spring and require connected habitats with adequate water quality and quantities to complete both their upstream and downstream migrations to and from spawning areas. Additionally, juveniles require freshwater for spawning and early rearing, and require connectivity between rearing habitat (lakes/rivers) to estuaries in addition to adequate water quality and quantities during emigration. Juvenile blueback herring (ages 1-3) have been reported to overwinter in estuaries (J. Stevens, pers. comm.) which makes the estuary a critical component of the blueback herring habitat year round. Their unique life history vulnerabilities provide several pinch points where climate change can have negative effects on individual populations. Increasing and irregular water temperature regimes will have large impacts at these stages. In the ocean, changing currents and thermal clines will affect prey availability as well as growth for juvenile and adult blueback herring. (Hare et al. 2016a, Hare et al. 2016b).

The overall mean score for climate change and vulnerability corresponded to a *Medium* ranking rangewide and in each DPS. The SRT noted that blueback herring currently persist in warmer habitats than alewives and therefore may be more resilient to warmer temperatures. However, the largest populations of blueback herring appear to be concentrated further south (Mid-Atlantic) than alewives, therefore the SRT expected the threats from climate change variability to be greater than that experienced by alewives. Early life stage growth/survival and successful spawning events are temperature dependent. Increasing and irregular water temperature regimes will have large impacts at these stages.

Bb-Southern Atlantic DPS

The SRT predicted that climate change and vulnerability threats would be greatest in the Bb-Southern Atlantic DPS because this region will be the first to experience extreme temperatures during spawning and juvenile phases. Numerous shifts in range and other signs of thermal stress have been observed in fish species in this region and the same can be expected for blueback herring. Being at the southern end of the species' range one would expect that they are already at the maximum tolerance for temperature effects. Additionally, solutions to climate change may include construction of floodgates, berms around cities, and changes in water structures, which may further reduce access to spawning habitat. This threat is magnified because there will be minimal opportunity to control negative climatic effects as they become more apparent.

6.3.2.1.3 Dams and Other Barriers

Dams prevent access to historical spawning habitat (e.g. Hall et al. 2012, Mattocks et al. 2016), but also alter stream continuity and impair water quality on a number of levels. Dams and other barriers often impact migration rates, influencing both upstream and downstream migration of adults and downstream migration of juveniles. Delayed migration can have serious impacts at both life stages, including timing with forage (zooplankton availability) as well as predator avoidance in juveniles, and preferred spawning temperatures in adults. There is some evidence, that of the two river herring species, alewife are better adapted to navigating fishways (K. Sullivan, pers. comm; B. Gahagan, unpublished). Finally, dams often have detrimental nutrient and temperature impacts on downstream river communities affecting both adult and early life stages.

The passage solutions to get fish above dams can have a wide range of efficacy, and in some instances be quite ineffective. Constructed fish passage also does not restore full riverine continuity or address water quality concerns. Further, both nature-like and technical fishways are engineered and built to function on flows modeled from historical records. Deviations in future flow patterns due to climate change could greatly reduce fishway efficacy. The overall mean score for dams and other barriers corresponded to a *Medium* threat ranking rangewide and in the Bb-Canada/Northern New England, and Bb-Mid-Atlantic DPSs.

Bb-Canada/Northern New England DPS

The overall mean score for dams and other barriers corresponded to a *Medium* threat ranking in the Bb-Canada/Northern New England, slightly elevated compared to the rangewide score. Specific barrier threats related to the Bb-Canada/Northern New England DPS include (1) head-of-tide dams that block access to freshwater habitat and (2) increased prevalence of dams and tidal barrages in the Bay of Fundy, Minas Basin, and St. Croix. The SRT took into account that the region was one of the epicenters of colonial and industrial era dam building and many of these structures remain in this area. According to ASFMC (2017a), dam construction in Maine 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.

Access to much of river herring habitat in Maine is still blocked by dams without upstream fish passage and other impediments (ASFMC 2017a). The SRT took into account high mortality associated with the tidal barrages present in the Canadian portion of the range. In Maine, Blueback herring populations appear to be increasing in the upper regions of the state’s watersheds (ASFMC 2017a). The SRT noted that compared to other DPS’s, there are many more dams closer to the head of tide in this region. As a result, there is limited spawning habitat below these dams and spawning runs are heavily influenced by management practices (e.g. truck and transport, fish lifts, fishway maintenance).

According to ASFMC (2017a), resource agencies in Maine are making progress by installing upstream and downstream fish passage facilities, especially in the Sebasticook River watershed and smaller coastal watersheds. In recent years rock-ramp or nature-like fishways have become increasingly popular for passing river herring in Maine.

Bb-Mid-Atlantic DPS

The overall mean score for dams and other barriers corresponded to a *Medium* threat ranking in the Bb-Mid-Atlantic DPS, slightly lower than the rangewide score. Specific barrier threats related to this DPS include the presence of man-made barriers within the historic range of river herring. While dams and other barriers to fish migration continue to be present in states within the range of this DPS, the SRT noted that the dams that do exist in the region are further upriver, leaving a lot of blueback herring habitat below the dams. As such, the SRT determined that barrier threats related to the Bb-Mid-Atlantic DPS are similar (and possibly less severe) compared to those considered in the rangewide analysis.

Several states within the range of this DPS have implemented restoration programs focused on a range of solutions to fish passage. These solutions include fish passage installation, dam removal, and trap-and-transport initiatives.

In Connecticut, the largest blueback run has historically been found in the Connecticut River. Between 1849 and 1955, anadromous fish had no access above the Holyoke Dam, in Holyoke, Massachusetts Today, the Connecticut River blueback herring population size below the

Holyoke dam is unknown and there are insufficient historical data to make an estimate. However, according to ASFMC (2017a), there continues to be stable juvenile blueback production in recent years with index values comparable to values produced with passage of several hundred thousand of fish at the lift despite the lack of adults passed at the Holyoke Dam. It is unknown as to whether or not the peak values of passage at the Holyoke Dam are a sustainable population for the Connecticut River above Holyoke since there is not enough historical population data.

In New Jersey, restoration programs for river herring have been limited to the installation of fish ladders and occasional minor trap and transport programs or dam removal. Fish ladders have also been installed in Delaware to restore river herring runs. 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.

In addition to fish passage installations, dam removal has been the focus of restoration effort is some states. In May 2016, the first dam upstream of the confluence with the Hudson River was removed from the Wynants Kill, a relatively small tributary in Troy, NY, downstream of the Federal Dam. According to ASMFC (2017a), within days of the removal, hundreds of herring moved past the former dam location into upstream habitat. Subsequent sampling efforts yielded river herring eggs, providing evidence that river herring were actively spawning in the newly available habitat which had not been accessible. This dam removal will provide an additional half kilometer of spawning habitat for river herring that has not been available for 85 years (ASMFC 2017). Similarly, Maryland DNR’s Fish Passage program has completed 79 projects, reopening a total 457 miles of upstream spawning habitat in Maryland since 2005.

In Pennsylvania, dam removals along with installation of fish passage have opened up 100 river miles to migratory fish. In 2000 and 2001, river herring were transported to the Conestoga River, a tributary of the Susquehanna River in Pennsylvania. The transported river herring left the Conestoga River, moved up the mainstem Susquehanna River, and were observed at the Safe Harbor Dam.

Bb-Southern Atlantic DPS

The SRT ranked the threat of dams in Bb-Southern Atlantic DPS as a *Medium* risk of extinction, slightly lower than the rangewide and DPS scores. An abundance of available coastal and estuarine habitat and the presence of long undammed sections of major rivers within the range of this DPS led the SRT to rank the mean score lower. Specific barrier threats related to this DPS include habitat loss and alterations occurring in tributaries of Winyah Bay, the Santee-Cooper system, and the Savannah River. The SRT determined that threats posed by dams and other barriers within the range of the South Atlantic DPS are less severe compared to those on a rangewide scale. The SRT noted that dams in this region are often very high in river systems and in many cases are not likely to block an abundance of blueback herring habitat. The SRT also considered this threat somewhat mitigated in this DPS by the ability of blueback herring to successfully use lotic spawning habitats such as those found below dams. The SRT added that alterations to flow regimes and thermal effects of dams are still a concern and may grow in importance with climate change.

Documented impacts of past flow manipulations support the SRT's assessment. In 1938, a large diversion project to move water from the Santee River to the Cooper River initiated. The project resulted in 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. According to Cooke and Coale (1996), large numbers of blueback herring that utilized the Cooper River before rediversion, switched to Santee River after rediversion. The mean score for dams and other barriers in the Bb-Southern Atlantic DPS corresponded to a *Medium,* slightly lower than the rangewide and DPS threat ranking for dams.

6.3.2.1.4 Dredging/Channelization

Similar to dams, dredging has affected historical spawning and nursery habitats. Maintenance dredging continues to reduce available habitat, negatively affect water quality, and change river flows. Although regulated through federal and state permitting, dredging and shoreline hardening associated with estuary/coastline development are not likely to decrease in spatial extent or scope through the next century. Both practices reduce wetland and nearshore habitats, impacting nursery habitats for river herring, including the macrophytes and natural streamflow important to nearshore ecosystem health. While widespread, the SRT ranked the rangewide threat of dredging/channelization as *Low.*

Bb-Mid-Atlantic DPS

The threat of dredging was slightly elevated in the Bb-Mid-Atlantic DPS compared to the rangewide and other DPS scores. The increased volume of industrial activity and growing number of dredge projects in the Bb-Mid-Atlantic DPS may pose a greater risk to blueback herring compared to other regions. This DPS encompasses several hundred miles of dredged river channels, the ports of New York and New Jersey, Baltimore Harbor, the Hudson and Delaware Rivers, as well as the Chesapeake Bay. The SRT ranked the threat of dredging in the Bb-Mid-Atlantic DPS to be at slightly higher risk compared to other DPSs, but still corresponded to a *Low* contribution to extinction risk.

6.3.2.1.5 Water Quality

Water quality is an important threat that in some parts of the species' range. While the large scale acute water quality issues that fueled the creation of the EPA and Clean Water Act have, in many areas, been remedied, the wide impacts of increasing urbanization on the eastern coast of the U.S. has led to widespread deleterious conditions (e.g., perennial hypoxic and anoxic areas in estuaries and nurseries, eutrophication of freshwater systems, invasive plants and eutrophication altering spawning habitat). Siltation resulting from erosional land use practices as well as natural disturbances such as hurricanes/flood events, reduces survival of aquatic vegetation and impacts streamflow. Additionally, climate variability may increase sedimentation in natal rivers, contributing to poorer water quality. These types of effects, often from non-point sources, occur over entire landscapes and are often more difficult to detect, measure, test, and remedy. Some SRT members noted improvements regionally; however, these improvements are not occurring on a rangewide scale. Estuaries are at a greater risk of excess nutrient loading and eutrophication due to increased urbanization. Therefore, blueback herring survival and growth in nursery habitats will continue to be at risk in the future. The overall mean score for water quality corresponded to a *Medium* ranking rangewide and in each DPS.

Bb-Mid-Atlantic DPS

The threat of water quality was slightly elevated in the Bb-Mid-Atlantic DPS compared to the rangewide ranking. Many of the major estuaries in the Bb-Mid-Atlantic DPS such as the Chesapeake and the Delaware have documented water quality issues. This DPS also has many growing population centers and anthropogenic threats are predicted to increase in the future. Similar to climate change and variability, the interactions between anthropogenic change and climate change are likely to severely affect water quality, especially temperature, in regions at the edge of the species’ tolerance.

6.3.2.1.6 Water Withdrawal

Water withdrawal facilities impact natural streamflow and result in impingement/ entrainment mortality of blueback herring. Disrupting streamflow can influence migratory timing as well as water quality below the facility. Additionally, water withdrawal for agriculture or other human activities degrades or destroys habitat for blueback herring and poses a significant threat to their survival, especially when coupled with other threats. The threat is likely to increase alongside coastal population growth, which in conjunction with climate change effects, will likely result in reduced base flows. Water withdrawals and reduced flows can disrupt connectivity between habitats and cause ontogenetic shifts in life history. For blueback herring to be successful, adults must be able to immigrate to nursery areas, spawn, and then emigrate. Juveniles should have adequate flow to emigrate volitionally. In this way, withdrawals act much like dams and other barriers but are less visible. The overall mean score for water quality corresponded to a *Medium* ranking rangewide and in each DPS.

Bb-Canada/Northern New England DPS

Human population density and the resulting anthropogenic effects on water quality (including animal husbandry and agriculture) and the demands and for water withdrawals/diversions are likely less of a threat to the species in this DPS compared to rangewide average. Because of the lower human population density in the Bb-Canada/Northern New England DPS and corresponding demands on water resources, there is a diminished risk to the species as compared to the rangewide average. However, the presence of numerous head of tide dams where emigration from head ponds is a function of fall flows/water levels remains a threat.

Bb-Mid-Atlantic DPS

The threat ranking for water withdrawal in the Bb-Mid-Atlantic DPS was similar to the rangewide score. The SRT noted that predicted population growth rate in this region will drive future demand for water. As anthropogenic pressures increase it will negatively affect affecting water quality (hypoxia, eutrophication) in most major estuaries. Further, the interactions between anthropogenic change and climate change are likely to severely affect water quality in portion of the species range where water quality is already impaired.

Bb-Southern Atlantic DPS

The threat ranking for water withdrawal in the Bb-Southern DPS was similar to the rangewide score. The SRT noted that utility water intake may be a larger issue in the Bb-Southern Atlantic DPS compared to water withdrawals rangewide.

6.3.2.2 *Overutilization*

The SRT assessed five different factors that may contribute to the overutilization of blueback herring: directed commercial harvest, retained and discarded incidental catch (including slippage), recreational harvest, scientific research and educational use. Retained and discarded incidental catch was the only threat that ranked in the *Medium* contribution to extinction risk in this section.

6.3.2.2.1 Directed Commercial Harvest

Overutilization for commercial purposes was once considered one of the primary threats to blueback herring populations. Significant declines have been documented throughout much of the blueback herring's range due to historic fishing pressure and other threats. Directed harvest does still occur in several states and the fishing occurs during migration to spawning grounds. Amendment 2 to the ASMFC Shad and River Herring Interstate Fishery Management Plan requires states to have a sustainable fishery management plan (SFMP) for each river with a river herring fishery (beginning in 2012). SFMPs must be reviewed by the ASMFC Shad and River Herring Technical Committee for adequate sustainability measures and approved by the ASMFC management board. Monitoring is required on all harvested runs in the U.S. Overall, SRT members felt that the current directed harvest was well regulated and occurred only on stocks that have demonstrated sustainability. The overall mean score for directed harvest corresponded to a *Low* ranking rangewide and in each DPS.

Bb-Canada/Northern New England DPS

The threat ranking for directed commercial harvest was slightly higher in the Bb-Canada/Northern New England DPS compared to the rangewide ranking and SRT members noted increased uncertainty related to directed harvest levels within Canada. Gibson et al. (2017) indicated high annual removal rates where recorded or reported. Additionally, Gibson et al. (2017) indicated that previous reporting and collection methods do not provide consistent and accurate information, increasing concern and uncertainty for this threat in the Bb-Canada/Northern New England DPS. Finally, the Department of Fisheries and Oceans still allows some fishing on mixed stocks in Canadian waters, which makes managing impacts to individual populations more difficult. Maine currently has an approved ASMFC sustainable fishing management plan within this DPS. The SRT noted uncertainty related to lack of publicly available commercial harvest data for Maine due to confidentiality, therefore the total removals by river system are unknown.

Bb-Mid-Atlantic DPS

The threat ranking for directed commercial harvest was slightly lower in the Bb-Mid-Atlantic DPS compared to the rangewide ranking. New York is the only state to have an approved ASMFC sustainable fishing management plan within this DPS.

6.3.2.2.2 Retained and Discarded Incidental Catch

Retained and discarded incidental catch (including slippage) is likely negatively impacting some blueback herring populations. The SRT noted that historical declines in blueback herring abundance were not likely driven by incidental catch, but because of current depleted abundances incidental catch may impede restoration and recovery efforts. As with all of the threats, the true magnitude of incidental catch remains largely unknown because there is no estimate of rangewide abundance. While some monitoring of incidental catch does occur in the Atlantic herring and mackerel fisheries, it has been estimated that monitored fisheries may only constitute half the discards in a given year (Wigley 2009). Further, the contribution of slippage also remains unknown because it is not currently reported. From 2005-2015, the total annual incidental catch of blueback herring ranged from 36.5-531.7 metric tons (mt) in New England waters and 10.9-295.0 mt in the Mid-Atlantic region (ASMFC 2017a).

Because incidental catch occurs in marine waters, and blueback herring stock complexes overlap in their distribution in the ocean, the retained and discarded incidental catch occurs on a mixed stock complex fishery (that is, there is no "oceanic" stock of blue back herring, the blueback herring in the ocean come from all of the stock complexes). Recent studies have also shown that blueback herring incidentally caught in a number of statistical areas were from several genetic stock complexes (Hasselman et al. 2016, Palkovacs unpublished). This finding increases the probability that blueback herring are being exploited from populations that do not meet sustainable harvest requirements. The SRT noted uncertainty around incidental catch related to estimates of exploitation, future monitoring coverage, and future use of bycatch avoidance programs. Based on the best available information, the SRT concluded that the threat from incidental catch rangewide and in all DPSs corresponded to a *Low* contribution to extinction risk rangewide and in the Bb-Southern Atlantic DPS. Incidental catch in both the Bb-Canada/Northern New England and Bb-Mid-Atlantic DPS's was ranked as a *Low* contribution to extinction risk.

Bb-Canada/ Northern New England DPS

The threat ranking for incidental harvest was slightly higher for the Bb-Canada/Northern New England DPS compared to the rangewide score. Limited information is available to estimate the impacts of incidental catch in the Bb-Canada/Northern New England DPS. Though fewer fish from this DPS are reported in the Atlantic herring/mackerel fisheries (Palkovacs, unpublished data), other small mesh fisheries in this region may incidentally catch river herring.

Bb-Mid-Atlantic DPS

The threat ranking for incidental harvest was slightly higher for the Bb-Mid-Atlantic DPS (2.6) compared to the rangewide score (2.4). Data available from the Herring and Mackerel fishery for the years 2012-2015 (Palkovacs, unpublished) suggest that blueback herring from this DPS are caught as bycatch in the Atlantic herring fishery. SRT members noted uncertainty due to limited information regarding the magnitude of small mesh coastal fisheries. Additional uncertainty comes from the limited sample area (Atlantic Herring Management Area 2 fisheries). Numerous small mesh fisheries exist in Atlantic Herring Management Areas 1 and 2 and information regarding bycatch in those fisheries would be very beneficial to understanding the level of impact on river herring populations in this DPS.

Bb-Southern Atlantic DPS

The threat ranking for incidental harvest was slightly lower for the Bb-Southern Atlantic DPS and corresponded to a *Low* contribution to extinction risk. While there is little information about small mesh fisheries operating in coastal waters for this DPS, few herring are landed in the SEAMAP survey, and there appeared to be relatively little incidental take of Bb-Southern Atlantic DPS blueback herring in the Atlantic Herring and Mackerel fishery off southern New England (Palkovacs, unpublished data).

6.3.2.2.3 Recreational Harvest

Recreational harvest has largely been eliminated and where it does exist, it is regulated. Amendment 2 to the ASMFC Shad and River Herring Interstate Fishery Management Plan requires states to have a sustainable fishery management plan for each river with a river herring fishery (beginning in 2012). Plans must be reviewed by the ASMFC S&RH technical committee for adequate sustainability measures and approved by the ASMFC management board. Historical rangewide, recreational catch is largely unknown and the recent ASMFC assessment (2017a) deemed recreational catch estimates unreliable. Based on the best available information the SRT concluded that the threat from recreational harvest corresponded to a *Low* contribution to extinction risk rangewide and in all DPSs, except for the Bb-Southern Atlantic DPS which corresponded to a *Very Low.* The threat ranking for directed commercial harvest was slightly higher in the Bb-Canada/Northern New England DPS compared to the rangewide ranking and SRT members noted increased uncertainty related to directed harvest levels within Canada. However, the SRT noted that illegal and unmonitored recreational harvest could have significant local impacts.

Bb-Canada/New England DPS

The SRT scored the threat of recreational harvest in the Bb-Canada/Northern New England DPS to be a *Low* contribution to extinction risk, slightly higher than the rangewide score. The increased risk score was due to uncertainty surrounding monitoring and reporting of recreational fisheries in Canada.

Bb-Southern Atlantic DPS

The SRT scored the threat of recreational harvest in the Southern DPS to be a *Low* contribution to extinction risk, slightly lower than the rangewide and other DPS scores. The SRT noted that there are fewer recreational fisheries in the Southern DPS compared to others. Unreported recreational bait use was noted as an uncertainty.

6.3.2.2.4 Scientific Research and Educational Harvest

The SRT could find little information linking scientific and educational use to declines in blueback herring populations. Therefore, based on the best available information, the SRT concluded that neither scientific use nor educational use is contributing to the species' risk of extinction. Both threats ranked in the *Very Low* category.

6.3.2.3 *Disease or Predation*

The SRT could find little information linking disease to declines in blueback herring populations. Predation also does not appear to increase this species' risk of extinction rangewide. Therefore, based on the best available information, the SRT concluded that neither disease nor predation is contributing to the species' risk of extinction. Both threats ranked in the *Very Low* category.

6.3.2.3.1 Disease

Little information exists on diseases that may affect river herring; however, there are reports of a variety of parasites that have been found in both alewife and blueback herring. The most comprehensive report is that of Landry et al. (1992) in which 13 species of parasites were identified in blueback herring and 12 species in alewives from the Miramichi River, New Brunswick, Canada. SRT members noted disease is of biggest concern at low population levels; however, warmer summer temperatures, changing fish communities, and changing migratory patterns due to climate change may make blueback herring populations more susceptible to disease in the future. The SRT concluded that the threat from disease corresponded to a *Low* contribution to extinction risk rangewide and in all DPSs.

6.3.2.3.2 Predation

While blueback herring are an important forage species, predators on the Northeast U.S. shelf are generally opportunistic (versus specialized) and will consume prey species in relation to their abundance in the environment. At high population levels, predation is likely not an issue; however, as populations decline predation can become a larger threat, especially locally. Recent papers (Davis et al. 2012, Ferry and Mather 2012) focus on the predation impacts of striped bass; however, the predatory impact by striped bass is likely localized to areas/times of overlap.

The overall mean score for predation corresponded to a *Low* ranking rangewide and in all DPSs. The SRT noted uncertainty surrounding introduced or invasive piscivores such as snakeheads or blue catfish, which could have larger impacts if they dramatically expand their ranges. Alterations to fish behavior, such as inability to break through predatory gauntlets to access fish passage, were also noted as components of predation that have not been well described.

6.3.2.4 *Inadequacy of Existing Regulatory Mechanisms*

The SRT assessed three different factors that may contribute to the inadequacy of existing regulatory mechanisms: international regulations, federal regulations and state regulations. The inadequacy of regulatory mechanisms to control the harvests of blueback herring was once considered a significant threat to their populations. The best available information indicates that legal protections for blueback herring vary between outright prohibitions on most directed harvest in the U.S. and limited fishing permitted in Canada, though uncertainties remain about international fishing regulations. All three threats were ranked in the *Low* or *Moderate* contributions to extinction risk category, with federal regulations and state regulations ranking as a slightly higher contribution than international regulations. However, SRT members also noted uncertainty with expertise related to other global or national environmental regulations in this category.

6.3.2.4.1 International Regulations

The inadequacy of international regulations was ranked in the *Low* contribution to extinction risk category. However, SRT members also noted uncertainty with expertise related to other global or national environmental regulations in this category.

Bb-Canada/Northern New England DPS

SRT members ranked the threat of International regulations as a slightly higher risk within the Bb-Canada/Northern New England DPS. This DPS is located partially within Canada, therefore international regulations are predicted to directly affect this DPS more than the other DPSs. Canada does not regularly separate river species and has less monitoring compared to the U.S. SRT members also noted uncertainties related to Canadian regulations on hydropower and fisheries.

Bb-Southern Atlantic DPS

SRT members ranked the threat of International regulations as *Low* contribution to extinction risk. This DPS is the southern extent of blueback herring,, SRT members predicted to international regulations (especially those related to Canada) to have a lower effect on this DPS compared to other DPSs.

6.3.2.4.2 Federal Regulations

SRT members noted that an adequate regulatory framework within ASMFC to effectively manage and recover both species of river herring currently. However, given the minimal commercial value in the present day, the SRT noted the uncertainty that river herring conservation would be prioritized compared to more important or valuable species. The SRT also expressed uncertainties around estimates of incidental take on the rangewide population. Low economic valuation has negative consequences for blueback herring in terms of incidental take in profitable fisheries and also, but perhaps less obvious, in relation to current management practices within regional fisheries management commissions and councils. Managers in inter-jurisdictional fisheries may have desired outcomes for species with high economic or cultural value and "vote trading" of less economically valuable species, such as river herring, to achieve these outcomes, can have negative conservation implications for the lower economic value species.

The SRT also considered other federal non-fishery regulations such as the Clean Water Act and Federal Power Act. Despite current regulations, habitat alterations, such as dams and culverts, excess nutrient loading and sedimentation due to poor land use practices, dredging, and coastal development continue to affect both marine and freshwater habitats, potentially limiting population growth. In tandem with the predicted effects of climate change, such as increased precipitation and warming ocean temperatures, the importance of federal regulations to blueback herring sustainability will likely increase in the future. The SRT also identified mismatches with the life cycle of blueback herring and the long regulatory processes (often 20-50 years) that accompany fish passage improvements via the Federal Power Act and relicensing of hydropower facilities through the Federal Energy Regulatory Commission. Federal Regulations were ranked in the *Moderate* contributions to extinction risk category.

6.3.2.4.3 State Regulations

As with federal regulations, SRT members noted that existing state regulations related to fisheries provided structure for protection of blueback herring at a state level through ASMFC. But like federal regulations, state regulations related to habitat loss remain a large concern for the future of the species, especially since spawning and nursery habitats are found in state waters.

Uncertainty related to the reliability of enforcement of state laws and concerns for non-fishing regulations affecting coastal and riverine habitat in the face of increasing populations and coastal development. State regulations were ranked in the *Moderate* contributions to extinction risk.

6.3.2.5 *Other Natural or Manmade Factors*

The SRT assessed four different threats that may contribute to other natural or manmade factors affecting the species continued existence: competition, artificial propagation/stocking, hybrids and landlocked populations. The SRT could find very little information linking any of these threats to declines in abundance of blueback herring. Therefore, based on the best available information, the SRT concluded that the threats in the other natural or man-made factors are unlikely to be contributing to the species' risk of extinction. All threats ranked in the *Very Low* or *Low* categories.

6.3.2.5.1 Competition

Competition among fish species is difficult to determine because it requires demonstration of limiting resource. Given the diet of blueback herring (and generalist nature), prey are likely not limiting. However, there is some possibility that space could be limiting (e.g. dams, poor fish passage, etc.). Competition ranked in the *Low* category rangewide and for all DPSs, except for the Bb-Southern Alantic DPS, which ranked in the *Very Low* category.

6.3.2.5.2 Artificial Propagation/Stocking

Artificial propagation ranked as a *Very Low* threat to blueback herring rangewide and in all DPSs except for the Bb-Canada/Northern New England DPS. However, SRT members noted that artificial propagation/stocking has detrimental effects on blueback herring populations. First, hatchery efforts often take focus and importance away from on-the-ground issues with a fish and its habitat, which would be harmful in the long term. Second, artificial propagation would almost certainly lead to a significant loss of genetic diversity, which is already likely substantially lower than most times in the past.

Bb-Canada/Northern New England DPS

The SRT ranked the threat of artificial propagation/stocking slightly higher in the Bb-Canada/Northern New England DPS (*Low)* compared to the rangewide and other DPS risk scores (*Very Low*). As noted in the Abundance portion of the Extinction Risk Assessment, the persistence of many populations in Maine are reliant on active management strategies (e.g. truck and transport, fish lifts, fishway maintenance) rather than volitional passage. Therefore, a change in management strategy, especially related to stocking/truck and transport would have dramatic impacts on these runs. In addition, the intensive stocking in this region has likely reduced genetic variability in the U.S. portion of this DPS.

6.3.2.5.3 Hybrids

Hybrids have likely been a natural occurrence throughout the history of alewives and blueback herring. In most cases they occur at low to very low rates in natural and impacted systems (McBride et al. 2014, Hasselman et al. 2014). Further, no research to date has even attempted to show any loss of viability or function in hybrids and hybrids have been shown to be completely viable and reproductively successful (Hasselman et al. 2014). Hybrids ranked in the *Very Low* category rangewide and for all DPSs.

6.3.2.5.4 Landlocked Populations

Landlocked populations are discrete from anadromous blueback herring, occupy different ecological niches, and have differing morphological features. The SRT ranked landlocked populations as *Very Low* contribution to extinction risk rangewide and for all DPSs.

6.3.3 Overall Risk Summary for Blueback Herring

The mean overall risk scores for blueback herring rangewide correspond to a 66% likelihood of a *Low risk* of extinction, currently or in the foreseeable future (defined by the SRT as 12-18 years). The distributions of likelihood points used in the Overall Extinction Risk Analysis are summarized below (Figure 26-27).

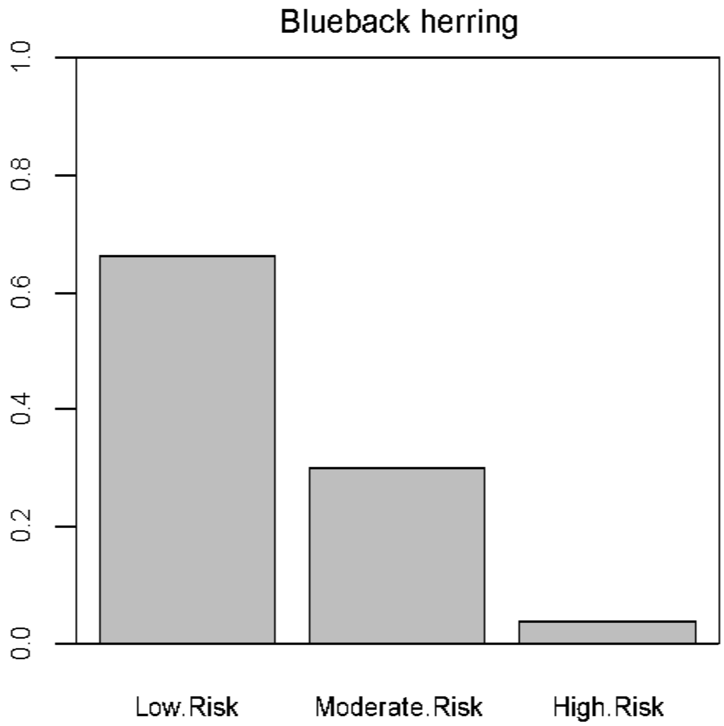


Figure 26. Overall level of extinction risk for blueback herring rangewide. Likelihood points were distributed amongst each of the categories based upon each SRT member's (n=8) expert judgment.

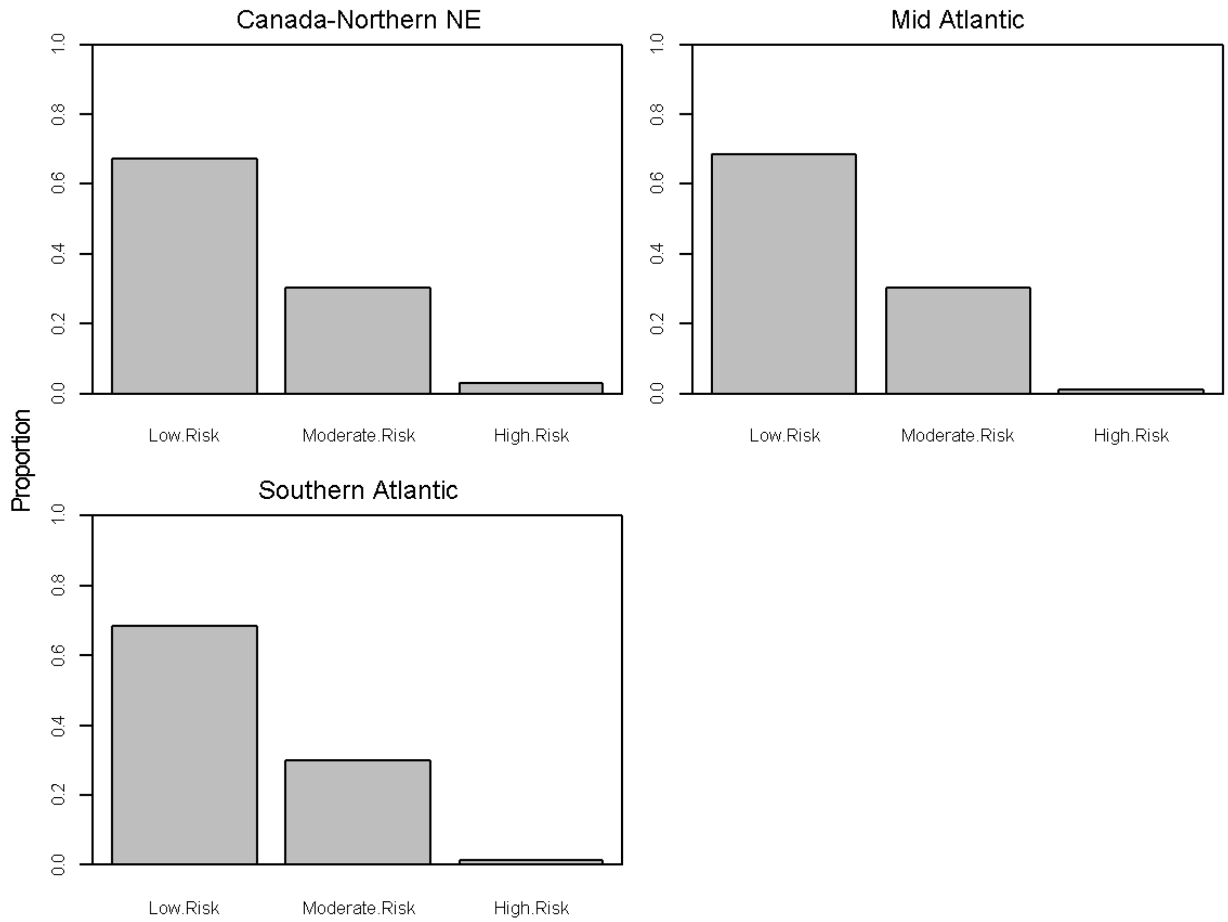


Figure 27. Overall level of extinction risk for blueback herring in the Bb-Canada/Northern New England, Bb-Mid-Atlantic, and Bb-Bb-Southern Atlantic DPS. Likelihood points were distributed amongst each of the categories based upon each SRT member's (n=7) expert judgment.

For blueback herring rangewide, SRT members indicated that there was a 66% low risk of extinction, a 30% moderate risk of extinction and a 4% high risk of extinction. This was due to the complex anadromous fish life history, uncertainty in climate change and vulnerability, incidental catch, potential habitat modification (e.g. increased coastal development and water use), and concern about the adequacy of current and future regulatory mechanisms, including fisheries rangewide. The mean overall risk scores for blueback herring in the Bb-Canada/Northern New England DPS correspond to a 67% low risk of extinction, a 30% moderate risk of extinction and a 3% high risk of extinction. The mean overall risk scores for blueback herring in the Bb-Mid-Atlantic DPS correspond to a 69% low risk of extinction, a 30% moderate risk of extinction and a 1% high risk of extinction. The mean overall risk scores for blueback herring in the Bb-Southern Atlantic DPS correspond to a 69% low risk of extinction, a 30% moderate risk of extinction and a 1% high risk of extinction.

To conclude, blueback herring have been subjected to habitat impacts for centuries and considerable fishing pressure for many decades. The SRT acknowledged that they are at historical low levels, but noted that improved fisheries management efforts in recent years have reduced fishing mortality rates on blueback herring stocks and hundreds of habitat improvement projects have been completed in the past 20 years. However, over one third of the SRT's allocation points were in the moderate/high categories, indicating that blueback herring are at a greater risk of extinction compared to alewives due to lower overall abundances, increased vulnerability to anthropogenic disturbances in combination with climate change, greater distances between populations, poorer performance at fishways, and uncertainties surrounding accurate distribution information rangewide. Based upon the available information summarized here and the SRT's individual expert opinions, considered as a mean score, blueback herring have a low risk of extinction, assuming the dominant threats to their populations continue to be managed.

7 SIGNIFICANT PORTION OF ITS RANGE ANALYSIS

The definitions of both "threatened" and "endangered" under the ESA contain the term" significant portion of its range" as an area smaller than the entire range of the species which must be considered when evaluating a species risk of extinction. The phrase "significant portion of its range "is not defined in the ESA. In response, the Services published the Significant Portion of its Range (SPR) Policy, which provides an interpretation of the phrase and guidance for how to evaluate whether a species is in danger of extinction, or likely to become so in the foreseeable future, in a "significant portion of its range" (79 FR 37578, July 1, 2014).

Under the policy, a species may be listed rangewide based on the status of the species in the significant portion of its range. In order for a portion of the range to be considered "significant" under the policy, the species in that portion must be both biologically significant and the species in the portion must be either in danger of extinction or in danger of extinction the foreseeable future.

As described above in **section 6 Extinction Risk Analysis,** the SRT first considered the risk of extinction for each species rangewide. The SRT determined that both alewife and blueback herring are at a low risk of extinction throughout their range. In accordance with the SPR Policy, the SRT next evaluated whether the species is in danger of extinction, or likely to become so in the foreseeable future, in a "significant portion of its range." The SPR Policy explains that it is necessary to fully evaluate a particular portion as a   "significant portion of its range" only if substantial information indicates that the members of the species in a particular area are likely both to meet the test for biological significance and to be currently endangered or threatened in that area.

The policy outlines, and the SRT followed, a step wise analysis that may be used to determine whether a portion of the range is significant. First, the SRT considered whether there is a particular geographic area where threats to the species are concentrated and whether that portion may meet the biological significance standard. Whether the portion actually meets these standards such that the species should be listed. To identify only those portions that warrant further consideration, the SRT was asked to determine whether there is substantial information indicating that (1) the portions may be significant and (2) the species may be in danger of extinction in those portions or likely to become so within the foreseeable future. As noted above, answering these questions in the affirmative is not a determination that the species is endangered or threatened throughout a significant portion of its range—rather, it is a step in determining whether a more detailed analysis of the issue is required (79 FR 37578, at 37586; July 1, 2014).

Thus, the preliminary determination that a portion may be both significant and endangered or threatened merely requires a more detailed analysis to determine whether the standards are actually met (79 FR 37578, July 1, 2014). Unless both standards are met, listing is not warranted. The SPR policy further explains that, depending on the particular facts of each situation, it may be more efficient to address the significance issue first, but in other cases it will make more sense to examine the status of the species in the potentially significant portions first. Whichever question is asked first, an affirmative answer is required to proceed to the second question. "[I]f we determine that a portion of the range is not 'significant,' we will not need to determine whether the species is endangered or threatened there; if we determine that the species is not endangered or threatened in a portion of its range, we will not need to determine if that portion is 'significant'." Thus, if the answer to the first question is negative—whether that regards the significance question or the status question—then the analysis concludes.

As defined in the SPR Policy, a portion of a species' range is "significant" "if the species is not currently endangered or threatened throughout its range, but the portion's contribution to the viability of the species is so important that, without the members in that portion, the species would be in danger of extinction, or likely to become so in the foreseeable future, throughout all of its range" (79 FR 37578, July 1, 2014). For purposes of the SPR Policy, "[t]he range of a species is considered to be the general geographical area within which that species can be found at the time FWS or NMFS makes any particular status determination. This range includes those areas used throughout all or part of the species' life cycle, even if they are not used regularly (e.g., seasonal habitats). Lost historical range is relevant to the analysis of the status of the species, but it cannot constitute a "significant portion of a species' range."

To identify only those portions that warrant further consideration under the SPR policy, the SRT had to determine whether there is substantial information indicating that (1) a portion may be significant and (2) the species may be at a higher risk of extinction within that portion. Because the policy allows that either prong may be analyzed first, the SRT examined the risk of extinction in a portion first.

7.1 Alewife SPR Analysis

As described previously (see **Section 3:Distribution and Abundance**), based on abundance estimates in the recent stock assessment update (ASMFC 2017a) and the SRT's extinction risk results, the SRT determined that alewife are at low risk of extinction rangewide and in each of the four DPSs. Applying the SPR Policy to the alewife, the SRT first evaluated whether there is substantial information indicating that any portions of the species' range are threatened or endangered. In light of the earlier findings that all four DPSs, which span the range of this species, are at low risk of extinction, and finding no other evidence of areas within the species range where there is a concentration of threats, the SRT did not identify portions of the alewife range that were at a *high* risk of extinction, nor could the SRT identify threats that significantly affected one portion of the range.

The SRT then applied the SPR Policy to each alewife DPS. In other words, the SRT evaluated whether there is substantial information indicating that any portions of any singular DPS may have a concentration of threats and should be further evaluated under the SPR Policy. After reviewing the best available data, the SRT found no information to suggest that any portion of the Aw-Canada, Aw-Northern New England, Aw-Southern New England, or Aw-Mid-Atlantic DPSs stood out as having a heightened risk of extinction now or in the foreseeable future, and the SRT found no reason to further evaluate areas of any particular DPS under the SPR Policy.

7.2 Blueback herring SPR Analysis

The SRT determined that rangewide blueback herring a 66% low risk of extinction, a 30% *moderate* risk of extinction and a 4% *high* risk of extinction. Applying the SPR Policy to the blueback herring, the SRT first identified geographic areas where there may be a concentration of threats. The SRT then evaluated whether there is substantial information indicating that any of these portions of the species' range may be facing a risk of extinction now or in the foreseeable future.

The SRT specifically considered whether recent information about the Bb-Mid-Atlantic stock complex of blueback herring suggested this region of the range may constitute an SPR. The SRT considered threats to this region (see previous **6.3.2 Threats Assessment for Blueback herring**). While some threats were ranked slightly higher numerically in the Bb-Mid-Atlantic compared to other areas (including, but not limited to water quality and water withdrawal), the scoring varied from other areas only by tenths of a point. Accordingly, the identified qualitative rankings (i.e., *very low* to *medium*) always matched at least one or more other areas for the particular threat category. Additionally, the SRT completed an overall extinction risk assessment for the Bb-Mid-Atlantic portion of the range (see previous **6.3.3 Overall Level of Extinction Risk**). The SRT allocated a 69 percent *low* risk of extinction, a 30 percent *moderate* risk of extinction and a 1 percent *high* risk of extinction. Overall, the best available data indicate blueback herring in the Bb-Mid-Atlantic stock complex are not at risk of extinction now or in the foreseeable future. Therefore, the SRT did not proceed to consider the biological significance of the Bb-Mid-Atlantic stock to the species.

Additionally, because in 2011 the petitioner identified the Long Island Sound portion of the range as a potential DPS, the SRT considered if this portion of the Bb-Southern New England stock complex would be considered "significant" under the SPR Policy. The petitioners considered this area to consist of the Monument, Namasket, Mattapoiset, Gilbert-Stuart, Shetucket, Farmington, Connecticut, Naugatuck and Mianus Rivers.

The SRT considered the threats affecting the Long Island Sound area, including habitat loss due to dams and other barriers, water withdrawal due to high population densities, and bycatch. Notably, this area is found within the Bb-Mid-Atlantic DPS (discussed previously in **6.3.2 Threats Assessment for Blueback herring**.

The SRT analyzed the available run data for the time series for the Long Island trawl survey, Connecticut juvenile seine survey, and Connecticut River and Monument River run counts. Overall blueback herring abundance for this portion is difficult to estimate accurately and managers have reported a mismatch of river wide trends in abundance in this region when comparing juvenile seine survey data from the Connecticut River and Holyoke fishway counts (ASMFC 2017b). While the Connecticut River watershed may act or have acted as a source population for blueback herring in this region, many other rivers in this portion are smaller coastal runs that drain directly into the ocean and are not expected to be large production rivers for blueback herring on the same scale .Over the full time series (2006-2015) in the most recent ASMFC assessment, run trends for blueback herring have decreased in the Monument River, were variable trends in the Connecticut River, and were stable in the Shetucket River and Mianus Rivers

When considering spatial distribution of blueback herring in this portion, the SRT noted that although the abundances are low, blueback herring were distributed through this entire portion and appear to be reasonably well connected with rivers to the south of the Connecticut and rivers to the north, which also have blueback herring populations. Recent genetic work by Reid *et al.* (2018) places river populations from this portion into at least two separate genetic groups. The Connecticut River and Mianus Rivers were assigned to the Bb-Mid Atlantic stock complex, and the Gilbert-Stuart and Monument Rivers were assigned to the Bb-Southern New England stock complex (Reid *et al.* 2018). The most recent genetic studies do not indicate that this portion is unique in its genetic diversity.

Finally, the SRT completed an overall extinction risk assessment for the Long Island portion identified by the petitioners. Overall, the SRT concluded that there is a *low* risk of extinction in the Long Island Sound portion currently and in the foreseeable future. The Long Island Sound population is not threatened or endangered, nor is it likely to become so in the foreseeable future. Therefore, the SRT did not proceed to consider whether the portion may be biologically significant to the species rangewide.

Next, the SRT considered the extinction risk of the Bb-Mid-New England Stock complex due to recent concerns related to very low run counts in New Hampshire rivers. The SRT considered the best available information on abundance, growth rates/productivity, spatial distribution, and diversity contained in the recent stock assessment update (ASMFC 2017a,b).
The SRT examined trends for the Oyster, Winnicut, Taylor, Lamprey, and Cocheco Rivers in New Hampshire and discussed threats in this region. The SRT questioned whether the fisheries-independent surveys that are currently conducted by the state adequately target blueback herring, but the reported indices in the most recent stock assessment (ASMFC 2017b) are the best available information. The best available data show blueback herring run count trends increasing over the time series (2006-2015). Data for other rivers in this portion are collected as "river herring" and show increasing trends over the time series for the Cocheco and Lamprey, decreasing trend in the Oyster River, and no trend in the Exeter River and Winnicut Rivers. The SRT noted that recent sampling in the Lamprey River resulted in zero blueback herring counted at the fishway. SRT members noted that there is likely some blueback herring spawning below the fishway, but the monitoring design only counts fish which ascend the fishway. However, this issue is not unique to this river system.

The most recent genetic information classified blueback herring in this portion of the species' range as belonging to the Bb-Mid New England stock complex (Reid *et al*. 2018) (see Figure 2).

The Bb-Mid New England portion is adjacent to stock complexes in the north (Bb-Canada/Northern New England) and south (Bb-Mid Atlantic), though the precise boundaries and distribution of this stock complex are not fully understood due to the unsampled blueback herring populations located between the Oyster River and the Sebasticook River.
The SRT considered the threats affecting the Bb-Mid New England area, including habitat loss due to dams and other barriers, threats to water quality, incidental catch, and inadequacies of state and Federal regulations. Notably, this area overlaps with the southern portion of the Aw-Northern New England (discussed in section **4. Assessment of the ESA Section 4(a)(1) Factors** and **6.3.2 Threats Assessment for Blueback herring**).

The SRT completed an overall extinction risk estimate for the Bb-Mid-New England stock complex of blueback herring and allocated 51 percent of the likelihood points to the *High* risk of extinction, 39 percent to *Moderate* risk of extinction and 10 percent to low risk of extinction. The allocation of likelihood points in the *High* risk category was primarily due to declining run trends and poor population metrics.

Because the SRT found the Bb-Mid-New England stock complex of blueback herring to be at a high risk of extinction, they considered the questions below and outlined in the Status Review Guidance (NMFS 2017) to determine if the Bb-Mid-New England stock complex might be considered biologically “significant” i.e., whether the portion’s contribution to the viability of the species is so important that, without the members in that portion, the species would be in danger of extinction or likely to become so in the foreseeable future.

Abundance:

- Without that portion, would the level of abundance of the remainder of the species cause the species to be at moderate or high risk of extinction due to environmental variation or anthropogenic perturbations (of the patterns and magnitudes observed in the past and expected in the future)?
- Without that portion, would the abundance of the remainder of the species be so low, or variability in abundance so high, that it would be at moderate or high risk of extinction due to depensatory processes?
- Without that portion, would abundance of the remainder of the species be so low that its genetic diversity would be at risk due to inbreeding depression, loss of genetic variation, or fixation of deleterious alleles?
- Without that portion, would abundance of the remainder of the species be so low that it would be at moderate or high risk of extinction due to its inability to provide important ecological functions throughout its life-cycle?
- Without that portion, would the abundance of the remainder of the species be so low that it would be at risk due to demographic stochasticity?

Productivity:

- Without that portion, would the average population growth rate of the remainder of the species be below replacement such that it would be at moderate or high risk of satisfying the abundance conditions described above?

- Without that portion, would the average population growth rate of the remainder of the species be below replacement such that it is unable to exploit requisite habitats/niches/etc. or at risk due to depensatory processes during any life-history stage?
- Without that portion, would the remainder of the species exhibit trends or shifts in demographic or reproductive traits that portend declines in the per capita growth rate, which pose a risk of satisfying any of the preceding conditions?

Spatial distribution:

- Will the loss of one or more of the portions significantly increase the risk of extinction to the species as a whole by making the species more vulnerable to catastrophic events such as storms, disease or temperature anomalies?
- Will connectivity between portions of the species' range be maintained if a portion is lost (e.g., does the loss of one portion of the range of the species create isolated groups or populations?)?
- Are there particular habitat types that the species occupies that are only found in certain portions of the species' range? If so, would these habitat types be accessible if a portion or portions of the range of the species are lost?
- Are threats to the species concentrated in particular portions of the species' range and if so, do these threats pose an increased risk of extinction to those portions' persistence?

Diversity:

- Will unique genetic diversity be lost if a portion of the range of the species is lost?
- Does the loss of this genetic diversity pose an increased risk of extinction to the species?

Specifically, the SRT considered a number of questions that inform the viability characteristics: abundance, productivity, spatial distribution, and genetic diversity. The SRT considered how the loss of the portion, given the current available information on abundance levels, would affect the species rangewide in a variety of ways. The SRT also considered how the loss of the portion would affect the spatial distribution of the species (i.e., would there be a loss of connectivity, would there be a loss of genetic diversity, or would there be an impact on the population growth rate of the remainder of the species).

The SRT found that the Bb-Mid-New England portion of blueback herring was unlikely to contribute in such a way as to be considered significant to the blueback herring rangewide. More specifically, the Bb-Mid-New England portion is very small compared to the rest of the range, spanning approximately 311 km (193 mi) of coastline and encompassing less than 3% of the estimated watershed area of the species. Additionally, the current run sizes in this portion in the last decade have numbered in the 10,000s and more recently in the 1,000's and are estimated at less than 1 percent of overall rangewide abundance. The historical contribution of the Mid-New England portion to the rangewide abundance is assumed to be a similar proportion, as historical declines were noted across the blueback herring's range. However, the historical contribution may have been slightly higher than one percent due to the intense current and historic industrial development (e.g., dam construction near head of tide for mills) in this region (see **6.3.2 Threats Assessment for Blueback herring**). Additional uncertainty exists as unsampled adjacent rivers may be attributed to this stock complex. The SRT noted that due to the small abundance in the Bb-Mid-New England portion and its small contribution to the overall population size, they would not expect deleterious effects to the remainder of the species from its loss. The SRT also noted that the loss of the Bb-Mid-New England potion would not cause the species as a whole to be below replacement rate. Additionally, this portion’s abundance is not large enough to drive rangewide populations or productivity nor does it have the capacity to drive rangewide shifts due to its relatively small production potential compared to populations found in the rest of the range. Loss of the Mid-New England portion could potentially disrupt connectivity in the very short term. However, the SRT noted that, straying rates would allow for recolonization of the rivers in the foreseeable future and therefore maintain overall spatial diversity. Populations from the north (Bb-Canada/Northern New England DPS) and south (Bb-Mid-Atlantic DPS) contain hundreds of thousands of blueback herring and would likely be the first recolonizers of this 311 km (193 mi) stretch of coastline.

If the Bb-Mid-New England portion was lost, blueback herring rangewide would lose one of five known regional stock complexes and potential genetic adaptation. However, four stock complexes would remain providing genetic diversity to the species as whole. Further, there is no evidence to indicate that the loss of genetic diversity from the Bb-Mid-New England stock complex would result in the remaining populations lacking enough genetic diversity to allow for adaptations to changing environmental conditions. In considering this portion of the range, the SRT was unaware of any particular habitat types that the species occupies that are found only in the Bb-Mid-New England portion (see **5.2.2 Distinct Population Segment**, significance discussion). In conclusion, the SRT determined that the the Bb-Mid-New England stock is not a significant portion of the range because the loss of the members in the portion would not render the species in danger of extinction, nor make the species likely to become so in the foreseeable future.

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