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AKRF REPORT

Update of Aquatic Impact Analyses Presented in NRC's FSEIS (December 2010) Regarding Potential Impacts of Operation of Indian Point Units 2 and 3

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 & 3
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Update of Aquatic Impact Analyses
Presented in NRC's FSEIS (December 2010)
Regarding Potential Impacts of
Operation of Indian Point Units 2 and 3

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Prepared for:

INDIAN POINT ENERGY CENTER
450 Broadway, Suite 1
Buchanan, NY 10511

Prepared by

AKRF, Inc.
7250 Parkway Drive, Suite 210
Hanover, MD 21076

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I. Introduction and Overview

A. Background

In December 2010, the Nuclear Regulatory Commission ("NRC") issued the "Generic Environmental Impact Statement for License Renewal of Nuclear Plants Supplement 38 Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3 Final Report. NUREG-1437" ("FSEIS"). The FSEIS included a chapter entitled "Environmental Impacts of Operation" which described an assessment of potential impacts of entrainment and impingement at Indian Point Units 2 and 3 ("IP2 and IP3") on fish populations in the Hudson River. That impact assessment was based on two sets of analyses: 1) an assessment of trends in young of year ("YOY") fish populations, and 2) and assessment of what NRC referred to as strength of connection ("SOC"). Both assessments were conducted using data provided to NRC by Entergy, which operates IP2 and IP3.

NRC's trends assessment had two components: 1) riverwide trends in fish abundance, and 2) trends in fish abundance in the sampling region adjacent to IP2 and IP3 (referred to as River Segment 4). For both components, NRC calculated indices of abundance using Entergy provided data from three Hudson River fish sampling programs: 1) Long River Survey ("LRL") which collected data on eggs, larvae and juvenile fish, 2) Fall Shoals Survey ("FSS") which collected data on juvenile and older fish, and 3) Beach Seine Survey ("BSS") which collected data on juvenile and older fish. Separate indices of abundance were calculated for each species addressed by the assessment.

NRC's indices of abundance for the riverwide trends assessment were estimates of catch per unit effort ("CPUE"), i.e., the number of fish collected divided by the number of samples taken. In addition, NRC used a riverwide index of abundance from annual reports prepared by electric utility companies that operate power plants on the Hudson River and fund and manage the LRS, FSS and BSS sampling programs. For the River Segment 4 indices of abundance, NRC calculated estimates of CPUE and estimates of density, i.e. the number of fish collected divided by the volume of water sampled.

NRC's SOC assessment used estimates of density from River Segment 4 from the BSS and FSS to characterize long-term linear trends in abundance and interannual variability in abundance. That information was coupled with NRC's estimates of entrainment and impingement mortality rates. NRC's estimates of entrainment and impingement mortality rates were based on annual estimates of total number of organisms entrained (1981-1987) and impinged (1984-1990) and estimates of the abundance of entrainable organisms within River Segment 4 from the LRS.

B. Inter-annual Changes in LRS, FSS and BSS Sampling Designs

The data on fish population abundance in the Hudson River that Entergy provided to NRC in 2007 and that NRC used for the FSEIS were collected from the 27 year period 1979 through 2005. Over that period of years, the data were affected by inter-annual changes in sampling designs. Major changes in sampling designs included: 1) different sets of weeks of sampling in each year and sampling program, and 2) a change in the sampling gear used by the Fall Shoals Survey to sample the bottom stratum of the Hudson River. That gear change, from an epibenthic sled to a beam trawl, occurred in 1985.

The BSS sampling design saw a dramatic change in 1981 when the number of weeks of sampling was greatly curtailed (Figure 1). The number of weeks of sampling more than doubled by the late 1980's and then remained the same. Starting in 1998, sampling by the FSS beam trawl (which began in 1985) expanded to include the late fall (Figure 2). Like the BSS, weeks of sampling by the FSS epibenthic sled (which was terminated in 1984) were curtailed in 1981 (Figure 3). The weeks of sampling by the FSS tucker trawl have been fairly consistent although fewer weeks were sampled in the early 1980's (Figure 4). Starting in 1991, the LRS increased the weeks of sampling to include much of the fall (Figures 5 and 6).

C. Potential Confounding Effects of Sampling Design Changes

Because the presence of early life stages of fish in the Hudson River is seasonal, changes in the weeks of sampling can introduce confounding effects to fish abundance data. For example, consider the hypothetical scenario of a species of fish whose larvae are only present in May of each year. If sampling only occurred during May, then an estimate of CPUE computed as the total number of those larvae collected divided by the total number of samples taken would be a valid index of abundance. Now consider the effect of doubling the sampling effort in the later years of the sampling program by extending the period of sampling to also include June (when the larvae are no longer present). Estimates of CPUE, computed as the total number of those larvae divided by the total number of samples taken, for the later years would not be comparable to the estimates of CPUE from the earlier years of the program. Even if the abundance of larvae did not change, it would appear as if the abundance had declined to half because the estimates of CPUE in the later years would be half the estimates from the earlier years.

Included in the data files provide to NRC by Entergy were data files that contained total counts of each species of fish (over all life stages) collected by each sampling program per year over *all* weeks of sampling. One data file of this type was provided for each of three sampling programs: LRS, FSS and BSS. An accompanying file for each sampling program was provided that listed the total number of samples collected by each program in each year. Those data files apparently were used by NRC to compute annual riverwide catch per unit of effort ("CPUE") indices of abundance.

For each sampling program, species and year, NRC apparently divided the total number of fish collected by the number of samples collected to compute an annual CPUE index of abundance. For the reasons discussed above, the historical changes in the weeks of sampling that occurred in the LRS, FSS and BSS appear to have introduced non-trivial confounding effects into NRC's CPUE indices of riverwide abundance.

For the River Segment 4 trends analyses, NRC apparently used a more detailed set of data files provided by Entergy that listed fish density by lifestage and week. For the River Segment 4 trends analyses, NRC subset the data to include a more consistent set of weeks in all years, and only included YOY fish (Table 1). Therefore, the River Segment 4 trends analyses likely were not as confounded by the changes in weeks sampled in each year or by changes in lifestage composition among years.

As previously provided in comments to NRC, the change in FSS sampling gear in 1985 appears to have also introduced non-trivial confounding effects to the FSEIS trends and SOC assessments. The gear change was substantial from the epibenthic sled with a 1 m^2 mouth opening and 3 mm mesh collection net to the beam trawl with a 2.7 m^2 mouth opening and 1.3 cm mesh collection net. The use of catch data from survey nets to address trends depends on the assumption of constant collection efficiency over all years of the survey. Collection efficiency can be thought of as the ratio of the average number of fish collected in a single sample to the underlying abundance of those fish in the portion of the river subject to sampling. For some species, like bay anchovy, the increase in mesh size of the beam trawl allowed YOY fish, which would have been retained by the smaller mesh of the epibenthic sled, to pass through the beam trawl net. Accordingly, for bay anchovy the collection efficiency of the beam trawl was lower than the collection efficiency of the epibenthic sled. Similarly, for species like striped bass, the smaller epibenthic sled appeared to be more easily avoided than the larger beam trawl. Under those circumstances the beam trawl would have a higher collection efficiency than the epibenthic sled.

D. Newly Available Data

As noted above, the data that Entergy provided and NRC used for the FSEIS were collected from the 27 year period of years 1979 through 2005. Since the time Entergy provided those data, the Hudson River Biological Monitoring Program has been continued, with fish data collected through the LRS, BSS and FSS. Data from those programs have been published in the annual series of reports titled, "Year Class Report for the Hudson River Estuary Monitoring Program" ("YCR"). Accordingly, data from the LRS, BSS and FSS now are available for the 27 year period 1985 through 2011. During this 27 year period of years, there were no gear changes in any of the sampling programs, thus eliminating this confounding effect and bringing the data current. Other regulators also have performed analyses, which allow the dataset, if brought current, to be more readily compared to these regulatory findings.

E. Analysis Update

This report describes an update to the trends and SOC analyses presented in the FSEIS. This update of the FSEIS analyses used the LRS, BSS and FSS data from 1985 through 2011. For this analysis update, the data were subset in every year to include only a consistent set of weeks for each sampling program (Table 2). Furthermore, the data used for the trends analyses were subset to include only YOY fish. These steps removed the confounding effects on riverwide CPUE indices of abundance due to changes in the weeks sampled in each year and due to the inclusion of all life stages collected. In addition, this analysis update avoids the confounding effects of the FSS gear change that occurred in 1985.

F. Conclusions

In comparison to the conclusions reported in the FSEIS, results from the updated analyses changed the impact conclusions for seven (7) of the 18 aquatic species evaluated in the FSEIS:

- Alewife changed from Moderate to Small
- Blueback Herring changed from Large to Small
- Hogchoker changed from Large to Moderate
- Rainbow Smelt changed from Moderate-Large to Moderate
- Striped Bass changed from Small to Moderate
- Weakfish changed from Moderate to Small
- White Perch changed from Large to Small

These changes in impact conclusions were due to a combination of changes in the results from the trends analyses and from the SOC analyses. The results from both sets of updated analyses were free from confounding effects due to inter-annual changes in the weeks of sampling by the LRS, BSS and FSS. The results from the updated analyses are also free from confounding effects of the FSS gear change that occurred in 1985. Also, results from the updated riverwide trends analyses were not affected by interannual changes in lifestage composition. The impact conclusion change for rainbow smelt is due to newly available information on the range contraction of rainbow smelt on the Atlantic coast.

II. Analysis Update Methods

A. Trends Analysis Methods

The updated trends analyses were conducted according to the methods described in section I.2.1 of Appendix I of the FSEIS (pages I-2 through I-50). Because the update is based on data from the 27-year period 1985-2011, analysis steps that NRC used to address the FSS gear change that occurred in 1985 did not have to be conducted. Steps described on the following pages of Appendix I were not performed:

1. pages I-9 through I-14: River Segment 4 trends in FSS density
2. pages I-23 through I-26: River Segment 4 trends in FSS CPUE
3. pages I-34 through I-37: Riverwide trends in FSS CPUE.

Not having to address the issue of the FSS gear change in 1985 greatly simplified the trends analyses and materially reduced the uncertainty in the results of the trends analyses.

B. SOC Analysis Methods

The updated SOC analyses were conducted according to the methods described in section I.2.2 of Appendix I of the FSEIS (pages I-50 through I-63). In the FSEIS, the coefficient of variation required for the SOC analyses was calculated from the first 12 years of data used in the FSEIS analyses, i.e., 1979-1990 (FSEIS Table I-46). For the updated analyses, the coefficient of variation was calculated from the first 12 years of data used in the updated analyses, i.e., 1985-1996. The species-specific entrainment mortality rates ("EMR") and impingement mortality rates ("IMR") used in the FSEIS SOC analyses were also used for the updated SOC analyses. For spottail shiner, the EMR estimate used for the update was taken from NRC's June 2012 "NUREG-1437, Supplement 38, Volume 4, draft supplement to final - Draft Report for Comment".

As described below, some minor changes to the methods as documented were made for the analysis update to account for apparent typographical errors in the FSEIS.

1. Apparent Typographical Errors in FSEIS

Equation (2) on page I-51 of the FSEIS indicates that the entrainment mortality rate (*EMR*) only affects the initial number of fish (N_0), and that the impingement mortality rate (*IMR*) only affects the slope parameter (r):

$$N_0^* = N_0(1 + EMR) \quad \text{and} \quad r^* = r_{UCL}(1 - IMR)/\max(1, CV)) \qquad (2)$$

"where *EMR* and *IMR* are conditional mortality rates for entrainment and impingement; r_{UCL} is the upper 95 percent confidence limit of the linear slope; and *CV* is the coefficient of variation of the annual 75th percentiles from the weekly catch density."

Because the FSEIS SOC analysis was intended to address entrainment and impingement, it appears that the omission of *IMR* from the definition of N_0^*, and the omission of *EMR* from the definition of r^* were typographical errors. Therefore, for the analysis update, equation (2) was revised so that both the entrainment mortality rate and the impingement mortality rate affected the initial number of fish and the slope parameter:

$$N_0^* = N_0(1 + EMR + IMR) \quad \text{and} \quad r^* = r_{UCL}(1 - EMR - IMR) / \max(1, CV)) \qquad (3)$$

Table I-46 in the FSEIS lists values for the "Upper 95% Confidence Limit of the Slope" that were used with equation (2). As shown below, the values in the column labeled "Upper 95% Confidence Limit of the Slope" apparently were mislabeled. Rather than the upper 95% confidence limits they are the slope estimates plus one standard error.

The "Linear Slope (r)" and "Upper 95% Confidence Limit of the Slope" entries in Table I-46 were taken from Table I-9 (for FSS) and Table I-12 (for BSS) of the FSEIS. For each species, the entry in the column labeled "Upper 95% Confidence Limit of the Slope" in Table I-46 is the corresponding linear regression slope estimate from Table I-9 or I-12 plus the undefined value to the right of the ± symbol in the linear regression slope column of the table. It can be shown from the "p-value", also listed in Tables I-9 and I-12, that the undefined value to the right of the ± symbol is the standard error of the linear slope estimate (Appendix A).

Therefore, the entries listed in Table I-46 are, if fact, the slopes plus one standard error. If those entries had been upper 95% confidence limits, they would have been approximately equal to the slopes plus two standard errors.

Based on the values listed in Table I-46, it appears that the SOC analyses presented in the FSEIS were conducted with r_{UCL} in equation (2) set equal to the estimated slope plus the standard error of the slope. Accordingly, to be consistent with the SOC analyses presented in the FSEIS, the value of r_{UCL} in equation (2) was set to the estimated slope plus the standard error of the slope for this analysis update.

C. Independent Quality Control Review

The updated analyses were conducted using data analysis programs written with SAS® computer software, and all data inputs were in SAS® format data files. The full set of computer programs and input data files used for the updated analyses were submitted to John Young, PhD of ASA Analysis & Communication, Inc. for a thorough quality control review. The purpose of the review was to determine whether the computer code was correctly written to accurately conduct the analyses documented in the FSEIS. Dr. Young has decades of experience working with data files from the Hudson River Biological Monitoring Program. Dr. Young's independent review of the computer programs and input data files used for the updated analyses confirmed the computer programs accurately reflected the analysis methods documented in the FSEIS and identified no computer programming errors (see Appendix B).

III. Results

A. Updated Trends Analyses

Following the trends analysis methods documented in the FSEIS, a total of nine sets of trends analyses were conducted: three for River Segment 4 density (FSS, BSS and LRS), two for River Segment 4 CPUE (FSS and LRS), three for riverwide CPUE (FSS, BSS and LRS), and one for the YCR abundance indices. Each set of trends analyses included analyses conducted using linear regression and analyses using segmented regression. For each species, one type of regression was selected using the decision rules documented in the FSEIS. Based on the results of the selected type of regression analysis, each species was assigned a trend score of either 1 (i.e., no decline detected) or 4 (i.e., decline detected).

For River Segment 4 trends, comparisons of results from the two types of regressions are summarized in the following tables:

- FSS Density (Table 3)
- BSS Density (Table 5)
- LRS Density (Table 7)
- FSS CPUE (Table 9)
- LRS CPUE (Table 11)

The corresponding trend conclusions (i.e., score of 1 or 4) for these five sets of analyses are summarized in the following tables:

- FSS Density (Table 4)
- BSS Density (Table 6)
- LRS Density (Table 8)
- FSS CPUE (Table 10)
- LRS CPUE (Table 12)

The River Segment 4 trends conclusions, based on the average score from the five sets of analyses are listed in Table 13.

For riverwide trends, comparisons of results from the two types of regressions are summarized in the following tables:

- FSS CPUE (Table 14)
- BSS CPUE (Table 16)
- LRS CPUE (Table 18)
- YCR Abundance Index (Table 20)

The corresponding trend conclusions (i.e., score of 1 or 4) for these four sets of analyses are summarized in the following tables:

- FSS CPUE (Table 15)
- BSS CPUE (Table 17)
- LRS CPUE (Table 19)
- YCR Abundance Index (Table 21)

The riverwide trends conclusions, based on the average score from the four sets of analyses are listed in Table 22.

The overall trends conclusions, which were based on weighted averages of the River Segment 4 scores and riverwide scores, are summarized in Table 23. In comparison to the conclusions reported in the FSEIS, results from the updated analyses changed the trends conclusions for 8 of the 13 species analyzed in the FSEIS:

- Alewife changed from Variable to Undetected Decline
- Bluefish changed from Detected Decline to Undetected Decline
- Hogchoker changed from Detected Decline to Variable
- Spottail Shiner changed from Detected Decline to Undetected Decline
- Striped Bass changed from Undetected Decline to Variable
- Weakfish changed from Variable to Undetected Decline
- White Catfish changed from Variable to Undetected Decline
- White Perch changed from Detected Decline to Undetected Decline

B. Updated SOC Analyses

Parameter values used in the updated SOC analyses are listed in Table 24. All parameter values except EMR and IMR (which remain the values that were used in the FSEIS) were computed using the same data files used for the updated trends analyses.

Results from the SOC Monte Carlo analyses, and corresponding SOC conclusions, are summarized in Table 25. In comparison to the conclusions reported in the FSEIS, results from the updated analyses changed the SOC conclusions for 3 of the 13 species analyzed in the FSEIS:

- Alewife changed from High to Low
- Blueback Herring changed from High to Low
- White Perch changed from High to Low

C. Updated Impact Conclusions

The overall impact conclusions based on the updated analyses (Table 26) were determined by combining the trends conclusions and SOC conclusions as described in Appendix H of the FSEIS. In comparison to the conclusions reported in the FSEIS, results from the updated analyses changed the subsidiary impact conclusions for 7 of the 18 species analyzed in the FSEIS:

- Alewife changed from Moderate to Small
- Blueback Herring changed from Large to Small
- Hogchoker changed from Large to Moderate
- Rainbow Smelt changed from Moderate-Large to Moderate
- Striped Bass changed from Small to Moderate
- Weakfish changed from Moderate to Small
- White Perch changed from Large to Small

The change for rainbow smelt was due to newly available information on the range contraction of Atlantic coast rainbow smelt (see Discussion section, below).

IV. Discussion

A. NRC's Precautionary Methodology

The methods applied by NRC to assess the magnitude of potential aquatic impacts due to the operation of IP2 and IP3 are highly conservative in that they include several components that tend to lead to conclusions of "Large" impacts. As discussed below, both the trends in YOY abundance analyses and the SOC analyses contain such components.

1. SOC Methods

NRC's SOC analyses are based on the comparison of the magnitude of entrainment (and impingement) mortality rates to the magnitude of interannual variability in YOY abundance. For the purpose of the SOC analyses, NRC defined the magnitude of entrainment mortality as the difference between: 1) projected population abundance with entrainment and 2) projected population abundance without entrainment.

Key among the conservative components of the SOC analyses are:

1. Estimates of entrainment mortality rates were based on total annual entrainment in comparison to the number of entrainable organisms found in sampling River Segment 4 only, rather than to the entire Hudson River population. Because most entrainable organisms found in sampling River Segment 4 are transient, moving with tidal currents into and out of sampling River Segment 4, the number of fish in River Segment 4 severely underestimated the total number of fish from which those entrained were drawn. Therefore, entrainment mortality rates were overstated.

2. Projected abundance in the absence of entrainment was based on the upper confidence limit of the estimated historical trend in abundance; whereas, projected abundance with entrainment was based on the estimated trend itself. Therefore, even in the absence of entrainment, the method would show a purported reduction in abundance due to entrainment.

2. Trends Analysis Methods

The methods applied by NRC to assess trends in abundance also contained conservative components. For each species, the trends assessment included a linear regression analysis and segmented regression analysis. If the residual error from the segmented regression was lower than the residual error from the linear regression analysis, NRC selected the segmented regression analysis for the trends assessment. Because the segmented regression included four parameters (compared to two parameters for the linear regression) it was able to fit the data more closely and therefore was often selected over the linear regression.

The segmented regression analysis resulted in two connected line segments being fit to the data, each with an estimated duration, and each with an estimated slope. If either slope was negative (and statistically significant) NRC's method was to conclude a detected decline in abundance, regardless of the duration. For example, a short-term decline followed by a long term increase would be recorded as a detected decline.

3. Conservative Results

For the reasons discussed above, the results from analyses conducted using NRC's methods can be viewed as being highly conservative. Therefore, even allowing for inherent uncertainties, the results from the updated analyses support the conclusion that the continued operation of IP2 and IP3 will not pose any meaningful risks of adverse impacts to fish populations in the Hudson River.

B. FSS Gear Change

As noted above, in addition to using datasets with a consistent set of weeks of sampling in all years, this analysis update also used data from the 27-year period 1985-2011, whereas the FSEIS used data from the 27-year period 1979-2005. Data from the period 1985-2011 do not suffer from the potential confounding effects of the FSS gear change in 1985, which may be substantial. The FSS gear for sampling the bottom stratum changed from the epibenthic sled with a 1 m^2 mouth opening and 3 mm mesh collection net to the beam trawl with a 2.7 m^2 mouth opening and 1.3 cm mesh collection net (i.e., 13 mm mesh). Those changes in gear specifications materially altered the collection efficiency of samples from the FSS, which necessarily affected estimates of CPUE and density.

In 1984, a gear comparison study was conducted that deployed over 250 paired epibenthic sled and beam trawl samples in the Tappan Zee, Croton-Haverstraw, and Indian Point regions of the Hudson River, during four alternate weeks of sampling in August and September (Normandeau Associates, Inc. 1986). Density estimates for striped bass young of the year ("YOY") were 4 times higher for the beam trawl than for the epibenthic sled, and the density estimates for YOY striped bass were higher for the beam trawl in all four weeks sampled. Density estimates for bay anchovy YOY were 46 times higher for the epibenthic sled, and the density estimates for YOY bay anchovy were higher for the epibenthic sled in all four weeks sampled. Comparisons for other species were not presented in the report.

The 1984 gear comparison study clearly demonstrated that the beam trawl and epibenthic sled had materially different collection efficiencies, and that the differences were species-specific. For that reason, data collected by the two gear types are not directly comparable and cannot be used together in a valid trends assessment without accounting for the species-specific differences in collection efficiencies.

NRC addressed the FSS gear change by conducting a series of statistical analysis that compared FSS densities to BSS densities before and after 1985, and FSS CPUE to BSS CPUE before and after 1985. Based on those analyses of densities in River Segment 4, NRC concluded that for the 12 species considered, the gear change only caused a biological difference to bay anchovy. For CPUE in River Segment 4, NRC concluded that for the 11 species considered, the gear change only caused a biological difference to bay anchovy and blueback herring. For riverwide CPUE, NRC concluded that for the 10 species considered, the gear change caused a biological difference to alewife, American shad, bay anchovy, blueback herring, and bluefish.

For these 8 out of 33 combinations of species and abundance indices, NRC conducted separate trends analyses for the period of year 1979-1984 and the period of years 1985-2005. For all other combinations of species (including striped bass) and abundance indices, NRC made no adjustments for the gear change. Furthermore, for the trends component of the SOC analyses (based on density estimates in River Segment 4), no adjustments for the gear change were made for any species.

Although NRC made efforts to address the FSS gear change, the results presented in the FSEIS still contain uncertainties due to the FSS gear change that occurred in 1985. Because the updated analyses were based on a 27 years of data that were not affected by any gear changes, the results from the updated analyses do not contain that layer of uncertainty.

C. Summary of Changes in Impact Conclusions

As noted above, impact conclusions from the updated analyses differed from the impact conclusions from the FSEIS for seven species: alewife, blueback herring, hogchoker, rainbow smelt, striped bass, weakfish and white perch. Each change is discussed below.

1. Hogchoker, Weakfish and White Perch

For three of these seven species the change was to a lower potential impact level due to revised trends conclusions:

Species	FSEIS Trends Conclusion	Updated Analyses Trends Conclusion
Hogchoker	Detected Decline	Variable
Weakfish	Variable	Undetected Decline
White Perch	Detected Decline	Undetected Decline

These changes in the trends conclusions were largely due to changes in Riverwide Assessment Scores:

Species	Riverwide Assessment Score		River Segment 4 Assessment Score	
	FSEIS (Table H-15)	Updated Analyses (Table 23)	FSEIS (Table H-15)	Updated Analyses (Table 23)
Hogchoker	3.0	1.0	4.0	4.0
Weakfish	2.5	1.0	2.5	2.5
White Perch	4.0	1.0	3.0	2.0

This pattern of changes is consistent with the expected confounding effects of the inadvertent inclusion of all weeks of sampling in the FSEIS Riverwide Assessment.

2. Striped Bass

For Striped Bass, the change in impact conclusion was to a higher level of potential impact (i.e., "Small" to "Variable"). This change was due to changes in both the Riverwide and River Segment 4 Assessments:

Species	Riverwide Assessment Score		River Segment 4 Assessment Score	
	FSEIS (Table H-15)	Updated Analyses (Table 23)	FSEIS (Table H-15)	Updated Analyses (Table 23)
Striped Bass	1.0	2.0	1.0	3.0

Because the updated analyses were based on a more recent period of years than the FSEIS analyses, these changes in trend scores reflect the recent decline in striped bass stock abundance that followed a period of abundance increases. Beginning in the mid-1980's the Atlantic coast striped bass stock experienced a surge in abundance in response to reduced fishing pressure due to a coastwide fishing moratorium on striped bass. After the moratorium was lifted in 1990, the stock continued to increase in abundance through the late 1990's after which it began to decline (Atlantic States Marine Fisheries Commission, 2013).

3. Alewife and Blueback Herring

For alewife and blueback herring, the change in impact conclusion from "Large" to "Small" is due to the change in the SOC conclusion from "High" (from the FSEIS) to "Low". The "Low" SOC conclusion from the updated analyses for alewife and blueback herring is consistent with the historical distribution patterns of entrainable life stages of river herring (i.e., collectively alewife and blueback herring). The vast majority of entrainable lifestages of river herring inhabit portions of the Hudson River that are far upstream of IP2 and IP3 (Figure 7). The documented distribution patterns of entrainable lifestages of river herring in the Hudson River, in comparison to the location of IP2 and IP3, are consistent with the "Low" SOC conclusion from the updated analyses.

The recent conclusion of the New York State Department of Environmental Conservation ("NYSDEC") that recruitment of river herring is variable but stable, despite the upsurge in the use of river herring as bait for striped bass (NYSDEC, 2011) is consistent with a finding of "Small" potential impacts as well. NYSDEC proposed to maintain the Hudson River and tributaries as a restricted river herring fishery because, under current conditions (including the operation of IP2 and IP3) the fishery was "sustainable" and would "not diminish potential future reproduction and recruitment of herring stocks." NYSDEC also noted that since the mid-1990's there has been an increasing trend in YOY alewife abundance.

• In addition, in the National Marine Fishery Service ("NMFS") decision not to list blueback herring as threatened or endangered (Fed. Reg. Vol. 78, No. 155. August 12, 2013), NMFS concluded that water withdrawals and outfalls (including pumped storage, irrigation, thermal discharges, industrial pollutants and atmospheric deposition) collectively posed only a "medium low" threat to blueback herring. The number one threat was listed as "dams and other barriers". Behind that, "climate change," "water quality (chemical)", "incidental catch", and "predation", ranked as medium threats. The NMFS's findings are consistent with the change in impact conclusion for blueback herring of "Large" to "Small" for IP2 and IP3.

4. Rainbow Smelt

For Rainbow Smelt, NRC modified the conclusion of a "Moderate" impact, that was determined using the impact assessment methodology of the FSEIS, to a conclusion of "Moderate to Large":

> "Although detectable population declines occurred in two of four river data sets, indicating population trend results were variable, the staff concluded that a MODERATE to LARGE, rather than just MODERATE, impact was present based on the dramatic population declines observed for this species over the past three decades." (FSEIS Section 4.1.3.3, page 4-24)

This position regarding rainbow smelt is not supported by recent evidence regarding large-scale changes in the distribution of rainbow smelt. The decline in abundance of rainbow smelt in the Hudson River has been due to a coastwide contraction of the range of rainbow smelt on the Atlantic coast. Several decades ago, rainbow smelt populations were found as far south as Chesapeake Bay. Now their range only includes waters north of Long Island Sound (Enterline and Chase, 2012; National Oceanic and Atmospheric Administration, 2010).

The decline in rainbow smelt abundance in the Hudson River occurred simultaneously with the decline in abundance in coastal streams in Connecticut, which supports the conclusion that the decline was not due to the operation of IP2 and IP3. Because rainbow smelt is a cold water species, the cause of its range contraction may be related to global warming.

> "The Hudson River population of rainbow smelt is at the southern extreme of the reproductive range (Lee et al. 1980), although historically it occurred farther south (Smith 1985). The abrupt decline in rainbow smelt early life stages in the ichthyoplankton may result from global warming. Ashizawa and Cole (1994) documented the trend of slowly increasing water temperature in the Hudson River. The rainbow smelt runs in the coastal streams of western Connecticut have drastically declined or disappeared simultaneously with the decline in the Hudson River population (S. Gephard, Connecticut Department of Environmental Protection, personal communication)." (Daniels, et al, 2005)

For these reasons, the impact conclusion for rainbow smelt from the updated analyses was kept at "Moderate", based on the results from applying the trends analysis and SOC methodologies of the FSEIS to the updated input data files.

V. Literature Cited

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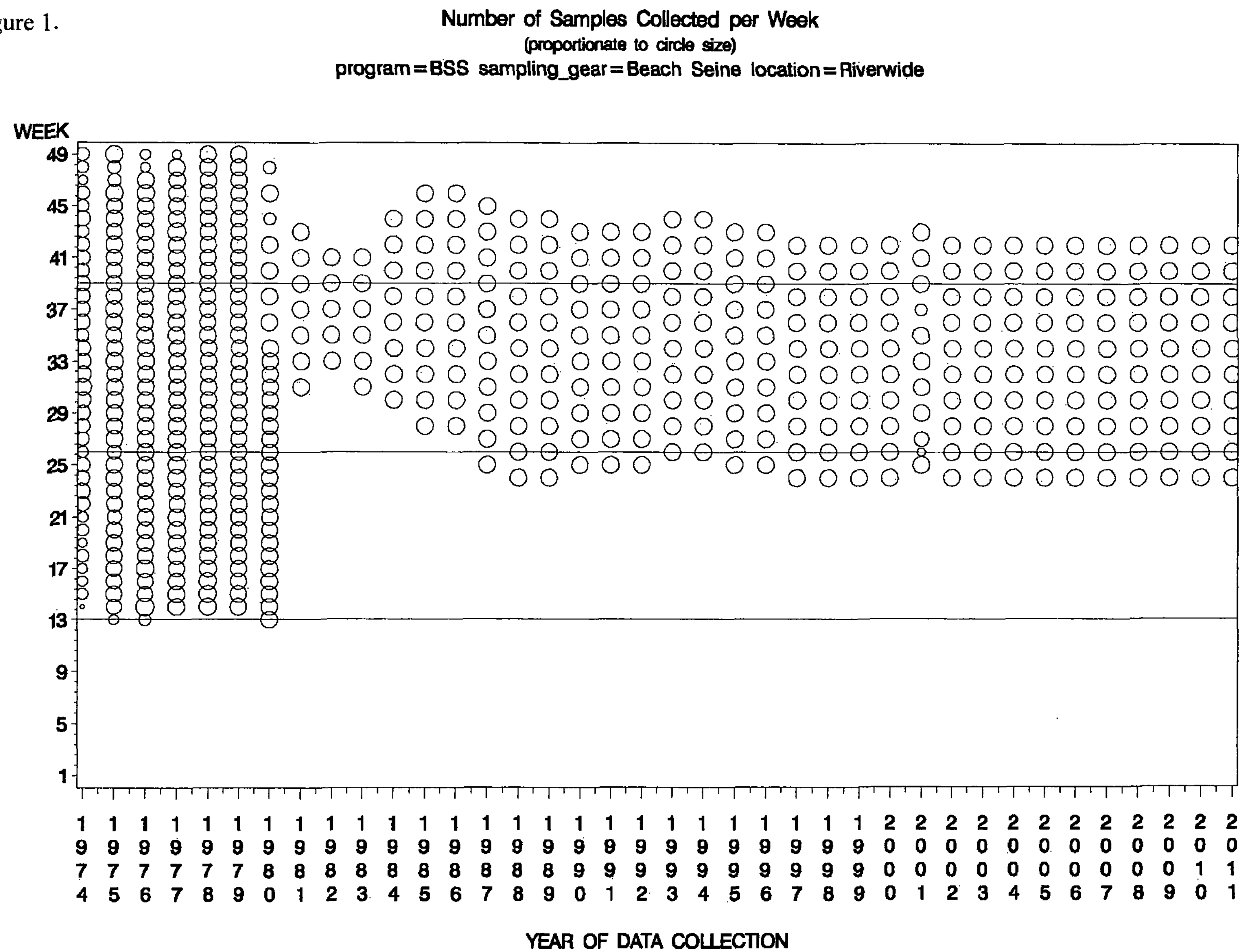
VI. Figures

Figure 1.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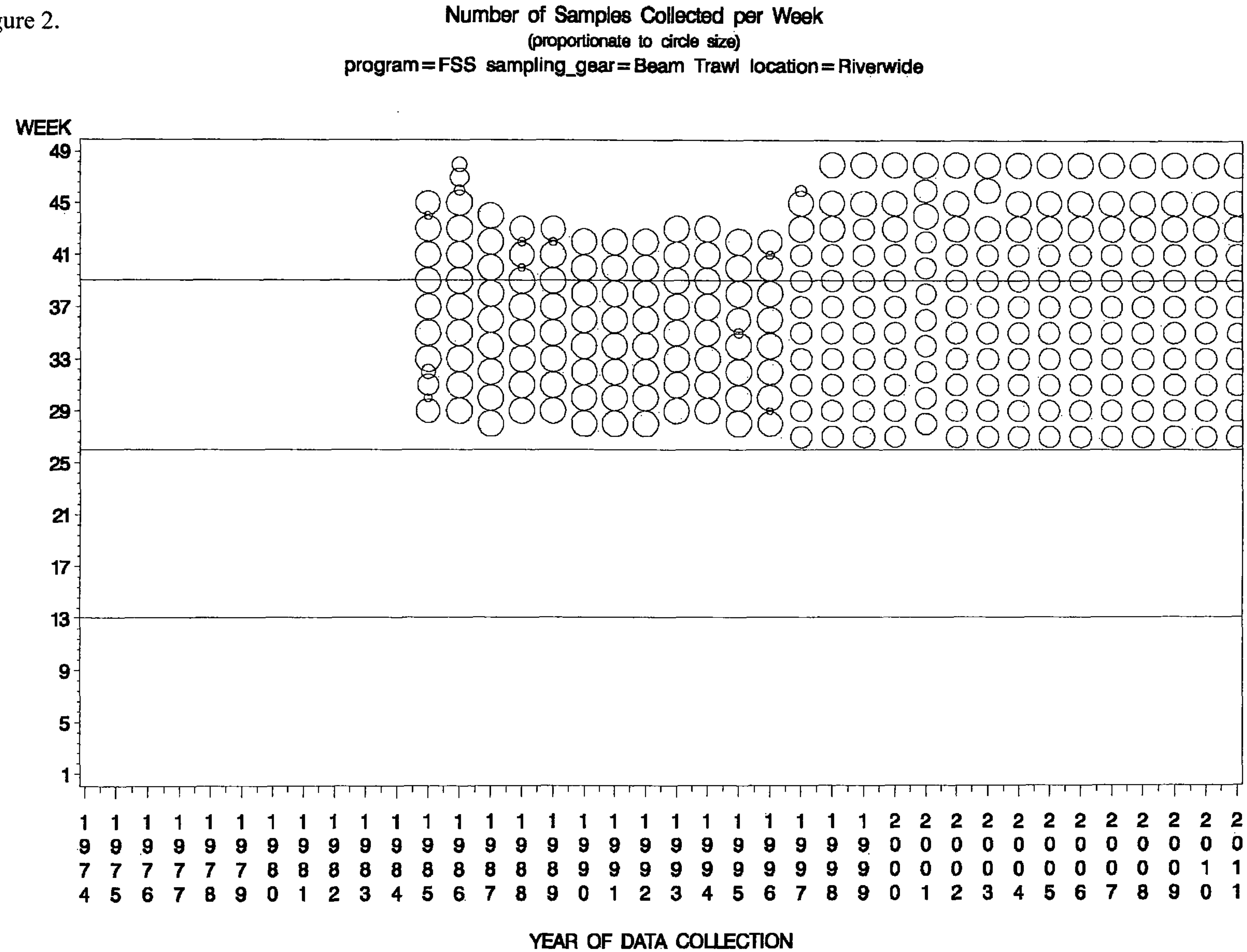
(proportionate to circle size)
program=BSS sampling_gear=Beach Seine location=Riverwide
WEEK
49
45
41
37
33
29
25
21
17
13
9
5
1
1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
YEAR OF DATA COLLECTION

Figure 2.



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(proportionate to circle size)
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WEEK
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45
41
37
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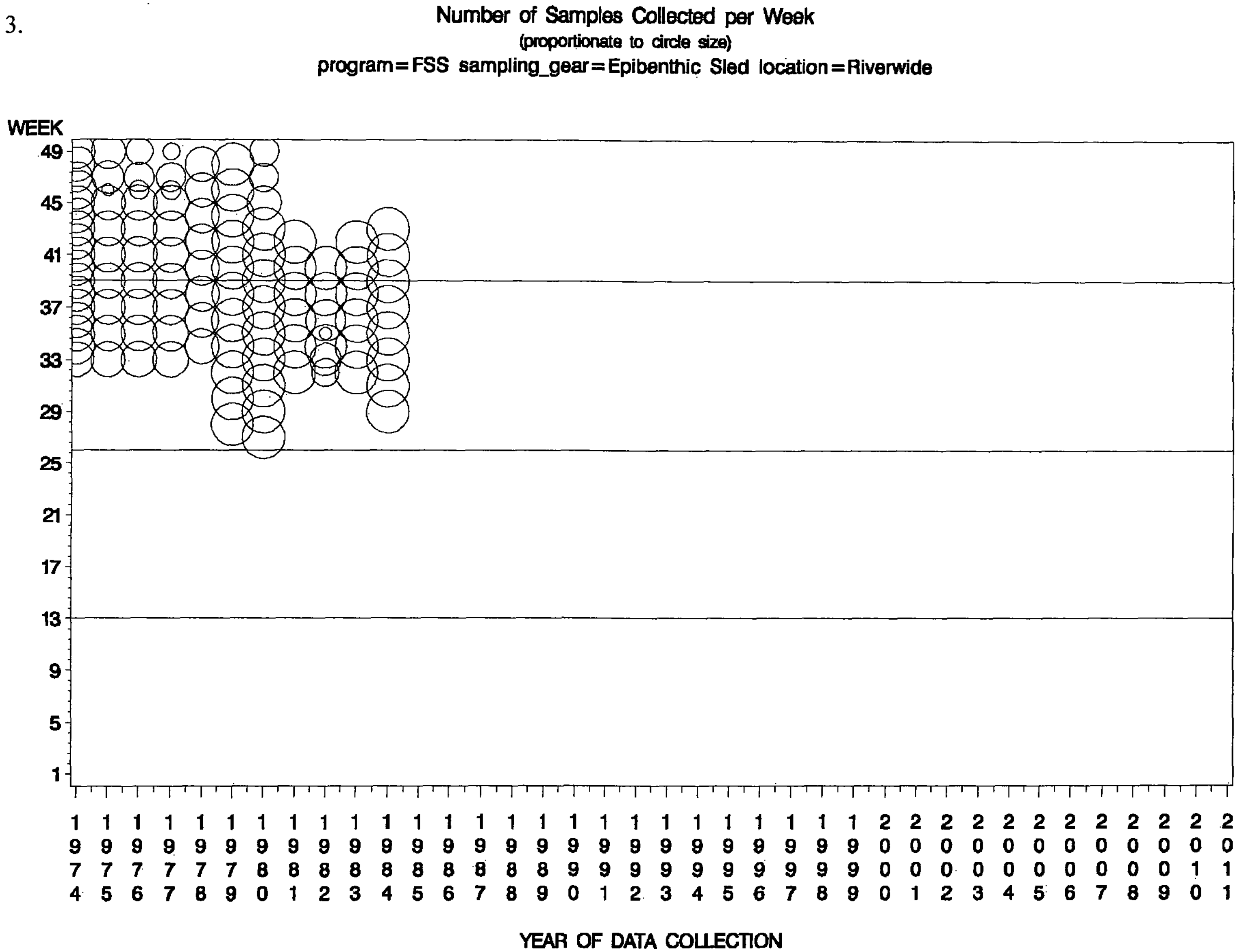
29
25
21
17
13
9
5
1
1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
YEAR OF DATA COLLECTION

Figure 3.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41
37
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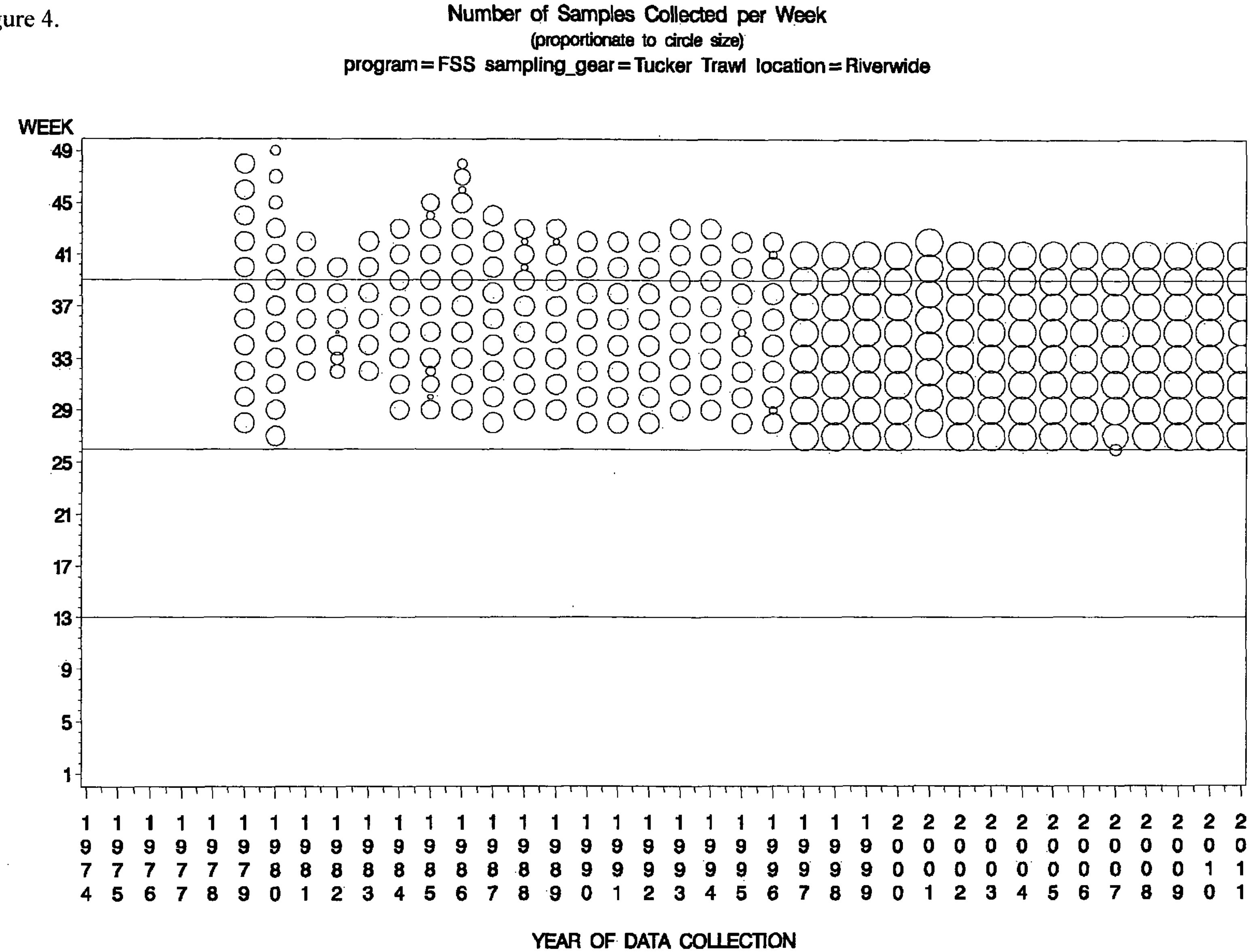
29
25
21
17
13
9
5
1
1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
YEAR OF DATA COLLECTION

Figure 4.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45
41
37
33
29
25
21
17
13
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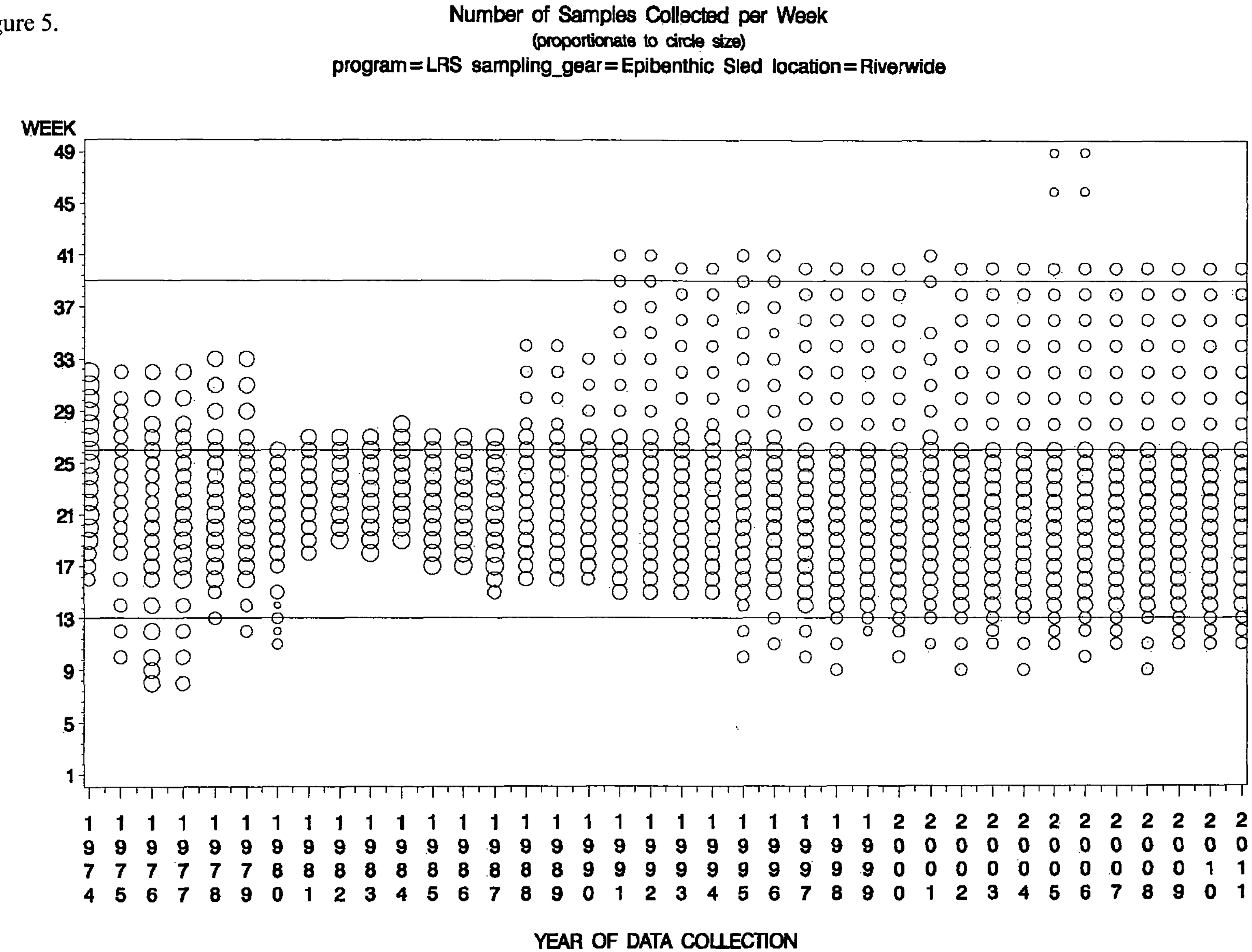
1
1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
YEAR OF DATA COLLECTION

Figure 5.



Number of Samples Collected per Week
(proportionate to circle size)
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WEEK
49
45
41
37
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25
21
17
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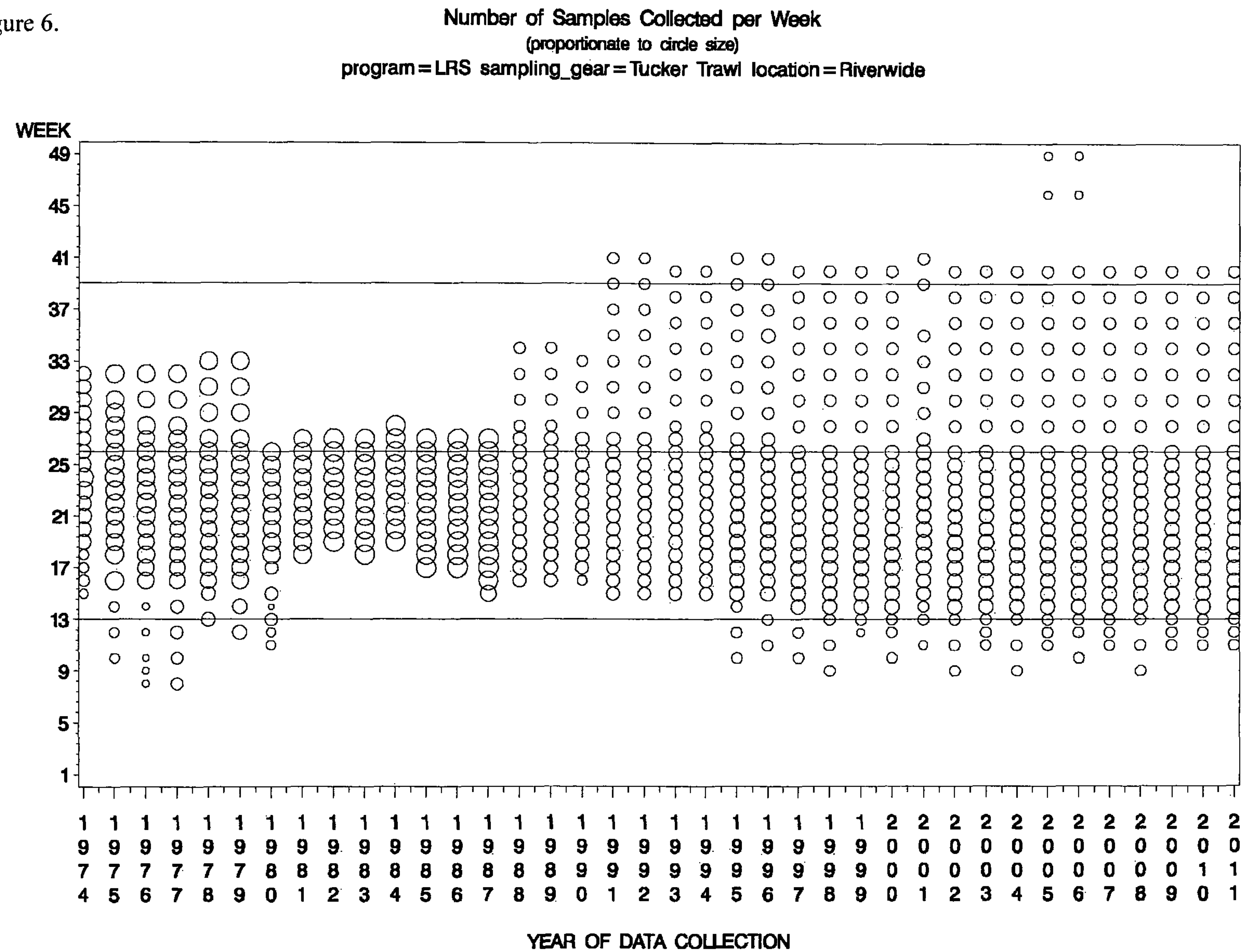
1
1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
YEAR OF DATA COLLECTION

Figure 6.



Number of Samples Collected per Week
(proportionate to circle size)
program=LRS sampling_gear=Tucker Trawl location=Riverwide
WEEK
49
45
41
37
33
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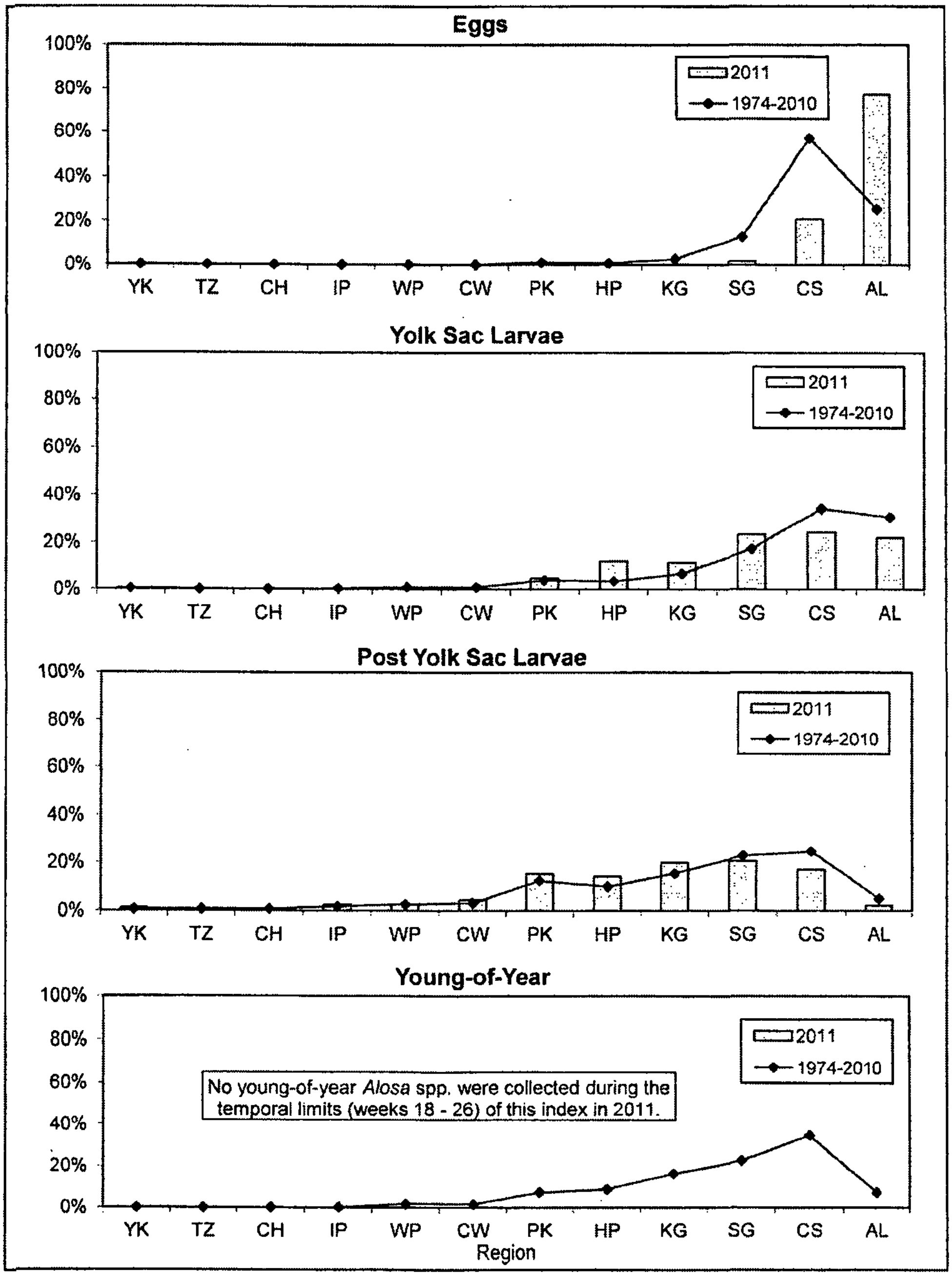
1
1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
YEAR OF DATA COLLECTION

Figure 7. Spatial distribution of early lifestages of river herring (Blueback herring and Alewife) in theHudson River based on LRS sampling (copy of Figure 4-46, 2011 Year Class Report for the Hudson River Estuary Monitoring Program).



VII. Tables

Table 1. Weeks, sampling gears and lifestages included in NRC FSEIS Trends Analyses (27 years: 1979-2005). Annual abundance indices confounded by inter-annual changes in sampling designs.

	River Segment 4 Density and CPUE			Riverwide CPUE		
	BSS	FSS	LRS	BSS	FSS	LRS
Lifestage	YOY	YOY	YOY	All	All	All
Weeks	22-43	27-43	20-40 *	All	All	All
Gears	Beach Seine	Tucker Trawl (1979-2005) Epibenthic Sled (1979-1984) Beam Trawl (1985-2005)	Tucker Trawl Epibenthic Sled	Beach Seine	Tucker Trawl (1979-2005) Epibenthic Sled (1979-1984) Beam Trawl (1985-2005)	Tucker Trawl Epibenthic Sled

* Inferred from FSEIS Atlantic Tomcod indices of abundance.

Table 2. Weeks, sampling gears and lifestages included in Trends Analyses Update (27 years: 1985-2011). Consistent set of sampling conditions among years.

	River Segment 4 Density and CPUE			RiverwideCPUE		
	BSS	FSS	LRS	BSS	FSS	LRS
Lifestage	YOY	YOY	YOY	YOY	YOY	YOY
Weeks	28-42	29-42	17-27	28-42	29-42	17-27
Gears	Beach Seine	Tucker Trawl Beam Trawl	Tucker Trawl Epibenthic Sled	Beach Seine	Tucker Trawl Beam Trawl	Tucker Trawl Epibenthic Sled

Table 3. Competing Models Used To Characterize the Standardized River Segment 4 FSS Population Trends of YOY Fish Density Using a 3-Year Moving Average (updated FSEIS Table I-9).

Species	Linear Regression				Segmented Regression					
	MSE	Slope	Std Err of Slope Estimate	p-value	MSE	Slope 1		Join Point	Slope 2	
						Lower 95% CL	Upper 95% CL		Lower 95% CL	Upper 95% CL
Alewife	0.877	-0.054	0.026	0.048	0.867	-0.827	1.912	1989	-0.135	-0.005
American Shad	0.232	-0.120	0.013	0.000	0.186	-2.198	0.339	1988	-0.139	-0.083
Atlantic Tomcod	0.678	-0.080	0.023	0.002	0.370	-1.075	-0.275	1991	-0.069	0.029
Bay Anchovy	0.601	-0.088	0.022	0.000	0.527	-1.453	2.818	1989	-0.158	-0.063
Blueback Herring	0.878	-0.054	0.026	0.048	0.081	-5.254	-3.578	1988	-0.027	0.010
Bluefish	0.925	-0.046	0.027	0.100	0.591	0.079	1.508	1990	-0.160	-0.044
Hogchoker	0.434	-0.104	0.018	0.000	Failed to Converge					
Rainbow Smelt	0.623	-0.086	0.022	0.001	0.535	-0.193	0.534	1992	-0.188	-0.060
Striped Bass	0.776	-0.069	0.024	0.010	0.684	-0.720	4.145	1988	-0.144	-0.036
Weakfish	0.811	-0.064	0.025	0.017	0.459	-0.030	0.157	2001	-0.408	-0.139
White Catfish	0.945	-0.042	0.027	0.136	0.967	-0.257	0.374	1995	-0.181	0.022
White Perch	0.838	-0.060	0.025	0.026	0.656	-0.542	-0.023	1995	-0.062	0.105

Table 4. River Segment 4 Assessment of the Level of Potential Negative Impact Based on the Standardized FSS Density Using a 3-Year Moving Average (updated FSEIS Table I-10).

Species	Best Fit	Slope from Linear Regression	Slope 1 from Segmented Regression	Slope 2 from Segmented Regression	Final Decision
Alewife	SR		S1=0	S2<0	4
American Shad	SR		S1=0	S2<0	4
Atlantic Tomcod	SR		S1<0	S2=0	4
Bay Anchovy	SR		S1=0	S2<0	4
Blueback Herring	SR		S1<0	S2=0	4
Bluefish	SR		S1>0	S2<0	4
Hogchoker	LR	S<0			4
Rainbow Smelt	SR		S1=0	S2<0	4
Striped Bass	SR		S1=0	S2<0	4
Weakfish	SR		S1=0	S2<0	4
White Catfish	LR	S=0			1
White Perch	SR		S1<0	S2=0	4

Table 5. Competing Models Used To Characterize the Standardized River Segment 4 BSS Population Trends of YOY Fish Density Using a 3-Year Moving Average (updated FSEIS Table I-12).

Species	Linear Regression				Segmented Regression					
	MSE	Slope	Std Err of Slope Estimate	p-value	MSE	Slope 1		Join Point	Slope 2	
						Lower 95% CL	Upper 95% CL		Lower 95% CL	Upper 95% CL
Alewife	0.725	0.075	0.024	0.004	0.698	-0.088	0.120	2002	-0.007	0.376
American Shad	0.235	-0.120	0.013	0.000	0.252	-0.149	-0.061	2005	-0.426	0.074
Bay Anchovy	0.844	0.059	0.025	0.029	Failed to Converge					
Blueback Herring	0.726	-0.075	0.024	0.004	0.665	-0.154	0.369	1994	-0.211	-0.043
Bluefish	1.034	0.013	0.028	0.646	0.915	-0.355	0.083	1997	-0.014	0.224
Hogchoker	0.776	0.069	0.024	0.010	0.331	-0.251	-0.023	1998	0.152	0.310
Spottail Shiner	0.989	-0.031	0.028	0.271	0.932	-0.556	2.283	1989	-0.123	0.012
Striped Bass	1.016	0.022	0.028	0.436	0.454	0.107	0.342	1999	-0.284	-0.076
White Perch	1.035	-0.012	0.028	0.663	0.873	-1.114	0.115	1991	-0.042	0.109

Table 6. River Segment 4 Assessment of the Level of Potential Negative Impact Based on the Standardized BSS Density Using a 3-Year Moving Average (updated FSEIS Table I-13).

Species	Best Fit	Slope from Linear Regression	Slope 1 from Segmented Regression	Slope 2 from Segmented Regression	Final Decision
Alewife	SR		S1=0	S2=0	1
American Shad	LR	S<0			4
Bay Anchovy	LR	S>0			1
Blueback Herring	SR		S1=0	S2<0	4
Bluefish	SR		S1=0	S2=0	1
Hogchoker	SR		S1<0	S2>0	4
Spottail Shiner	SR		S1=0	S2=0	1
Striped Bass	SR		S1>0	S2<0	4
White Perch	SR		S1=0	S2=0	1

Table 7. Competing Models Used To Characterize the Standardized River Segment 4 LRS Population Trends of YOY Atlantic Tomcod Density Using a 3-Year Moving Average (updated FSEIS Table I-15).

Species	Linear Regression				Segmented Regression					
	MSE	Slope	Std Err of Slope Estimate	p-value	MSE	Slope 1		Join Point	Slope 2	
						Lower 95% CL	Upper 95% CL		Lower 95% CL	Upper 95% CL
Atlantic Tomcod	1.030	-0.015	0.028	0.590	0.471	-2.721	-0.702	1989	-0.007	0.089

Table 8. River Segment 4 Assessment of the Level of Potential Negative Impact Based on the Standardized LRS Atlantic Tomcod YOY Density Using a 3-Year Moving Average (updated FSEIS Table I-16).

Species	Best Fit	Slope from Linear Regression	Slope 1 from Segmented Regression	Slope 2 from Segmented Regression	Final Decision
Atlantic Tomcod	SR		S1<0	S2=0	4

Table 9. Competing Models Used To Characterize the Standardized River Segment 4, FSS Population Trends of YOY Fish CPUE (updated FSEIS Table I-19).

Species	Linear Regression				Segmented Regression					
	MSE	Slope	Std Err of Slope Estimate	p-value	MSE	Slope 1		Join Point	Slope 2	
						Lower 95% CL	Upper 95% CL		Lower 95% CL	Upper 95% CL
Alewife	0.955	-0.036	0.024	0.149		-0.097	0.009	2010		
American Shad	0.753	-0.066	0.021	0.005	0.677	-0.106	0.179	1996	-0.234	-0.030
Atlantic Tomcod	0.791	-0.062	0.022	0.010	Failed to Converge					
Bay Anchovy	1.039	0.003	0.025	0.905	0.880	-0.030	0.227	1999	-0.265	0.023
Blueback Herring	0.936	-0.040	0.024	0.108	0.596	-2.448	-0.190	1987	-0.045	0.050
Bluefish	0.861	-0.052	0.023	0.031	0.848	-0.099	0.090	2002	-0.371	0.049
Hogchoker	0.832	-0.056	0.023	0.019	0.805	-1.988	3.263	1987	-0.125	-0.022
Rainbow Smelt	0.839	-0.055	0.023	0.022	0.837	-0.265	0.451	1992	-0.163	-0.016
Striped Bass	0.952	-0.037	0.024	0.141	0.895	-0.560	2.207	1987	-0.115	0.001
Weakfish	1.014	-0.020	0.025	0.432	0.968	-0.091	0.130	2000	-0.296	0.092
White Perch	0.948	-0.038	0.024	0.132	0.943	-0.318	0.065	1996	-0.091	0.127

Table10. River Segment 4 Assessment of the Level of Potential Negative Impact Based on the Standardized FSS CPUE (updated FSEIS Table I-20).

Species	Best Fit	Slope from Linear Regression	Slope 1 from Segmented Regression	Slope 2 from Segmented Regression	Final Decision
Alewife	LR	S=0			1
American Shad	SR		S1=0	S2<0	4
Atlantic Tomcod	LR	S<0			4
Bay Anchovy	SR		S1=0	S2=0	1
Blueback Herring	SR		S1<0	S2=0	4
Bluefish	SR		S1=0	S2=0	1
Hogchoker	SR		S1=0	S2<0	4
Rainbow Smelt	SR		S1=0	S2<0	4
Striped Bass	SR		S1=0	S2=0	1
Weakfish	SR		S1=0	S2=0	1
White Perch	SR		S1=0	S2=0	1

Table 11. Competing Models Used To Characterize the Standardized River Segment 4 LRS Population Trends of YOY Atlantic Tomcod CPUE Using a 3-Year Moving Average (updated FSEIS Table I-22).

Species	Linear Regression				Segmented Regression					
	MSE	Slope	Std Err of Slope Estimate	p-value	MSE	Slope 1		Join Point	Slope 2	
						Lower 95% CL	Upper 95% CL		Lower 95% CL	Upper 95% CL
Atlantic Tomcod	1.012	-0.021	0.025	0.410	0.842	-1.609	0.089	1988	-0.044	0.076

Table 12. River Segment 4 Assessment of the Level of Potential Negative Impact Based 7 on the Standardized LRS Atlantic Tomcod YOY CPUE Using a 3-Year Moving Average (updated FSEIS Table I-23).

Species	Best Fit	Slope from Linear Regression	Slope 1 from Segmented Regression	Slope 2 from Segmented Regression	Final Decision
Atlantic Tomcod	SR		S1=0	S2=0	1

Table 13. Assessment of Population Impacts for IP2 and IP3 River Segment 4 (updated FSEIS Table I-24).

Species	Density			CPUE		River Segment Assessment
	FSS	BSS	LRS	FSS	LRS	
Alewife	4	1	N/A	1	N/A	2.0
American Shad	4	4	N/A	4	N/A	4.0
Atlantic Menhaden	N/A	N/A	N/A	N/A	N/A	Unknown
Atlantic Sturgeon	N/A	N/A	N/A	N/A	N/A	Unknown
Atlantic Tomcod	4	N/A	4	4	1	3.3
Bay Anchovy	4	1	N/A	1	N/A	2.0
Blueback Herring	4	4	N/A	4	N/A	4.0
Bluefish	4	1	N/A	1	N/A	2.0
Gizzard Shad	N/A	N/A	N/A	N/A	N/A	Unknown
Hogchoker	4	4	N/A	4	N/A	4.0
Rainbow Smelt	4	N/A	N/A	4	N/A	4.0
Shortnose Sturgeon	N/A	N/A	N/A	N/A	N/A	Unknown
Spottail Shiner	N/A	1	N/A	N/A	N/A	1.0
Striped Bass	4	4	N/A	1	N/A	3.0
Weakfish	4	N/A	N/A	1	N/A	2.5
White Catfish	1	N/A	N/A	N/A	N/A	1.0
White Perch	4	1	N/A	1	N/A	2.0
Blue Crab	N/A	N/A	N/A	N/A	N/A	Unknown

Table 14. Competing Models Used To Characterize the Standardized Riverwide FSS Population Trends of YOY Fish CPUE (updated FSEIS Table I-27).

Species	Linear Regression				Segmented Regression					
	MSE	Slope	Std Err of Slope Estimate	p-value	MSE	Slope 1		Join Point	Slope 2	
						Lower 95% CL	Upper 95% CL		Lower 95% CL	Upper 95% CL
Alewife	1.006	0.023	0.025	0.370	1.011	-0.038	0.188	2000	-0.266	0.130
American Shad	0.553	-0.086	0.018	0.000	0.556	-0.380	0.596	1989	-0.151	-0.048
Atlantic Tomcod	0.725	-0.069	0.021	0.003	0.768	-0.414	0.146	1993	-0.125	0.026
Bay Anchovy	1.036	0.008	0.025	0.763	0.902	-0.027	0.348	1995	-0.175	0.038
Blueback Herring	0.701	-0.072	0.021	0.002	0.746	-0.394	0.460	1991	-0.154	-0.025
Bluefish	0.822	-0.058	0.022	0.016	0.828	-0.121	0.104	1999	-0.281	0.034
Hogchoker	0.921	-0.043	0.024	0.084	0.912	-0.222	0.014	1999	-0.126	0.204
Spottail Shiner	0.827	-0.057	0.022	0.018	0.880	-0.174	0.019	2002	-0.218	0.209
Striped Bass	0.833	-0.056	0.023	0.020	0.614	0.088	2.381	1987	-0.135	-0.039
White Perch	1.004	-0.023	0.025	0.352	0.988	-0.479	0.155	1993	-0.066	0.106

Table 15. Riverwide Assessment of the Level of Potential Negative Impact Based on the Standardized FSS CPUE (updated FSEIS Table I-28).

Species	Best Fit	Slope from Linear Regression	Slope 1 from Segmented Regression	Slope 2 from Segmented Regression	Final Decision
Alewife	LR	S=0			1
American Shad	LR	S<0			4
Atlantic Tomcod	LR	S<0			4
Bay Anchovy	SR		S1=0	S2=0	1
Blueback Herring	LR	S<0			4
Bluefish	LR	S<0			4
Hogchoker	SR		S1=0	S2=0	1
Spottail Shiner	LR	S<0			4
Striped Bass	SR		S1>0	S2<0	4
White Perch	SR		S1=0	S2=0	1

Table 16. Competing Models Used To Characterize the Standardized Riverwide BSS Population Trends of YOY Fish CPUE (updated FSEIS Table I-30).

Species	Linear Regression				Segmented Regression					
	MSE	Slope	Std Err of Slope Estimate	p-value	MSE	Slope 1		Join Point	Slope 2	
						Lower 95% CL	Upper 95% CL		Lower 95% CL	Upper 95% CL
Alewife	0.744	0.067	0.021	0.004	0.726	-0.054	0.107	2002	-0.053	0.402
American Shad	0.551	-0.086	0.018	0.000	0.554	-0.285	0.451	1990	-0.162	-0.051
Atlantic Tomcod	0.543	-0.087	0.018	0.000	0.341	-1.704	0.004	1988	-0.087	-0.016
Bay Anchovy	0.813	0.059	0.022	0.014	0.607	-0.046	0.062	2006	-0.026	0.994
Blueback Herring	1.036	-0.008	0.025	0.760	1.072	-0.515	0.839	1990	-0.101	0.043
Bluefish	1.040	0.003	0.025	0.919	1.073	-0.076	0.180	1999	-0.240	0.119
Hogchoker	1.034	0.010	0.025	0.695	1.068	-0.204	0.113	1998	-0.076	0.208
Rainbow Smelt	0.972	-0.032	0.024	0.199	1.002	-0.269	0.370	1993	-0.139	0.034
Spottail Shiner	0.743	0.067	0.021	0.004	0.805	-0.124	0.230	1996	-0.026	0.176
Striped Bass	1.020	0.018	0.025	0.488	0.932	-0.017	0.127	2005	-0.704	0.251
Weakfish	0.918	-0.043	0.024	0.081				1986	-0.055	0.024
White Catfish	1.034	-0.010	0.025	0.699	1.010	-1.315	0.545	1989	-0.047	0.083
White Perch	1.033	-0.010	0.025	0.691	1.015	-0.367	0.092	1994	-0.063	0.144

Table 17. Riverwide Assessment of the Level of Potential Negative Impact Based on the BSS CPUE (updated FSEIS Table I-31).

Species	Best Fit	Slope from Linear Regression	Slope 1 from Segmented Regression	Slope 2 from Segmented Regression	Final Decision
Alewife	SR		S1=0	S2=0	1
American Shad	LR	S<0			4
Atlantic Tomcod	SR		S1=0	S2<0	4
Bay Anchovy	SR		S1=0	S2=0	1
Blueback Herring	LR	S=0			1
Bluefish	LR	S=0			1
Hogchoker	LR	S=0			1
Rainbow Smelt	LR	S=0			1
Spottail Shiner	LR	S>0			1
Striped Bass	SR		S1=0	S2=0	1
Weakfish	LR	S=0			1
White Catfish	SR		S1=0	S2=0	1
White Perch	SR		S1=0	S2=0	1

Table 18. Competing Models Used To Characterize the Standardized Riverwide LRS Population Trend of YOY Atlantic Tomcod CPUE (updated FSEIS Table I-33).

Species	Linear Regression				Segmented Regression					
	MSE	Slope	Std Err of Slope Estimate	p-value	MSE	Slope 1		Join Point	Slope 2	
						Lower 95% CL	Upper 95% CL		Lower 95% CL	Upper 95% CL
Atlantic Tomcod	0.938	-0.039	0.024	0.112		-0.089	0.010	2016		

Table 19. Riverwide Assessment of the Level of Potential Negative Impact Based on the Standardized LRS CPUE of Atlantic Tomcod (updated FSEIS Table I-34).

Species	Best Fit	Slope from Linear Regression	Slope 1 from Segmented Regression	Slope 2 from Segmented Regression	Final Decision
Atlantic Tomcod	LR	S=0			1

Table 20. Competing Models Used To Characterize the Standardized Riverwide YOY Abundance Index Trends (updated FSEIS Table I-36).

Species	Linear Regression				Segmented Regression					
	MSE	Slope	Std Err of Slope Estimate	p-value	MSE	Slope 1		Join Point	Slope 2	
						Lower 95% CL	Upper 95% CL		Lower 95% CL	Upper 95% CL
Alewife	1.017	0.019	0.025	0.458						
American Shad	0.596	-0.082	0.019	0.000	0.594	-0.588	0.838	1989	-0.150	-0.050
Atlantic Tomcod	0.576	-0.084	0.019	0.000	0.547	-1.637	2.690	1987	-0.141	-0.056
Bay Anchovy	0.744	-0.067	0.021	0.004	0.786	-0.194	0.005	2000	-0.198	0.152
Blueback Herring	0.792	-0.062	0.022	0.010	0.794	-0.154	-0.021	2006	-0.300	0.581
Bluefish	1.035	0.009	0.025	0.731	0.967	-0.038	0.205	1999	-0.259	0.081
Hogchoker	0.902	-0.046	0.023	0.062	0.942	-0.165	0.017	2003	-0.219	0.299
Rainbow Smelt	0.971	-0.033	0.024	0.193	0.960	-0.216	0.409	1992	-0.148	0.022
Spottail Shiner	0.844	0.055	0.023	0.024	0.879	-0.008	0.168	2003	-0.273	0.227
Striped Bass	1.039	0.005	0.025	0.855	0.925	-0.024	0.131	2005	-0.657	0.095
Weakfish	0.647	-0.077	0.020	0.001	0.576	-0.561	0.032	1992	-0.095	0.027
White Catfish	0.833	-0.056	0.023	0.020	0.863	-0.198	0.011	2001	-0.173	0.193
White Perch	1.039	-0.003	0.025	0.906	1.093	-0.079	0.103	2003	-0.424	0.243

Table 21. Riverwide Assessment of the Level of Potential Negative Impact Based in the Abundance Index (updated FSEIS Table I-37).

Species	Best Fit	Slope from Linear Regression	Slope 1 from Segmented Regression	Slope 2 from Segmented Regression	Final Decision
Alewife	LR	S=0			1
American Shad	SR		S1=0	S2<0	4
Atlantic Tomcod	SR		S1=0	S2<0	4
Bay Anchovy	LR	S<0			4
Blueback Herring	LR	S<0			4
Bluefish	SR		S1=0	S2=0	1
Hogchoker	LR	S=0			1
Rainbow Smelt	SR		S1=0	S2=0	1
Spottail Shiner	LR	S>0			1
Striped Bass	SR		S1=0	S2=0	1
Weakfish	SR		S1=0	S2=0	1
White Catfish	LR	S<0			4
White Perch	LR	S=0			1

Table 22. Assessment of Riverwide Population Impacts (updated FSEIS Table I-38).

Species	**CPUE**			**Abundance Index**	**Riverwide Assessment**
	FSS	**BSS**	**LRS**		
Alewife	1	1	N/A	1	1.0
American Shad	4	4	N/A	4	4.0
Atlantic Menhaden	N/A	N/A	N/A	N/A	Unknown
Atlantic Sturgeon	N/A	N/A	N/A	N/A	Unknown
Atlantic Tomcod	4	4	1	4	3.3
Bay Anchovy	1	1	N/A	4	2.0
Blueback Herring	4	1	N/A	4	3.0
Bluefish	4	1	N/A	1	2.0
Gizzard Shad	N/A	N/A	N/A	N/A	Unknown
Hogchoker	1	1	N/A	1	1.0
Rainbow Smelt	N/A	1	N/A	1	1.0
Shortnose Sturgeon	N/A	N/A	N/A	N/A	Unknown
Spottail Shiner	4	1	N/A	1	2.0
Striped Bass	4	1	N/A	1	2.0
Weakfish	N/A	1	N/A	1	1.0
White Catfish	N/A	1	N/A	4	2.5
White Perch	1	1	N/A	1	1.0
Blue Crab	N/A	N/A	N/A	N/A	Unknown

Table 23. Weight of Evidence Results for the Population Trend Line of Evidence (updated FSEIS Table H-15).

Species	River Segment Assessment Score	Riverwide Assessment Score	WOE Score	Impact Conclusion
Alewife	2.0	1.0	1.6	Undetected Decline
American Shad	4.0	4.0	4.0	Detected Decline
Atlantic Menhaden	Unknown	Unknown	Unknown	Unresolved
Atlantic Sturgeon	Unknown	Unknown	Unknown	Unresolved
Atlantic Tomcod	3.3	3.3	3.3	Detected Decline
Bay Anchovy	2.0	2.0	2.0	Undetected Decline
Blueback Herring	4.0	3.0	3.6	Detected Decline
Bluefish	2.0	2.0	2.0	Undetected Decline
Gizzard Shad	Unknown	Unknown	Unknown	Unresolved
Hogchoker	4.0	1.0	2.8	Variable
Rainbow Smelt	4.0	1.0	2.8	Variable
Shortnose Sturgeon	Unknown	Unknown	Unknown	Unresolved
Spottail Shiner	1.0	2.0	1.4	Undetected Decline
Striped Bass	3.0	2.0	2.6	Variable
Weakfish	2.5	1.0	1.9	Undetected Decline
White Catfish	1.0	2.5	1.6	Undetected Decline
White Perch	2.0	1.0	1.6	Undetected Decline
Blue Crab	Unknown	Unknown	Unknown	Unresolved

Table 24. Parameter Values Used in the Monte Carlo Simulation (updated FSEIS Table I-46).

RIS	Survey Used	Linear Slope (r)	Slope plus Standard Error of the Slope Estimate	Error Mean Square from Regression	CV of Density Data (1985-1996)	EMR	IMR
Alewife	BSS	0.075	0.099	0.725	1.294	0.095	0.0020
American Shad	BSS	-0.120	-0.106	0.235	0.510	0.042	0.0005
Atlantic Tomcod	FSS	-0.080	-0.058	0.678	0.794	0.036	0.0300
Bay Anchovy	FSS	-0.088	-0.067	0.601	0.511	0.213	0.0040
Blueback Herring	BSS	-0.075	-0.051	0.726	1.034	0.095	0.0040
Bluefish	BSS	0.013	0.041	1.034	0.754	0.003	0.0005
Hogchoker	FSS	-0.104	-0.086	0.434	1.225	0.386	0.0005
Rainbow Smelt	FSS	-0.086	-0.064	0.623	1.211	0.258	0.0005
Spottail Shiner	BSS	-0.031	-0.004	0.989	1.182	0.031	0.0070
Striped Bass	BSS	0.022	0.050	1.016	0.523	0.106	0.0080
Weakfish	FSS	-0.064	-0.039	0.811	0.698	0.544	0.0005
White Catfish	FSS	-0.042	-0.015	0.945	2.566	0.114	0.0005
White Perch	BSS	-0.012	0.016	1.035	1.005	0.076	0.0320

Table 25. Quartiles of the Relative Difference in Cumulative Abundance and Conclusions for the Strength-of-Connection From the Monte Carlo Simulation (updated FSEIS Table I-47).

Taxa	Number of Years	$N_0 = 1000$			$N_0 = 1 \times 10^8$			Strength of Connection Conclusion
		Median	Q1	Q3	Median	Q1	Q3	
Alewife	20	-0.07	-1.19	1.03	-0.07	-1.17	1.01	Low
	27	-0.32	-1.63	1.02	-0.32	-1.69	1.04	
American Shad	20	0.07	-0.01	0.14	0.07	-0.01	0.14	Low
	27	0.06	0.00	0.11	0.06	0.00	0.11	
Atlantic Tomcod	20	0.15	-0.03	0.34	0.16	-0.03	0.35	Low
	27	0.16	0.01	0.30	0.15	0.01	0.30	
Bay Anchovy	20	0.29	0.13	0.44	0.29	0.13	0.44	High
	27	0.27	0.15	0.39	0.27	0.15	0.39	
Blueback Herring	20	0.21	-0.03	0.46	0.22	-0.02	0.46	Low
	27	0.22	0.04	0.41	0.23	0.04	0.42	
Bluefish	20	0.45	-0.09	0.99	0.45	-0.09	0.98	Low
	27	0.67	0.11	1.21	0.69	0.15	1.23	
Hogchoker	20	0.58	0.31	0.85	0.57	0.30	0.86	High
	27	0.56	0.35	0.78	0.56	0.35	0.78	
Rainbow Smelt	20	0.45	0.16	0.74	0.46	0.16	0.76	High
	27	0.45	0.23	0.68	0.45	0.23	0.68	
Spottail Shiner	20	0.27	-0.14	0.68	0.27	-0.13	0.69	Low
	27	0.34	-0.00	0.69	0.34	0.00	0.68	
Striped Bass	20	0.84	0.25	1.43	0.83	0.24	1.42	High
	27	1.27	0.64	1.93	1.28	0.64	1.92	
Weakfish	20	0.74	0.42	1.07	0.75	0.42	1.07	High
	27	0.76	0.49	1.02	0.76	0.50	1.02	
White Catfish	20	0.42	-0.26	1.10	0.44	-0.27	1.13	Low
	27	0.49	-0.07	1.06	0.47	-0.10	1.06	
White Perch	20	0.40	-0.08	0.90	0.40	-0.07	0.88	Low
	27	0.51	0.10	0.93	0.51	0.08	0.93	

Table 26. Impingement and Entrainment Impact Summary for Hudson River YOY RIS (updated FSEIS Table H-17).

Species	Population Trend Line of Evidence	Strength of Connection Line of Evidence	Impacts of IP2 and IP3 Cooling Systems on YOY RIS
Alewife	Undetected Decline	Low	Small
American Shad	Detected Decline	Low	Small
Atlantic Menhaden	Unresolved	Low[(b)]	Small
Atlantic Sturgeon	Unresolved	Low[(b)]	Small
Atlantic Tomcod	Detected Decline	Low	Small
Bay Anchovy	Undetected Decline	High	Small
Blueback Herring	Detected Decline	Low	Small
Bluefish	Undetected Decline	Low	Small
Gizzard Shad	Unresolved	Low[(b)]	Small
Hogchoker	Variable	High	Moderate
Rainbow Smelt	Variable	High	Moderate
Shortnose Sturgeon	Unresolved	Low[(b)]	Small
Spottail Shiner	Undetected Decline	Low	Small
Striped Bass	Variable	High	Moderate
Weakfish	Undetected Decline	High	Small
White Catfish	Undetected Decline	Low	Small
White Perch	Undetected Decline	Low	Small
Blue Crab	Unresolved	Low[(b)]	Small

[(b)] Strength of connection could not be established using Monte Carlo Simulation; therefore, strength of connection was based on the rate of entrainment and impingement.

VIII. Appendix A

The "p-value" is the probability level for the significance test of the estimated slope $(\hat{r})$ from the linear regression. It is the probability that the absolute value of a random variable from a t-distribution is greater than the ratio:

$$\frac{\hat{r}}{se(\hat{r})}$$

where $se(\hat{r})$ is the standard error of the estimated slope (Draper and Smith, 1966). For Tables I-9 and I-12 it is a t-distribution with 23 degrees of freedom because the time series of 3-year averages of River Segment 4 density estimates contained 25 index values and the linear regression model had 2 parameters.

For each linear slope estimate listed in Table I-46, the corresponding "p-value" listed in Table I-9 or Table I-12 was equal (allowing for round-off errors with 3 significant digits listed in Tables I-9 and I-12) to the probability that the absolute value of a random variable with a t-distribution with 23 degrees of freedom was greater than the ratio:

$$\frac{\textit{estimated slope}}{\textit{value to the right of the} \pm \textit{symbol}}.$$

This demonstrates that the undefined value to the right of the $\pm$ symbol in the slope column of Tables I-9 and I-12 was, in fact, the standard error of the estimated slope.

IX. Appendix B

Report on QC Review of Analysis Update

Prepared by John Young, PhD

ASA Analysis & Communication, Inc.
921 Pike Street, PO Box 303
Lemont, PA 16851-0303

October 18, 2013

ASA reviewed the SAS programs used to analyze clean data files (1985-2011) from the Hudson River Biological Monitoring Program with NRC's trend assessment methods. The first step in the review process was to create SAS datasets from 1974-2011 level files for BSS, FSS, and LRS programs. These datasets contained one observation for each of the target species for each sample from each program. A separate dataset was constructed for each program each year. Once the datasets had been created, the next step was to run the following series of SAS programs used for the analyses:

1. NRC Region 4 Indices Corrected v10
2. NRC Riverwide Indices Corrected v10
3. NLIN and REG NRC trends Corrected v13
4. NRC Trends summary Corrected v16
5. SOC input updated trends results v1
6. SOC update v10

Each line of the resulting SAS log files was evaluated for error, warning and other unexpected messages. The presence of such messages indicates an error is present in the program that may lead to inaccurate results. All six programs ran successfully and were found to be free of errors. The draft results presented in table H-15, H-17, I-24, and I-38 were reproduced.

After confirming that the programs were running successfully, the methodology applied within the programs was compared to that used by NRC to ensure that the analysis was accurately reproduced. The following steps were taken during the methodology review:

1. Reviewed all input and output datasets of the program

2. Evaluated sort order of all datasets

3. Evaluated all macros

4. Evaluated code logic

These steps ultimately tested the accuracy and integrity of the program logic and output which it produces. The methodology review did not identify deviances from the NRC data analysis methodology. All input and output datasets were accurate, sorting was not found to be an issue, macros ran without error, and code logic mirrored that used by NRC.

In summary, the programs used to apply NRC trend assessment methodology to the clean data files from the Hudson River Biological Monitoring Program were found to be free of errors. The results produced by the programs are considered to be accurate.

ATTACHMENT 2 TO NL-14-030

78 Fed. Reg. 48944 (August 12, 2013);

Sustainable Fishing Plan for New York River Herring Stocks (2011);

Rainbow Smelt: An Imperiled Fish in a Changing World (2010);

A Regional Conservation Plan for Anadromous Smelt (2012); and,

Correspondence from Mark D. Sanza, Assistant Counsel for NYSDEC to ALJs Villa and O'Connell, Administrative Law Judges for NYSDEC, *re: Entergy Nuclear Indian Point Units 2 and 3, CWA Section 401 WQC Application Proceeding.*

FEDERAL REGISTER

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Part II

Department of Commerce

National Oceanic and Atmospheric Administration

Endangered and Threatened Wildlife and Plants; Endangered Species Act Listing Determination for Alewife and Blueback Herring; Notice

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

[Docket No. 111024651–3630–02]

RIN 0648–XA739

Endangered and Threatened Wildlife and Plants; Endangered Species Act Listing Determination for Alewife and Blueback Herring

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Notice of a listing determination.

SUMMARY: We, NMFS, have completed a comprehensive review of the status of river herring (alewife and blueback herring) in response to a petition submitted by the Natural Resources Defense Council (NRDC) requesting that we list alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) as threatened under the Endangered Species Act (ESA) throughout all or a significant portion of their range or as specific distinct population segments (DPS) identified in the petition. The Atlantic States Marine Fisheries Commission (ASMFC) completed a comprehensive stock assessment for river herring in May 2012 which covers over 50 river specific stocks throughout the range of the species in the United States. The ASMFC stock assessment contained much of the information necessary to make an ESA listing determination for both species; however, any deficiencies were addressed through focused workshops and working group meetings and review of additional sources of information. Based on the best scientific and commercial information available, we have determined that listing alewife as threatened or endangered under the ESA is not warranted at this time. Additionally, based on the best scientific and commercial information available, we have determined that listing blueback herring as threatened or endangered under the ESA is not warranted at this time.

DATES: This finding is effective on August 12, 2013.

ADDRESSES: The listing determination, list of references used in the listing determination, and other related materials regarding this determination can be obtained via the Internet at: *http://www.nero.noaa.gov/prot_res/CandidateSpeciesProgram/RiverHerringSOC.htm* or by submitting a request to the Assistant Regional Administrator, Protected Resources Division, Northeast Region, NMFS, 55 Great Republic Drive, Gloucester, MA 01930.

FOR FURTHER INFORMATION CONTACT: Kim Damon-Randall, NMFS Northeast Regional Office, (978) 282–8485; or Marta Nammack, NMFS, Office of Protected Resources (301) 427–8469.

SUPPLEMENTARY INFORMATION:

Background

On August 5, 2011, we, the National Marine Fisheries Service (NMFS), received a petition from the Natural Resources Defense Council (NRDC), requesting that we list alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) under the ESA as threatened throughout all or a significant portion of their ranges. In the alternative, they requested that we designate 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 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 petition also included information regarding potential DPSs of alewife and blueback herring as described above. 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.

We reviewed the petition and determined that, based on the information in the petition and in our files at the time we received the petition, the petitioned action may be warranted. Therefore, we published a positive 90-day finding on November 2, 2011, and as a result, we were required to review the status of the species (e.g., anadromous alewife and blueback herring) to determine if listing under the ESA is warranted. We formed an internal status review team (SRT) comprised of nine NMFS staff members (Northeast Regional Office (NERO) Protected Resources Division and Northeast Fisheries Science Center staff) to compile the best commercial and scientific data available for alewife and blueback herring throughout their ranges.

In May 2012, the ASMFC completed a river herring stock assessment, which covers over 50 river-specific stocks throughout the ranges of the species in the United States (ASMFC, 2012; hereafter referred to in this determination as "the stock assessment"). In order to avoid duplicating this extensive effort, we worked cooperatively with ASMFC to use this information in the review of the status of these two species and identify information not in the stock assessment that was needed for our listing determination. We identified the missing required elements and held workshops/working group meetings focused on addressing information on stock structure, extinction risk analysis, and climate change.

Reports from each workshop/working group meeting were compiled and independently peer reviewed (the stock structure and extinction risk reports were peer reviewed by reviewers selected by the Center for Independent Experts, and the climate change report was peer reviewed by 4 experts identified during the workshops). These reports did not contain any listing advice or reach any ESA listing conclusions—such synthesis and analysis for river herring is solely within the agency's purview. We used this information to determine which extinction risk method and stock structure analysis would best inform the listing determination, as well as understand how climate change may impact river herring, and ultimately, we are using these reports along with the stock assessment and all other best available information in this listing determination.

Alewife and blueback herring are collectively referred to as "river herring." Due to difficulties in distinguishing between the species, they are often harvested together in commercial and recreational fisheries, and managed together by the ASMFC. Throughout this finding, where there are similarities, they will be collectively referred to as river herring, and where there are distinctions, they will be identified by species.

Range

River herring can be 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). The coastal ranges of the two species overlap. Blueback herring range from Nova Scotia south to the St. John's River, Florida; and alewife range from Labrador and Newfoundland south to South Carolina, though their occurrence in the extreme southern range is less common (Collette and Klein-MacPhee, 2002; ASMFC, 2009a; Kocik *et al.*, 2009).

In Canada, river herring (i.e., gaspereau) are most abundant in the Miramichi, Margaree, LaHave, Tusket, Shubenacadie and Saint John Rivers (Gaspereau Management Plan, 2001). They are proportionally less abundant in smaller coastal rivers and streams (Gaspereau Management Plan, 2001). Generally, blueback herring in Canada occur in fewer rivers than alewives and are less abundant in rivers where both species coexist (DFO 2001).

Habitat and Migration

River herring are anadromous, meaning that they mature in the marine environment and then migrate up coastal rivers to estuarine and freshwater rivers, ponds, and lake habitats to spawn (Collette and Klein-MacPhee, 2002; ASMFC, 2009a; Kocik *et al.*, 2009). In general, adult river herring are most often 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). They are highly migratory, pelagic, schooling species, with seasonal spawning migrations that are cued by water temperature (Collette and Klein-MacPhee, 2002; Schultz *et al.*, 2009). Depending upon temperature, blueback herring typically spawn from late March through mid-May. However, they spawn in the southern parts of their range as early as December or January, and as late as August in the northern portion of their range (ASMFC, 2009a). Alewives have been documented spawning as early as February in the southern portion of their range, and as late as August in the northern portion of the range (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 2 weeks later than alewives do (DFO, 2001). River herring conform to a metapopulation paradigm (e.g., a group of spatially separated populations of the same species which interact at some level) with adults frequently returning to their natal rivers for spawning but with some limited straying occurring between rivers (Jones, 2006; ASMFC, 2009a).

Throughout their life cycle, river herring use many different habitats, including the ocean, estuaries, rivers, and freshwater lakes and ponds. The substrate preferred for spawning varies greatly and can include gravel, detritus, and submerged aquatic vegetation. Blueback herring prefer swifter moving waters than alewives do (ASMFC, 2009a). Nursery areas include freshwater and semi-brackish waters. Little is known about their habitat preference in the marine environment (Meadows, 2008; ASMFC, 2009a).

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 & Lackey, 1974). Many landlocked 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 also 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). Though 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). Since their divergence, landlocked alewives have evolved to a point they now 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 that would suggest that landlocked populations can or would revert back to an anadromous life history if they had the opportunity to do so (Gephard, CT DEEP, Pers. comm. 2012; Jordaan, UMASS Amherst, Pers. comm. 2012).

The discrete life history and morphological differences between the two life history variants (anadromous and landlocked) provide substantial evidence that upon becoming 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 which could provide passage over dams and access to historic spawning habitats restored for anadromous populations, where it did not previously exist. The implications of this are not known at this time.

In summary, genetics indicate that anadromous alewife populations are discrete from landlocked populations, and that this divergence can be estimated to have taken place from 300 to 5,000 years ago. 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.

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, we did not include the landlocked populations of alewife and blueback herring in our review of the status of the species and do not consider landlocked populations in this listing determination in response to the petition to list these anadromous species.

Listing Species Under the Endangered Species Act

We are responsible for determining whether alewife and blueback herring are threatened or endangered under the ESA (16 U.S.C. 1531 *et seq.*). Accordingly, based on the statutory, regulatory, and policy provisions described below, the steps we followed in making our listing determination for alewife and blueback herring were to: (1) Determine how alewife and blueback herring meet the definition of "species"; (2) determine the status of the species and the factors affecting them; and (3) identify and assess efforts being made to protect the species and determine if these efforts are adequate to mitigate existing threats.

To be considered for listing under the ESA, a group of organisms must constitute a "species." Section 3 of the ESA defines a "species" as "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." Section 3 of the ESA further 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 one "which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." Thus, we interpret an "endangered species" to be one that is presently in danger of extinction. A "threatened species," on the other hand, is not presently in danger of extinction, but is likely to become so in the foreseeable future (that is, at a later time). In other words, the primary statutory difference between a threatened and endangered species is the timing of when a species may be in danger of extinction, either presently (endangered) or in the foreseeable future (threatened).

On February 7, 1996, the Services adopted a policy to clarify our interpretation of the phrase "distinct population segment of any species of vertebrate fish or wildlife" (61 FR 4722). The joint DPS policy describes two criteria that must be considered when identifying DPSs: (1) The discreteness of the population segment in relation to the remainder of the species (or subspecies) to which it belongs; and (2) the significance of the population segment to the remainder of the species (or subspecies) to which it belongs. As further stated in the joint policy, if a population segment is discrete and significant (i.e., it meets the DPS policy criteria), its evaluation for endangered or threatened status will be based on the ESA's definitions of those terms and a review of the five factors enumerated in section 4(a)(1) of the ESA.

As provided in section 4(a) of the ESA, the statute requires us to determine whether any species is endangered or threatened because of any of the following five factors: (1) The present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; or (5) other natural or manmade factors affecting its continued existence (section 4(a)(1)(A)(E)). Section 4(b)(1)(A) of the ESA further requires that listing determinations be based solely on the best scientific and commercial data available after taking into account efforts being made to protect the species.

Distribution and Abundance

United States

The stock assessment (described above) was prepared and compiled by the River Herring Stock Assessment Subcommittee, hereafter referred to as the 'subcommittee,' of the 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 subcommittee conducted its assessment on the coastal stocks of alewife and blueback herring by individual rivers as well as coast-wide depending on available data. The subcommittee concluded that river herring should ideally be assessed and managed by individual river system, but that the marine portion of their life history likely influences survival through mixing in the marine portion of their range. However, coast-wide assessments are complicated by the complex life history of these species as well, given that factors influencing population dynamics for the freshwater portion of their life history can not readily be separated from marine factors. In addition, it was noted that data quality and availability varies by river and is mostly dependent upon the monitoring efforts that each state dedicates to these species, which further complicated the assessment.

The subcommittee also noted that most state landings records listed alewife and blueback herring together as 'river herring' rather than identifying by species. 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 submitted and obtained 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. Because the stock assessment contains the most recent and comprehensive description of this information and the subcommittee's conclusions, the following sections were taken from the stock assessment (ASMFC, 2012).

Commercial CPUE

Since the mid-1990s, CPUE indices for alewives showed declining trends in the Potomac River and James River (VA), no trend in the Rappahannock River (VA), and increasing trends in the York River (VA) and Chowan River (NC). CPUE indices available for blueback herring showed a declining trend in the Chowan River and no trend in the Santee River (SC). Combined species CPUE indices showed declining trends in Delaware Bay and the Nanticoke River, but CPUE has recently increased in the Hudson River (ASMFC, 2012).

Run Counts

Major declines in run sizes occurred in many rivers from 2001 to 2005. These declines were followed by increasing trends (2006 to 2010) in the Androscoggin River (ME), Damariscotta River (ME), Nemasket River (MA), Gilbert-Stuart River (RI), and Nonquit River (RI) for alewife and in the Sebasticook River (ME), Cocheco River (NH), Lamprey River (NH), and Winnicut River (NH) for both species combined. No trends in run sizes were evident following the recent major declines in the Union River (ME), Mattapoisett River (MA), and

Monument River (MA) for alewife and in the Exeter River (NH) for both species combined. Run sizes have declined or are still declining following recent and historical major declines in the Oyster River (NH) and Taylor River (NH) for both species, in the Parker River (MA) for alewife, and in the Monument River (MA) and Connecticut River for blueback herring (ASMFC, 2012).

Young-of-the-Year Seine Surveys

The young-of-the-year (YOY) seine surveys were quite variable and showed differing patterns of trends among rivers. Maine rivers showed similar trends in alewife and blueback herring YOY indices after 1991, with peaks occurring in 1995 and 2004. YOY indices from North Carolina and Connecticut showed declines from the 1980s to the present. New York's Hudson River showed peaks in YOY indices in 1999, 2001, 2005, and 2007. New Jersey and Maryland YOY indices showed peaks in 1994, 1996, and 2001. Virginia YOY surveys showed peaks in 1993, 1996, 2001, and 2003 (ASMFC, 2012).

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

The juvenile-adult indices from fisheries-independent seine, gillnet and electrofishing surveys showed a variety of trends in the available datasets for the Rappahanock River (1991–2010), James River (2000–2010), St. John's River, FL (2001–2010), and Narragansett Bay (1988–2010). The gillnet indices from the Rappahannock River (alewife and blueback herring) showed a low and stable or decreasing trend after a major decline after 1995 and has remained low since 2000 (except for a rise in alewife CPUE during 2008). The gillnet and electrofishing indices in the James River (alewife and blueback herring) showed a stable or increasing trend. Blueback herring peak catch rates occurred in 2004, and alewife peak catch rates occurred in 2005. The blueback herring index from electrofishing in the St. John's River, FL, showed no trend after a major decline from 2001–2002. The seine indices in Narragansett Bay, RI (combined species) and coastal ponds (combined species) showed no trends over the time series. The CPUE for Narragansett Bay fluctuated without trend from 1988–1997, increased through 2000, declined and then remained stable from 2001–2004. The pond survey CPUE increased during 1993–1996, declined through 1998, increased in 1999, declined through 2002, peaked in 2003 and then declined and fluctuated without trend thereafter. The electrofishing indices showed opposing trends and then declining trends in the Rappahannock River (alewife and blueback herring) with catch rates of blueback herring peaking during 2001–2003, and catch rates of alewives lowest during the same time period (ASMFC, 2012).

Juvenile and Adult Trawl Surveys

Trends in trawl survey indices varied greatly with some surveys showing an increase in recent years, some showing a decrease, and some remaining stable. Trawl survey data were available from 1966–2010 (for a complete description of data see ASMFC (2012)). Trawl surveys in northern areas tended to show either an increasing or stable trend in alewife indices, whereas trawl surveys in southern areas tended to show stable or decreasing trends. Patterns in trends across surveys were less evident for blueback herring. The NMFS surveys showed a consistent increasing trend coast-wide and in the northern regions for alewife and the combined river herring species group (ASMFC, 2012).

Mean Length

Mean sizes for male and female alewife declined in 4 of 10 rivers, and mean sizes for female and male blueback herring declined in 5 of 8 rivers. Data were available from 1960–2010 (for a complete description of data see ASMFC (2012)). The common trait among most rivers in which significant declines in mean sizes were detected is that historical length data were available for years prior to 1990. Mean lengths started to decline in the mid to late 1980s; therefore, it is likely that declines in other rivers were not detected because of the shortness of their time series. Mean lengths for combined sexes in trawl surveys were quite variable through time for both alewives and blueback herring. Despite this variability, alewife mean length tended to be lowest in more recent surveys. This pattern was less apparent for blueback herring. Trend analysis of mean lengths indicated significant declines in mean lengths over time for alewives coast-wide and in the northern region in both seasons, and for blueback coast-wide and in the northern region in fall (ASMFC, 2012).

Maximum Age

Except for Maine and New Hampshire, maximum age of male and female alewife and blueback herring during 2005–2007 was 1 or 2 years lower than historical observations (ASMFC, 2012).

Mean Length-at-Age

Declines in mean length of at least one age were observed in most rivers examined. The lack of significance in some systems is likely due to the absence of data prior to 1990 when the decline in sizes began, similar to the pattern observed for mean length. Declines in mean lengths-at-age for most ages were observed in the north (NH) and the south (NC). There is little indication of a general pattern of size changes along the Atlantic coast (ASMFC, 2012).

Repeat Spawner Frequency

Examination of percentage of repeat spawners in available data revealed significant, declining trends in the Gilbert-Stuart River (RI—combined species), Nonquit River (RI—combined species), and the Nanticoke River (blueback herring). There were no trends in the remaining rivers for which data are available, although scant data suggest that current percentages of repeat spawners are lower than historical percentages in the Monument River (MA) and the Hudson River (NY) (ASMFC, 2012).

Total Mortality (Z) Estimates

With the exception of male blueback herring from the Nanticoke River, which showed a slight increase over time, there were no trends in the Z estimates produced using age data (ASMFC, 2012).

Exploitation Rates

Exploitation of river herring appears to be declining or remaining stable. In-river exploitation estimates have fluctuated, but are lower in recent years. A coast-wide index of relative exploitation showed a decline following a peak in the 1980s, and the index indicates that exploitation has remained fairly stable over the past decade. The majority of depletion-based stock reduction analysis (DB–SRA) model runs showed declining exploitation rates coast-wide. Exploitation rates estimated from the statistical catch-at-age model for blueback herring in the Chowan River also showed a slight declining trend from 1999 to 2007, at which time a moratorium was instituted. There appears to be a consensus among various assessment methodologies that exploitation has decreased in recent times. 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, 2012).

Summary of Stock Assessment Conclusions

Of the in-river stocks of alewife and blueback herring for which data were available and were considered in the stock assessment, 22 were depleted, 1 was increasing, and the status of 28 stocks could not be determined because the time-series of available data was too short. In most recent years, 2 in-river stocks were increasing, 4 were decreasing, and 9 were stable, with 38 rivers not having enough data to assess recent trends. The coast-wide meta-complex of river herring stocks in the United States is depleted to near historical 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 that occurred prior to 1970. There appears to be a consensus among various assessment methodologies that exploitation has decreased in recent times. 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, 2012).

Canada

The Department of Fisheries and Oceans (DFO) monitors and manages river herring runs in Canada. River herring runs in the Miramichi River in New Brunswick and the Maragree River in Cape Breton, Nova Scotia were monitored intensively from 1983 to 2000 (DFO, 2001). More recently (1997 to 2006) 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). 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 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.

Consideration as a Species Under the ESA

Distinct Population Segment Background

According to Section 3 of the ESA, the term "species" includes "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife that interbreeds when mature." Congress included the term "distinct population segment" in the 1978 amendments to the ESA. On February 7, 1996, the Services adopted a policy to clarify their interpretation of the phrase "distinct population segment" for the purpose of listing, delisting, and reclassifying species (61 FR 4721). The policy described two criteria a population segment must meet in order to be considered a DPS (61 FR 4721): (1) It must be discrete in relation to the remainder of the species to which it belongs; and (2) it must be significant to the species to which it belongs.

Determining if a population is discrete requires either one of the following conditions: (1) It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation; or (2) it is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the ESA.

If a population is deemed discrete, then the population segment is evaluated in terms of significance. Factors to consider in determining whether a discrete population segment is significant to the species to which it belongs include, but are not limited to, the following: (1) Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon; (2) evidence that loss of the discrete population segment would result in a significant gap in the range of the taxon; (3) evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range; or (4) evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

If a population segment is deemed discrete and significant, then it qualifies as a DPS.

Information Related to Discreteness

To obtain expert opinion about anadromous alewife and blueback herring stock structure, we convened a working group in Gloucester, MA, on June 20–21, 2012. This working group meeting brought together river herring experts from state and Federal fisheries management agencies and academic institutions. Participants presented information to inform the presence or absence of stock structure such as genetics, life history, and morphometrics. A public workshop was held to present the expert working group's findings on June 22, 2012, and during this workshop, additional information on stock structure was sought from the public. Subsequently, a summary report was developed (NMFS, 2012a), and a peer review of the document was completed by three independent reviewers. The summary report and peer review reports are available on the NMFS Web site (see the **ADDRESSES** section above).

Steve Gephard of the Connecticut Department of Energy and Environmental Protection (CT DEP) presented a preliminary U.S. coast-wide genetic analysis of alewife and blueback herring data (Palkovacs *et al.*, 2012, unpublished report). Palkovacs *et al.*, (2012, unpublished report) used 15 novel microsatellite markers on samples collected from Maine to Florida. For alewife, 778 samples were collected from spawning runs in 15 different rivers, and 1,201 blueback herring samples were collected from 20 rivers.

Bayesian analyses identified five genetically distinguishable stocks for alewife with similar results using both STRUCTURE and Bayesian Analysis of Population Structure (BAPS) software models. The alewife stock complexes identified were: (1) Northern New England; (2) Southern New England; (3)

Connecticut River; (4) Mid-Atlantic; and (5) North Carolina. For blueback herring, no optimum solution was reached using STRUCTURE, while BAPS suggested four genetically identifiable stock complexes. The stock complexes identified for blueback herring were: (1) Northern New England; (2) Southern New England; (3) Mid Atlantic; (4) and Southern. However, it should be noted that these Bayesian inferences of population structure provide a minimum number of genetically distinguishable groups. In the future, in order to better define potential stock complexes, further tests examining structure within designated stocks should be conducted using hierarchical clustering analysis and genetic tests.

The study also examined the effects of geography and found a strong effect of latitude on genetic divergence, suggesting a stepping stone model of population structure, and a strong pattern of isolation by distance, where gene flow is most likely among neighboring spawning populations. The preliminary results from the study found significant differentiation among spawning rivers for both alewife and blueback herring. Based on the results of their study, the authors' preliminary management recommendations suggest that river drainage is the appropriate level of management for both of the species. This inference was also supported by genetic tests which were conducted later. These tests suggest that there is substantial population structure at the drainage scale.

The authors noted a number of caveats for their study including: (1) Collection of specimens on their upstream spawning run may pool samples from what are truly distinct spawning populations within the major river drainages sampled, thereby, underestimating genetic structure within rivers (Hasselman, 2010); (2) a more detailed analysis of population structure within the major stocks identified (i.e., using hierarchical Bayesian clustering methods and genic test) would be useful for identifying any substructure within these major stocks; (3) neutral genetic markers used in this study represent the effects of gene flow and historical population isolation, but not the effects of adaptive processes, which are important to consider in the context of stock identification; (4) the analysis is preliminary, and there are a number of issues that need to be further investigated, including the effect of deviations in the Hardy-Weinberg Equilibrium model encountered in four alewife loci and the failure of STRUCTURE to perform well on the blueback herring dataset; and (5) hybridization may be occurring between alewife and blueback herring and may influence the results of the species-specific analyses.

Following the Stock Structure Workshop, additional analyses were run on the alewife dataset to examine the uniqueness of the (tentatively) designated Connecticut River alewife stock complex. Hybrids and misidentified samples were found and subsequently removed for this analysis, and the results were refined. By removing these samples from the Connecticut River alewife dataset, Palkovacs *et al.* (2012, unpublished report) found that, for alewife, the Connecticut and Hudson Rivers belong to the Southern New England stock. The analyses were further refined and Palkovacs *et al.* (2012, unpublished report) provided an updated map of the alewife genetic stock complexes, combining the tentative North Carolina stock with the Mid-Atlantic stock. This information and analysis is complete and is currently being prepared for publication. Thus, the refined genetic stock complexes for alewife in the coastal United States include Northern New England, Southern New England, and the Mid-Atlantic. For blueback herring, the identified genetic stocks include Northern New England, Southern New England, Mid-Atlantic and Southern (Palcovacs *et al.*, 2012, unpublished report).

Bentzen *et al.* (2012) 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. 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 isolation by distance, suggesting that homing behavior indicative of alewives' metapopulation conformance does produce genetically distinguishable populations. Further testing also suggested that there may be interbreeding between alewives and blueback herring (e.g., hybrids), especially at sample sites with impassible dams.

The unusual genetic groupings of river herring in Maine are likely a result of Maine's complex stocking history, as 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. These genetic analyses suggest that river herring from Canadian waters are genetically distinct from Maine river herring.

All of the expert opinions we received during the Stock Structure Workshop suggested evidence of regional stock structure exists for both alewife and blueback herring as shown by the recent genetics data (Palkovacs *et al.*, 2012, unpublished report; Bentzen *et al.*, unpublished data). However, the suggested boundaries of the regional stock complexes differed from expert to expert. Migration and mixing patterns of alewives and blueback herring in the ocean have not been determined, though regional stock mixing is suspected. Therefore, the experts suggested that the ocean phase of alewives and blueback herring should be considered a mixed stock until further tagging and genetic data become available. There is evidence to support regional differences in migration patterns, but not at a level of river-specific stocks.

In the mid-1980s, Rulifson *et al.* (1987) tagged and released approximately 19,000 river herring in the upper Bay of Fundy, Nova Scotia with an overall recapture rate of 0.39 percent. Alewife tag returns 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. Rulifson *et al.* (1987) 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 (n = 2) made it difficult to generalize about the natal rivers of blueback herring caught in the Bay of Fundy. The results of this tagging study show that river herring present in Canadian waters may originate from U.S. waters and vice versa.

Metapopulations of river herring are believed to exist, with adults frequently returning to their natal rivers for spawning and some straying occurring between rivers—straying rates have been estimated up to 20 percent (Jones, 2006; ASMFC, 2009a; Gahagan *et al.*, 2012). Given the available information on genetic differentiation coast-wide for alewife and blueback herring, it appears that stock complexes exist for both species.

River herring originating from Canadian rivers are delimited by international governmental boundaries. Differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist and, therefore, meet the discreteness criterion under the DPS policy; however, intermixing between both alewife and blueback herring from U.S. and Canadian coastal waters occurs, and the extent of this mixing is unknown.

Given the best available information, it is possible to determine that the various stocks of both alewife and blueback herring are discrete. The best available information suggests that the delineation of the stock complexes is as described above; however, future work will likely further refine these preliminary boundaries. Additionally, further information is needed on the oceanic migratory patterns of both species.

Information Related to Significance

If a population is deemed discrete, the population is evaluated in terms of significance. Significance can be determined using the four criteria noted above. Since the best available information indicates that the stock complexes identified for alewives and blueback herring are most likely discrete, the SRT reviewed the available information to determine if they are significant.

In evaluating the significance criterion, the SRT considered all of the above criteria. As indicated earlier, both alewives and blueback herring occupy a large range spanning almost the entire East Coast of the United States and into Canada. They appear to migrate freely throughout their oceanic range and return to freshwater habitats to spawn in streams, lakes and rivers. Therefore, they occupy many different ecological settings throughout their range.

As described earlier, the Palkovacs *et al.* (2012, unpublished report) study assessed the genetic composition of alewife and blueback herring stocks within U.S. rivers using 15 neutral loci and documented that there are at least three stock complexes of alewife in the United States and four stock complexes of blueback herring in the United States. Palkovac *et al.* (2012, unpublished report) showed a strong effect of latitude on genetic divergence, suggesting that although most populations are genetically differentiated, gene flow is greater among neighboring runs than among distant runs. The genetic data are consistent with the recent results of the ASMFC stock assessment (2012), which noted that even among rivers within the same state, there are differences in trends in abundance indices, size-at-age, age structure and other metrics, indicating there are localized factors affecting the population dynamics of both species.

Neutral genetic markers such as microsatellites have a longstanding history of utilization in stock designation for many anadromous fish species (Waples, 1998). However, these markers represent the effects of gene flow and historical population isolation and not the effects of adaptive processes. The effects of adaptive genetic and phenotypic diversity are also extremely important to consider in the context of stock designation, but are not captured by the use of neutral genetic markers. Therefore, the available genetic data are most appropriately used in support of the discreteness criterion, rather than to determine significance.

Determining whether a gap in the range of the taxon would be significant if a stock were extirpated is difficult to determine with anadromous fish such as river herring. River herring are suspected to migrate great distances between their natal rivers and overwintering areas, and therefore, estuarine and marine populations are comprised of mixed stocks. Consequently, the loss of a stock complex would mean the loss of riverine spawning subpopulations, while the marine and estuarine habitat would most likely still be occupied by migratory river herring from other stock complexes. As it has been shown that gene flow is greater among neighboring runs than among distant runs, we might expect that river herring would re-colonize neighboring systems over a relatively short time frame. Thus, the loss of one stock complex in itself may not be significant; the loss of contiguous stock complexes may be. The goal then for river herring stock complexes is to maintain connectivity between genetic groups to support proper metapopulation function (spatially separated populations of the same species that interact, recolonize vacant habitats, and occupy new habitats through dispersal mechanisms (Hanski and Gilpin, 1991)).

DPS Determination

Evidence for genetic differentiation exists for both alewife and blueback herring, allowing for preliminary identification of stock complexes; however, available data are lacking on the significance of each of these individual stock complexes. Therefore, we have determined that there is not enough evidence to suggest that the stock complexes identified through genetics should be treated under the DPS policy as separate DPSs. The stock complexes may be discrete, but under the DPS policy, they are not significant to the species as a whole. Furthermore, given the unknown level of intermixing between Canadian and U.S. river herring in coastal waters, the Canadian stock complex should also not be considered separately under the DPS policy.

Throughout the rest of this determination, the species will be referred to by species (alewife or blueback herring), as river herring where information overlaps, and by the identified stock complexes (Palkovacs *et al.*, 2012, unpublished report) for each species as necessary. While the individual stock complexes do not constitute separate DPSs, they are important components of the overall species and relevant to the evaluation of whether either species may be threatened or endangered in a significant portion of their overall range. Therefore, we have evaluated the threats to, and extinction risk of the overall species and each of the individual stock complexes as presented below. For this analysis, the identified stock complexes for alewife (Figure 1) in the coastal United States for the purposes of this finding will include Northern New England, Southern New England, the Mid-Atlantic, and Canada; and stock complexes for blueback herring (Figure 2) will include Northern New England, Southern New England, Mid-Atlantic, Southern Atlantic, and Canada. While the SRT concluded that there was not sufficient information at this time to determine with any certainty whether alewife or blueback herring stock complexes constitute separate DPSs, they recognized that future information on behavior, ecology and genetic population structure may reveal significant differences, showing fish to be uniquely adapted to each stock complex. We agree with this conclusion. Thus, we are not identifying DPSs for either species.

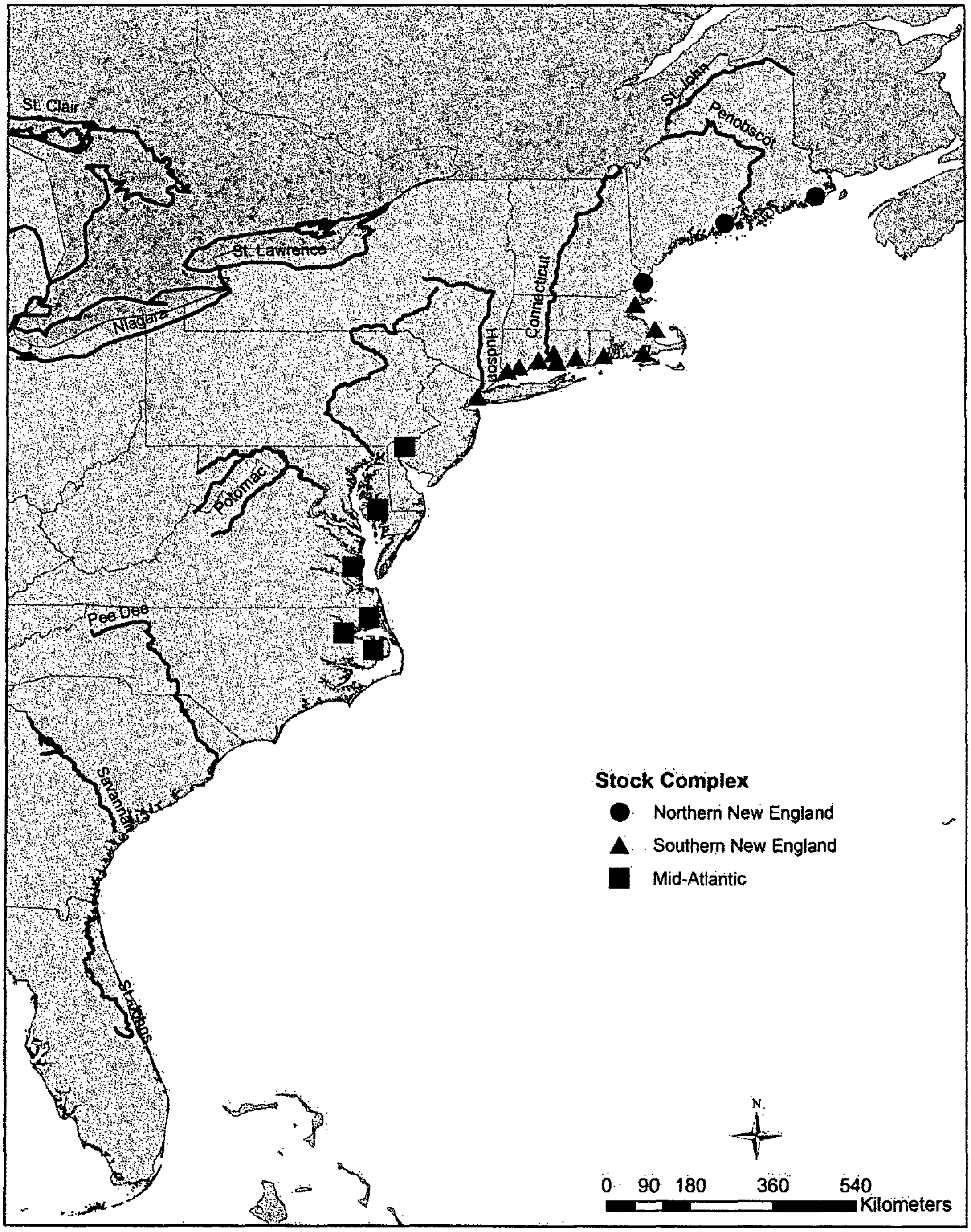

Figure 1. Alewife stock structure identified in Palkovacs et al., 2012, unpublished report.

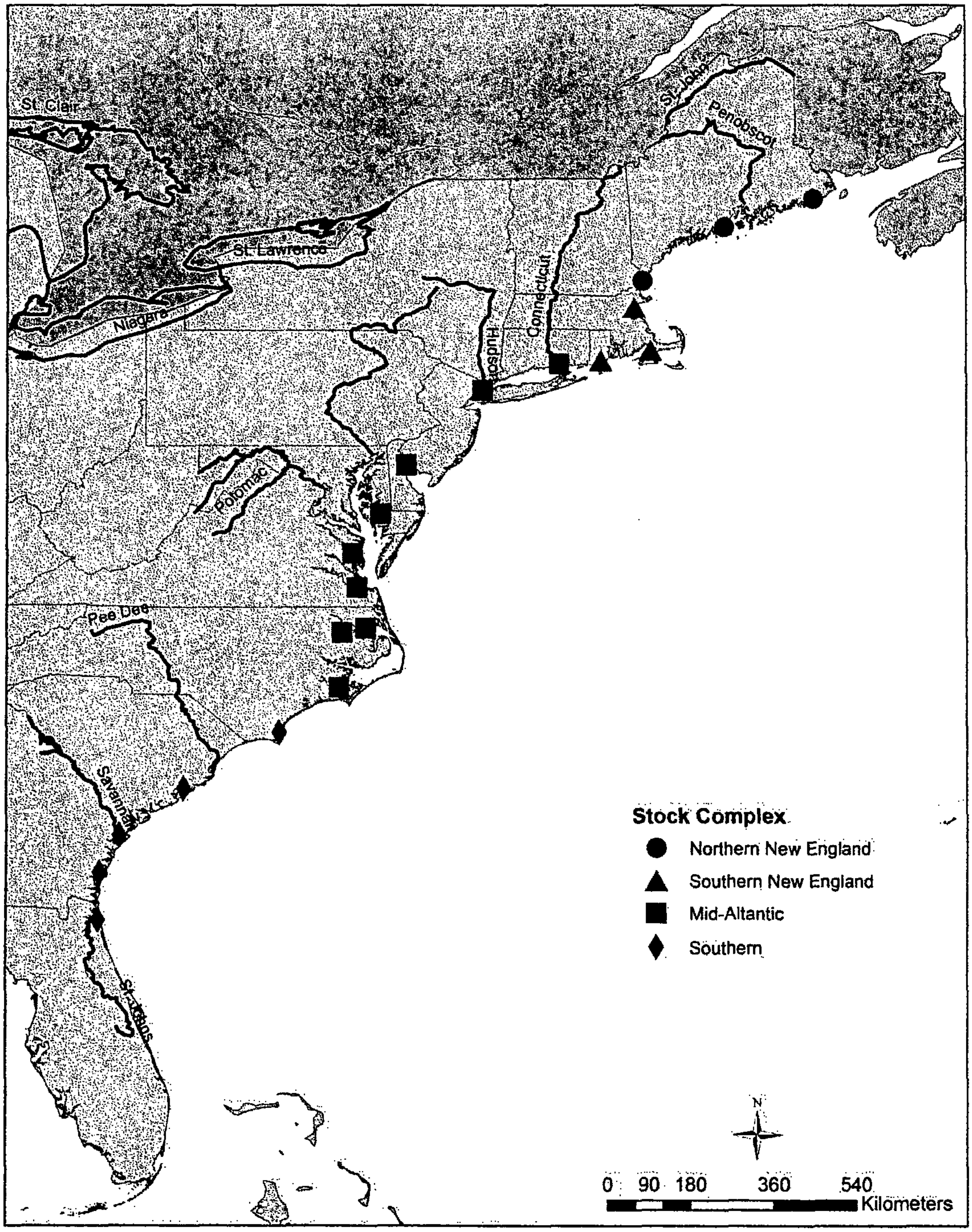

Figure 2. Blueback herring stock structure identified in Palkovacs et al., 2012, unpublished report.

Foreseeable Future and Significant Portion of Its Range

The ESA defines an "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range," while a "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." NMFS and the U.S. Fish and Wildlife Servce (USFWS) recently published a draft policy to clarify the interpretation of the phrase "significant portion of the range" in the ESA definitions of "threatened" and "endangered" (76 FR 76987; December 9, 2011). The draft policy provides that: (1) If a species is found to be endangered or threatened in only a significant portion of its range, the entire species is listed as endangered or threatened, respectively, and the ESA's protections apply across the species' entire range; (2) a portion of the range of a species is "significant" if its contribution to the viability of the species is so important that, without that portion, the species would be in danger of extinction; (3) the range of a species is considered to be the general geographical area within which that species can be found at the time USFWS or NMFS makes any particular status determination; and (4) if the species is not endangered or threatened throughout all of its range, but it is endangered or threatened within a significant portion of its range, and the population in that significant portion is a valid DPS, we will list the DPS rather than the entire taxonomic species or subspecies.

The Services are currently reviewing public comment received on the draft policy. While the Services' intent is to establish a legally binding interpretation of the term "significant portion of the range," the draft policy does not have legal effect until such time as it may be adopted as final policy. Here, we apply the principles of this draft policy as non-binding guidance in evaluating whether to list alewife or blueback herring under the ESA. If the policy changes in a material way, we will revisit the determination and assess whether the final policy would result in a different outcome.

While we have determined that DPSs cannot be defined for either of these species based on the available information, the stock complexes do represent important groupings within the range of both species. Thus, in our analysis of extinction risk and threats assessment below, we have evaluated whether either species is at risk rangewide and within any of the individual stock complexes so that we can evaluate whether either species is threatened or endangered in a significant portion of its range.

We established that the appropriate period of time corresponding to the foreseeable future is a function of the particular type of threats, the life-history characteristics, and the specific habitat requirements for river herring. The timeframe established for the foreseeable future takes into account the time necessary to provide for the conservation and recovery of each species and the ecosystems upon which they depend, but is also a function of the reliability of available data regarding the identified threats and extends only as far as the data allow for making reasonable predictions about the species' response to those threats. As described below, the SRT determined that dams and other impediments to migration have already created a clear and present threat to river herring that will continue into the future. The SRT also evaluated the threat from climate change from 2060 to 2100 and climate variability in the near term (as described in detail below).

Highly productive species with short generation times 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). Given the high population variability among clupeids, projecting out further than three generations could lead to considerable uncertainty in the probability that the model will provide an accurate representation of the population trajectory for each species. Thus, a 12 to 18 year timeframe (e.g., 2024–2030), or a three-generation time period, for each species was determined by the Team to be appropriate for use as the foreseeable future for both alewife and blueback herring. We agree with the Team that a three-generation time period (12–18 years) is a reasonable foreseeable future for both alewife and blueback herring.

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).

Threats Evaluation

As described above, Section 4(a)(1) of the ESA and NMFS implementing regulations (50 CFR 424) states that we must determine whether a species is endangered or threatened because of any one or a combination of the following factors: (A) Current or threatened habitat destruction or modification or curtailment of habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) inadequacy of existing regulatory mechanisms; and (E) other natural or man-made factors affecting the species' continued existence. This section briefly summarizes the findings regarding these factors.

A. The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

Past, present, and reasonably foreseeable future factors that have the potential to affect river herring habitat include, but are not limited to, dams and hydropower facilities, dredging, water quality (including land use change, water withdrawals, discharge and contaminants), climate change and climate variability. As noted above, river herring occupy a variety of different habitats including freshwater, estuarine and marine environments throughout their lives, and thus, they are subjected to habitat impacts occurring in all of these different habitats.

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. 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 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 percent of lake spawning habitat and 20 percent of river habitat remains accessible for river herring (Hall *et al.*, 2010). 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 and impingement (Ruggles 1980; NRC 2004). River herring can undergo indirect 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).

The following summary of the effects of dams and other barriers on river herring is taken from Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring (hereafter, referred to as "Amendment 2" and cited as "ASMFC, 2009"). Because it includes a detailed description of barriers to upstream and downstream passage, it is the best source of comprehensive information on this topic. Please refer to Amendment 2 for more information.

Dams and spillways impeding rivers along the East Coast of the United States have resulted in a considerable loss of historical spawning habitat for shad and river herring. Permanent man-made structures pose an ongoing barrier to fish passage unless fishways are installed or 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 often 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, and in some cases cause rivers to run dry at the base for much of the summer (MEOEA, 2005; ASMFC, 2009).

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 have been found 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 percent to 82 percent) 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 percent to 3 percent 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 rate increased to 11 percent in passage through a low-head Francis turbine (Mathur and Heisey, 1992). Other studies reported less than 5 percent 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 percent (NA, 2001). At another site, mortality rate was about 15 percent where higher revolution, Francis-type runners were used (RMC, 1992; ASMFC, 2009).

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) (ASMFC, 2009).

Changes to the river system, resulting in delayed migration among other things, were also identified in Amendment 2 as impacting 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 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, 2005a). 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; J. McCord, South Carolina Department of Natural Resources, personal observation). Releasing water from dams and impoundments (or reservoirs) may lead to flow alterations, altered sediment transport, disruption of nutrient availability, changes in downstream water quality (including both reduced and increased temperatures), streambank erosion, concentration of sediment and pollutants, changes in species composition, solubilization of iron and manganese and their absorbed or chelated ions, and hydrogen sulfide in hypolimnetic (water at low level outlets) releases (Yeager, 1995; Erkan, 2002; ASMFC, 2009).

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). Conversely, water released from deep reservoirs 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 (ASMFC, 2009).

Reducing minimum 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; ASMFC, 2009).

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; ASMFC, 2009).

Although most dams that impact diadromous fish are located along the lengths of rivers, 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 other surrounding waters are used as foraging areas during summer months by 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; ASMFC, 2009).

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; ASMFC, 2009).

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; ASMFC, 2009).

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. Additional study is underway to determine if river herring are absent from these areas because of the culverts (NCDENR, 2000). Even structures only 8 to 12 in (20 to 30 cm) above the water can block shad and river herring migration (ASMFC, 1999; ASMFC, 2009).

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 (ASMFC, 2009).

Dredging

Wetlands provide migratory corridors and spawning habitat for river herring. The combination of incremental losses of wetland habitat, changes in hydrology, and nutrient and chemical inputs over time, can be extremely harmful, resulting in diseases and declines in the abundance and quality. 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 wetlands loss vary according to the different agencies. The U.S. Department of Agriculture (USDA) attributes 57 percent of wetland loss to development, 20 percent to agriculture, 13 percent to the creation of deepwater habitat, and 10 percent to forest land, rangeland, and other uses. Of the wetlands lost between 1985 and 1995, the USFWS estimates that 79 percent of wetlands were lost to upland agriculture. Urban development and other types of land use activities were responsible for 6 percent and 15 percent of wetland loss, respectively.

Amendment 2 identifies channelization and dredging as a threat to river herring habitat. The following section, taken from Amendment 2, describes these threats.

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). 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.*, 1991b; ASMFC, 2009).

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. 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).

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 re-suspension from dredging can also deplete dissolved oxygen, and increase bioavailability of any contaminants that may be bound to the sediments (Clark and Wilber, 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 (ASMFC, 2009).

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; ASMFC, 2009).

Dredging can negatively affect alosine populations by producing suspended sediments (Reine *et al.*, 1998), and migrating alosines are known to avoid waters of high sediment load (ASMFC, 1985; Reine *et al.*, 1998). Fish may also avoid areas that are being dredged because of suspended sediment in the water column. 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; ASMFC, 2009).

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 and 2009).

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, pollute ground water, or move into streams and coastal waters. Nutrient inputs are known to 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.

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, 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.

Amendment 2 identified land use changes including agriculture, logging/forestry, urbanization and non-point source pollution as threats to river herring habitat. The following section, taken from Amendment 2, describes these threats.

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; ASMFC, 2009).

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). SAV is important because it improves water quality (Carter *et al.*, 1991). SAV consumes nutrients in the water and as the plants die and decay, they slowly release the nutrients 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; ASMFC, 2009).

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; ASMFC, 2009).

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).

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; ASMFC, 2009).

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).

Water Withdrawal/Outfall

Water withdrawal facilities and toxic and thermal discharges have also been identified as impacting river herring, and the following section is summarized from Amendment 2.

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 result in delayed movement past a facility or 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 (Hauck and Edson, 1976; Robbins and Mathur, 1976; ASMFC, 2009).

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-percent mortality when temperatures in the cooling system of a power plant were elevated above 82 °F (28°C); 80 percent of the total mortality was caused by mechanical damage, 20 percent 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 (ASMFC, 2009).

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 (ASMFC, 2009).

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 (ASMFC, 1999). 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; ASMFC, 2009).

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; ASMFC, 2009).

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 as a result of eutrophication and other factors (Winslow *et al.*, 1983; ASMFC, 2009).

Klauda *et al.* (1991a) provides an extensive review of temperature thresholds for alewife and bluback herring. In summary, the spawning migration for alewives most often occurs when water temperatures range from 50–64 °F (10–18 °C), and for bluebacks when temperatures range from 57–77 °F (14–25 °C). Alewife egg deposition most often occurs when temperatures range between 50–72 °F (10 and 22 °C), and for bluebacks when temperatures range between 70–77 °F (21 and 25 °C). Alewife egg and larval development is optimal when temperatures range from 63—70 °F (17–21 °C), and for bluebacks when temperatures range from 68–75 °F (20–24 °C) (temperature ranges were also presented and discussed at the Climate Workshop (NMFS, 2012b)). 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. 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 (ASMFC, 2009).

Water withdrawal for irrigation can cause dewatering or reduced streamflow of freshwater streams, which can decrease the quantity of both spawning and nursery habitat for anadromous fish. Reduced streamflow can reduce water quality by concentrating pollutants and/or increasing water temperature (ASMFC, 1985). 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; ASMFC, 2009).

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).

Climate Change and Climate Variability

Possible climate change impacts to river herring were noted in the stock assessment (ASMFC, 2012) based on regional patterns in trends (e.g., trawl surveys in southern regions showed declining trends more frequently compared to those in northern regions). However, additional information was needed on this topic to inform our listing decision, and as noted above, we held a workshop to obtain expert opinion on the potential impacts of climate change on river herring (NMFS, 2012b).

As discussed at the workshop, both natural climate variability and anthropogenic-forced climate change will affect river herring (NMFS, 2012b). Natural climate variability includes the Atlantic Multidecadal Oscillation, the North Atlantic Oscillation, and the El Niño Southern Oscillation. During the workshop, it was noted that impacts from global climate change induced by human activities are likely to become more apparent in future years (Intergovernmental Panel on Climate Change (IPCC), 2007). Results presented from the North American Regional Climate Change Assessment Program (NARCCAP—a group that uses fields from the global climate models to provide boundary conditions for regional atmospheric models covering most of North America and extending over the adjacent oceans) suggest that temperature will warm throughout the years over the northeast, mid-Atlantic and Southeast United States (comparing 1968–1999 to 2038–2069; NMFS, 2012b). Additionally, it was noted that there is an expected but less certain increase in precipitation over the northeast United States during fall and winter during the same years (NMFS, 2012b). In conjunction with increased evaporation from warmer temperatures, the Northeast and mid-Atlantic may experience decrease in runoff and decreased stream flow in late winter and early spring (NMFS, 2012b). Additionally, enhanced ocean stratification could be caused by greater warming at the ocean surface than at depth (NMFS, 2012b).

Many observed changes in river herring biology related to environmental conditions were noted at the workshop, but few detailed analyses were available to distinguish climate change from climate variability. One analysis by Massachusetts Division of Marine Fisheries showed precipitation effects on spawning run recruitment at Monument River, MA (1980–2012; NMFS, 2012b). Jordaan and Kritzer (unpublished data) showed normalized run counts of alewife and blueback herring have a stronger correlation with fisheries and predators than various climate variables at broad scales (NMFS, 2012b). Once fine-scale (flow related to fishways and dams) data were used, results indicate that summer and fall conditions were more important. Nye *et al.* (2012) investigated climate-related mechanisms in the marine habitat of the United States that may impact river herring. Their preliminary results indicate the following: (1) A shift in northern ocean distribution for both blueback herring and alewife depending on the season; (2) decrease in ocean habitat within the preferred temperature for alewife and blueback herring in the spring; and (3) effects of climate change on river herring populations may depend on the current condition (e.g., abundance and health) of the population, assumptions, and temperature tolerances (e.g., blueback herring have a higher temperature tolerance than alewife).

Although preliminary, Nye *et al.* (2012) indicate that climate change will impact river herring. The results (also supported by Nye *et al.*, 2009) indicate that both blueback herring and alewife have and will continue to shift their distribution to more northerly waters in the spring, and blueback herring has also shifted its distribution to more northerly waters in the fall (1975–2010) (Nye *et al.*, 2012). Additionally, Nye *et al.* (2012) found a decrease in habitat (bottom waters) within the preferred temperature for alewife and blueback herring in the spring under future climate predictions (2020–2060 and 2060–2100). They concluded that an expected decrease in optimal marine habitat and natal spawning habitat will negatively affect river herring populations at the southern extent of their range. Additionally, Nye *et al.* (2012) infer that this will have negative population level effects and cause population declines in southern rivers, resulting in an observed shift in distribution which has already been observed. Nye *et al.* (2012) also found that the effects of climate change on river herring populations may depend on the current condition (e.g., abundance and health) of the population, assumptions, and temperature tolerances. Using the model, projections of alewife distribution and abundance can be predicted for each year, but for ease of interpretation, 2 years of low and high relative abundance were chosen to illustrate the effects of population abundance and temperature on alewife distribution. The low and high abundance years were objectively chosen as the years closest to −1 and +1 standard deviation from overall mean abundance. Two years closest to the −1 and +1 standard deviation from mean population abundance were selected to reflect the combined effect of warming with low and high abundance of blueback herring. The difference in species response (as noted below) may reflect the different temperature tolerances (9–11 °C for blueback herring and 4–11 °C for alewife) as indicated by the southern limit of their ranges. Blueback herring may be able to tolerate higher temperature as their range extends as far south as Florida, but the southern extent of the alewife's range is limited to North Carolina. For both species, the Nye *et al.* (2012) analysis indicates that, if robust populations of these species are maintained, declines due to the effects of climate change will be reduced. Their specific results include the following:

- Alewife: At low population size, coast-wide abundance is projected to decrease with less suitable habitat and patchy areas of high density in the Gulf of Maine and Georges Bank in 2060–2100. At high population size, abundance is projected to increase slightly from 2020–2060 (+4.64 percent) but is projected to decrease (−39.14 percent) and become more patchy in 2060–2100.
- Blueback herring: Abundance is projected to increase at both high and low population size throughout the Northeast United States, especially in the mid-Atlantic and Georges Bank. However, at low abundance the increase is minimal and remains at a level below the 40-year mean. The percentage change due to climate change (factoring only temperature) is +29.93 percent for the time period 2020–2060 and +55.81 percent from 2060–2100.

We hoped to obtain information during the workshop on potential impacts of climate change by region, including information on species, life stage, indicators, potential impacts, and available data/relevant references (NMFS, 2012b). Although we did obtain information on each of these categories, substantial data gaps in the species information were apparent (NMFS, 2012b). For example, although no specific information on impacts of ocean acidification on river herring was presented, possible effects on larval development, chemical signaling (olfaction), and de-calcification of prey were noted (NMFS, 2012b). Additional research is needed to identify the limiting factor(s) for river herring populations. As Nye *et al.* (2012) noted, the links between climate and river herring biology during freshwater stages are unclear and will require additional time to research and thoroughly analyze. This conclusion is supported by the results of the workshop, which noted numerous potential climate effects on the freshwater stages, but little synthesis has been accomplished to date. The preliminary analysis of Nye *et al.* (2012) indicates that water temperatures in the rivers will be warmer, and there will be a decrease in the river flow in the northeast and Mid-Atlantic in late winter/early spring.

Although current information indicates climate change is and will continue to impact river herring (e.g., Nye *et al.*, 2012), climate variability rather than climate change is expected to have more of an impact on river herring from 2024–2030. Several studies have shown that the climate change signal is readily apparent by the end of the 21st century (Hare *et al.*, 2010; Hare *et al.*, 2012). At intermediate time periods (e.g., 2024–2030), the signal of natural climate variability is likely similar to the signal of climate change. Thus, a large component of the climate effect on river herring in 2024–2030 will be composed of natural climate variability, which could be either warming or cooling.

Summary and Evaluation of Factor A

Dams and hydropower facilities, water quality and water withdrawals from urbanization and agricultural runoff, dredging and other wetland alterations are likely the causes of historical and recent declines in abundance of alewife and blueback herring populations. Climate variability rather than climate change is expected to have more of an impact on river herring from 2024–2030 (NMFS' foreseeable future for river herring). Nye *et al.*, (2012) conducted a preliminary analysis investigating climate-related mechanisms in the marine habitat of the United States that may impact river herring, and found that changes in the amount of preferred habitat and a potential northward shift in distribution as a result of climate change may affect river herring in the future (e.g., 2020–2100). Thus, the level of threat posed by these potential stressors is evaluated further in the qualitative threats assessment as described below.

B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Directed Commercial Harvest

This following section on river herring fisheries in the United States is from the stock assessment (ASMFC, 2012).

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.

The earliest commercial river herring data were generally reported in state and town reports or local newspapers. In 1871, the U.S. Fish Commission was founded (later became known as the U.S. Fish and Fisheries Commission in 1881). This organization collected fisheries statistics to characterize the biological and economic aspects of commercial fisheries. Data describing historical river herring fisheries were available from two of this organization's publications—the Bulletin of the U.S. Fish Commission (renamed Fishery Bulletin in 1971; Collins and Smith, 1890; Smith, 1891) and the U.S. Fish Commission Annual Report (USFC, 1888–1940). In the stock assessment, the river herring data were transcribed and when available, dollar values were converted to 2010 dollar values using conversion factors based on the annual average consumer price index (CPI) values, which were obtained from the U.S. Bureau of Labor Statistics. Note that CPI values are not available for years prior to 1913 so conversion factors could not be calculated for years earlier than 1913 (ASMFC, 2012).

There are several caveats to using the historical fisheries data. There is an apparent bias in the area sampled. In most cases, there was no systematic sampling of all fisheries; instead, sampling appeared to be opportunistic, concentrating on the mid-Atlantic States. It is also difficult to assess the accuracy and precision of these data. In some instances, the pounds were reported at a fine level of detail (e.g., at the state/county/gear level), but details regarding the specific source of the data were often not described. The level of detail provided in the reports varied among states and years. Additionally, not all states and fisheries were canvassed in all years, so absence of landings data does not necessarily indicate the fishery was not active as it is possible that the data just were not collected. For these reasons, these historical river herring landings should not be considered even minimum values because of the variation in detail and coverage over the time series. No attempt was made to estimate missing river herring data since no benchmark or data characteristics could be found, and the stock assessment subcommittee also did not attempt to estimate missing data in a time series at a particular location because of the bias associated with these estimates (ASMFC, 2012).

During 1880 to 1938, reported commercial landings of river herring along the Atlantic Coast averaged approximately 30.5 million lbs (13,835 mt) per year. The majority of river herring landed by commercial fisheries in these early years are attributed to the mid-Atlantic region (NY–VA). The dominance of the mid-Atlantic region is, in part, due to the apparent bias in the spatial coverage of the canvass (see above). From 1920 to 1938, the average annual weight of reported commercial river herring landings was about 22.8 million lbs (10,351 mt). The value of the commercial river herring landings during this same time period was approximately 2.87 million dollars (2010 USD) (ASMFC, 2012).

Domestic commercial landings of river herring were presented in the stock assessment by state and by gear from 1887 to 2010 where available. 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 time period and are likely underestimated, particularly for the first third of the time series, since not all river landings were reported (ASMFC, 2012).

Total domestic coast-wide landings averaged 18.5 million lb (8,399 mt) from 1887 to 1928 (*See table 2.2* in ASMFC (2012)). During this early time 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. Coast-wide landings started increasing sharply in the early 1940s and peaked at over 68.7 million lb (31,160 mt) in 1958 (*See Table 2.2,* ASMFC, 2012). In the 1950s and 1960s, a large proportion of the harvest came from Massachusetts purse seine fisheries that operated offshore on Georges Bank targeting Atlantic herring (G. Nelson, Massachusetts Division of Marine Fisheries, Pers. comm., 2012). Landings from North Carolina were also at their highest during this time and originated primarily from the Chowan River pound net fishery. 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 the following states: New Jersey, Delaware, Pennsylvania, Maryland, DC, Virginia (for all waters), Georgia and Florida (ASMFC, 2012).

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, gill nets made up a small percentage of the overall harvest. However, even though the actual pounds landed continued to decline, the proportion of gill nets that contributed to the overall harvest has increased in recent years (ASMFC, 2012).

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 <7.5 in (190 mm) in length) by foreign fleets began in the late 1960s and landings peaked at about 80 million lbs (36,320 mt) in 1969 (ASMFC, 2012).

Total U.S. and foreign fleet harvest of river herring from the waters off the coast of the United States (NAFO areas 5 and 6) peaked at about 140 million lb (63,560 mt) in 1969, after which landings declined dramatically. After 1977 and the formation of the Fishery Conservation Zone, foreign allocation of river herring (to both foreign vessels and joint venture vessels) between 1977 and 1980 was 1.1 million lb (499 mt). The foreign allocation was reduced to 220,000 lb (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, area restrictions were passed 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 (ASMFC, 2012).

In-river Exploitation

The stock assessment subcommittee 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. 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. Exploitation declined in all rivers through 1991 to 1992. 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 Massachusetts 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. Exploitation rates of alewives in the Union River declined through 2005 but have remained above 0.50 since 2007 (ASMFC, 2012).

According to the stock assessment, exploitation of river herring appears to be declining or remaining stable. In-river exploitation was highest in Maine rivers (Damariscotta and Union) and has fluctuated, but it is currently lower than levels seen in the 1980s. Also, in-river exploitation in Massachusetts rivers (Monument and Mattapoisett) was declining at the time a moratorium was imposed in 2005. The coast-wide index of relative exploitation also declined following a peak in the late 1980s and has remained fairly stable over the past decade. Exploitation rates declined in the DB–SRA model runs except when the input biomass-to-*K* ratio in 2010 was 0.01. 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 among various assessment methodologies 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, 2012).

Past high exploitation may also be a reason for the high amount of variation and inconsistent patterns observed in fisheries-independent indices of abundance. Fishing effort has been shown to increase variation in fish abundance through truncation of the age structure, and recruitment becomes primarily governed by environmental variation (Hsieh *et al.*, 2006; Anderson *et al.*, 2008). When fish species are at very low abundances, as is believed for river herring, it is possible that the only population regulatory processes operating are stochastic fluctuations in the environment (Shepherd and Cushing, 1990) (ASMFC, 2012).

Canadian Harvest

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 lb (11,577 mt) in 1980, 23.1 million lb (10,487 mt) in 1988, and 11 million lb (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 lb (1,000 mt) (DFO, 2001). 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.

Incidental Catch

The following section on river herring incidental catch in the United States is from the stock assessment (ASMFC, 2012).

Three recent 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.* (2010) extended this analysis with additional years of data. Further work is needed to elucidate how the landed 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 plus 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 percent 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. The methodology used in this study differed from the Standardized Bycatch Reporting Methodology (SBRM) (the method used by NOAA's Northeast Fisheries Science Center (NEFSC) to quantify bycatch in stock assessments) (Wigley *et al.*, 2007; Wigley *et al.*, 2012). Data from NEFOP were analyzed 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. 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 SBRM. 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 all trips will not exhibit the same attributes. Lessard and Bryan (2011) also did not provide precision estimates, which are imperative for estimation of incidental catch.

The total incidental catch of river herring was estimated as part of the work for Amendment 14 to the Atlantic Mackerel, Squid and Butterfish (MSB) Fishery Management Plan, that includes measures to address incidental catch of river herring and shads. From 2005–2010, the total annual incidental catch of alewife ranged from 41,887 lb (19.0 mt) to 1.04 million lb (472 mt) in New England and 19,620 lb (8.9 mt) to 564,818 lb (256.4 mt) in the Mid-Atlantic. The dominant gear varied across years between paired midwater trawls and bottom trawls. Corresponding estimates of precision (COV) exhibited substantial interannual variation and ranged from 0.28 to 3.12 across gears and regions. Total annual blueback herring incidental catch from 2005 to 2010 ranged from 30,643 lb (13.9 mt) to 389,111 lb (176.6 mt) in New England and 2,645 lb (1.2 mt) to 843,479 lb (382.9 mt) in the Mid-Atlantic. Across years, paired and single midwater trawls exhibited the greatest blueback herring catches, with the exception of 2010 in the mid-Atlantic where bottom trawl was the most dominant gear. Corresponding estimates of precision ranged from 0.27 to 3.65. The temporal distribution of incidental catches was summarized by quarter and fishing region for the most recent 6-year period (2005 to 2010). River herring catches occurred primarily in midwater trawls (76 percent, of which 56 percent were from paired midwater trawls and the rest from single midwater trawls), followed by small mesh bottom trawls (24 percent). Catches of river herring in gillnets were negligible. Across gear types, catches of river herring were greater in New England (56 percent) than in the Mid-Atlantic (44 percent). The percentages of midwater trawl catches of river herring were similar between New England (37 percent) and the Mid-Atlantic (38 percent). However, catches in New England small mesh bottom trawls were three times higher (18 percent) than those from the Mid-Atlantic (6 percent). Overall, the highest quarterly catches of river herring occurred in midwater trawls during Quarter 1 in the Mid-Atlantic (35 percent), followed by catches in New England during Quarter 4 (16 percent) and Quarter 3 (11 percent). Quarterly catches in small mesh bottom trawls were highest in New England during Quarter 1 (7 percent) and totaled 3 to 4 percent during each of the other three quarters.

Recreational Harvest

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 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 stock assessment concluded that these data are not useful for management purposes. MRFSS concentrates their sampling strata in coastal water areas and does not capture any data on recreational fisheries that occur in inland waters. Few states conduct creel surveys or other consistent survey instruments (diary or log books) in their inland waters to collect data on recreational catch of river herring. Some data are reported in the state chapters in the stock assessment; but the stock assessment committee concluded that data are too sparse to conduct any systematic comparison of trends (ASMFC, 2012).

Scientific Monitoring and Educational Harvest

Maine, New Hampshire, Massachusetts and Rhode Island estimate run sizes using electronic counters or visual methods. Various counting methods are used at the Holyoke Dam fish lift and fishways 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 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.

Summary and Evaluation of Factor B

Historical commercial and recreational fisheries for river herring likely contributed to the decline in abundance of both alewife and blueback herring populations. Current directed commercial and recreational alewife and blueback herring fisheries, as well as commercial fishery incidental catch may continue to pose a threat to these species. Since the 1970s, regulations have been enacted in the United States on the directed harvest of river herring in an attempt to halt or reverse their decline with the most recent regulations being imposed in January 2012. Additionally, there are regulations in Canada on river herring harvest. Historical landings data and current fishery effort is the best available information to describe the impact that the commercial fishery may be having on river herring.

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 extent to which incidental catch is affecting river herring has not been quantified and is not fully understood. Thus, the level of threat posed by directed and indirect catch is evaluated further in the qualitative threats assessment as described below. Scientific collections or collections for educational purposes do not appear to be significantly affecting the status of river herring, as they result in low mortality.

C. Disease and Predation

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 prespawning and 10 percent of postspawning 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 percent 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).

Predation

Information on predation of river herring was compiled and published in Volume I of the River Herring Benchmark Assessment (2012) by ASMFC. The following section on predation was compiled by Dr. Katie Drew from this assessment.

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 percent of striped bass diet by weight) (Smith and Link, 2010), while studies that sampled striped bass in rivers and estuaries during the spring spawning runs found much higher rates of consumption (greater than 60 percent 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.

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 have been observed to 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 specifically, 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.

Predation and multispecies models, such as the MS–VPA (NEFSC, 2006), have tremendous data needs, and more research needs to be conducted before they can be applied to river herring. However, given the potential magnitude of predatory interactions, it is an area of research worth pursuing (ASMFC, 2012).

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, and are, therefore, being 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 percent 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; however, they exhibit no consistent trends along the coast.

Summary and Evaluation for Factor C

While data are limited, the best available information indicates that river herring are not likely affected to a large degree by diseases caused by viruses, bacteria, protozoans, metazoans, or microalgae. Much of the information on diseases in alewife or blueback herring comes from studies on landlocked species; therefore, even if studies indicated that landlocked alewife and blueback herring were highly susceptible to diseases and suffered high mortality rates, it is not known whether anadromous river herring would be affected in the same way. While it may be possible that disease threats to river herring could increase in prevalence or magnitude under various climate change scenarios, there are currently no data available to support this supposition. We have included disease as a threat in the qualitative threats assessment described in detail below.

Alewife and blueback herring are considered to be an important forage fish for many marine and anadromous predators, and therefore, may be affected by predation, especially if some populations of predators (e.g., striped bass, spiny dogfish) continue to increase. There may also be effects from predation by invasive species such as the blue and flathead catfish. Some predation and multispecies models have estimated an effect of predation on river herring, while others have not. In general, the effect of predation on the persistence of river herring is not fully understood; however, predation may be affecting river herring populations and consequently, it is included as a threat in the qualitative threats assessment described below.

D. Inadequacy of Existing Regulatory Mechanisms

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. These regulatory mechanisms are described in detail in the following section.

International

The Canadian 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 includes requirements when fishing for or catching and retaining river herring in recreational and commercial fisheries (DFO, 2006; *http://laws-lois.justice.gc.ca*).

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 number of licenses to existing levels in all areas (DFO, 2001). Logbooks are issued to commercial fishermen 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), while in other rivers river herring were harvested at or below the reference point (e.g., St. John River at Mactaquac Dam). 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, 2006). 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). For example, it notes a management problem of gear congestion in some rivers and an approach to establish a carrying capacity of the river and find a solution to the gear limit by working with fishermen (DFO, 2006). At this time, an updated Eastern New Brunswick IFMP is not available.

Federal

ASMFC and Enabling Legislation

Authorized under the terms of the Atlantic States Marine Fisheries Compact, as amended (Pub. L. 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."

Given management authority in 1993 under the Atlantic Coastal Fisheries Cooperative Management Act (16 U.S.C. 5101–5108), the ASMFC may issue interstate FMPs that must be administered by state agencies. If the ASMFC believes 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 not in compliance with the management plan, the Secretaries must declare a moratorium on the fishery in question.

Atlantic Coastal Fisheries Cooperative Management Act

We manage river herring stocks 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 Interstate Fishery Management Plan for American Shad and River Herring (ISFMP) developed by the ASMFC; and (2) consistent with the national standards set forth in section 301 of the MSA.

The ASMFC adopted Amendment 2 to the ISFMP in 2009. Amendment 2 establishes the foundation for river herring management. It was developed to address concerns that many Atlantic coast populations of river herring were in decline or are at depressed but stable 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 is 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, the states of ME, NH, RI, NY, NC, and SC have approved river herring management plans (see "State section of Factor D" for more information).

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 sea herring, occurs outside state jurisdiction and remains a substantial source of fishing mortality according to the ASMFC. Consequently, the ASMFC has requested that the New England and Mid-Atlantic Fishery Management Councils (NEFMC and MAFMC) increase efforts to monitor river herring incidental catch in small-mesh fisheries (See section on "NEFMC and MAFMC recommendations for future river herring bycatch reduction efforts").

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 2006. 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. A 1996 amendment focused on rebuilding overfished fisheries, protecting Essential Fish Habitat (EFH), and reducing bycatch. A 2006 amendment mandated the use of Annual Catch Limits (ACL) and Accountability Measures (AM) 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 is encountered both as 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, squid and butterfish) and are either discarded or retained in those fisheries.

Essential Fish Habitat Under the MSA

Under the MSA, there is a requirement to describe and identify 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 selected 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 middle Atlantic south to Cape Hatteras out to the offshore U.S. boundary of the EEZ (see NEFMC 1998). These areas incorporate nearly all of the U.S. marine areas most frequently used by river herring for growth and maturity. Subsequently, in areas where EFH designations for Atlantic salmon and Atlantic herring overlap with freshwater and marine habitats used by river herring, conservation benefits afforded through the designation of EFH for these species may provide similar benefits to river herring.

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 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. With regard to fish passage, Section 18 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. Interested parties may intervene in the FERC proceeding for any project to receive pertinent documentation and to appeal an adverse decision by FERC.

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 many habitats 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.

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. This Act was last authorized in 2002, which provided 5 million dollars for the fiscal years 2005 and 2006 (Pub. L. 107–372). There was an attempt to reauthorize the Act in 2012; however, this action has not yet been authorized.

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 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.

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

Also called 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 River 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. Examples include reductions in sewage discharges into the Hudson River (A. Kahnle, New York State DEC, Pers. comm. 1998) and nutrient reduction strategies implemented in the Chesapeake Bay (R. St. Pierre, USFWS, Pers. comm. 1998).

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.

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 impact fish and wildlife habitat.

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.

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, Energy and Interior (National Parks and National Wildlife Refuges, 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.

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.

Atlantic Salmon ESA Listing and Critical Habitat Designation

In 2009, the Gulf of Maine (GOM) DPS of Atlantic salmon was listed as endangered under the Endangered Species Act (74 FR 29344). 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 as a result 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 a lot 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 must be considered during consultation with NMFS to ensure that Atlantic salmon critical habitat is not adversely affected by a Federal action.

Atlantic Sturgeon ESA Listing

In 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.

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.

State Regulations

A historical review of state regulations was compiled and published in Volume I of the stock assessment. The following section on state regulations includes current requirements only and is cited from Volume I of the assessment as compiled by Dr. Gary Nelson and Kate Taylor (ASMFC, 2012). Otherwise, updates are provided by Kate Taylor, supplemental information from state river herring plans or state regulations.

Maine

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. Maine increased the weekly fishing closure from a 24-hour closure in the 1960s to a 48-hour closure beginning in 1988. The closed period increased to 72 hours beginning in 1995 to protect spawning fish. 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 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. The commercial fishery does not exploit the estimated 1.5 to 2.0 million river herring that return to the East Machias River annually. These regulations have been approved through a sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River Herring FMP (Taylor, Pers. Comm., 2013).

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. These regulations have been approved through a sustainable fisheries management plan, as required under ASMFC Amendment 2 to the Shad and River Herring FMP (Taylor, Pers. Comm., 2013).

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; and 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) × 18 in (45.72 cm) × 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. 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 (Taylor, Pers. Comm., 2013). The exception is for federally permitted vessels which are allowed to land up to 5 percent of total bait fish per trip (Taylor, Pers. Comm., 2013).

Rhode Island

The Rhode Island Division of Fish and Wildlife (RIDFW) will implement a 5 percent 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. As of Jan 1, 2013, there is a prohibition to land, catch, take, or attempt to catch or take river herring which is a continuation of measures that RIDFW has had in place since 2006 when a moratorium was originally established (Taylor, Pers. comm., 2013).

Connecticut

Since April 2002, there has been a prohibition on the commercial or recreational taking of migratory alewives and blueback herring from all marine waters and most inland waters. 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 (Taylor, Pers. Comm., 2013).

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. 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/Delaware

As of January 1, 2012, commercial harvest of river herring was prohibited in New Jersey and Delaware, as required by ASMFC Amendment 2 to the Shad and River Herring FMP. Additionally, only commercial vessels fishing exclusively in Federal waters while operating with a valid Federal permit for Atlantic mackerel and/or Atlantic herring may possess river herring up to a maximum of five percent by weight of all species possessed (Taylor, Pers. Comm.).

Maryland

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 (Taylor, Pers. comm). This will allow bait shops to sell, and fishermen to possess, river herring for bait that was harvested from a state whose fishery remains open, as an ASMFC approved sustainable fishery (Taylor, Pers. Comm).

Potomac River Fisheries Commission (PRFC)/District of Columbia

The PRFC regulates only the mainstem of the 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. Today, the river herring harvest in the Potomac is almost exclusively taken by pound nets. In 1964, licenses were required to commercially harvest fish in the Potomac River. After Maryland and Virginia established limited entry fisheries in the 1990s, the PRFC responded to industry's request and, in 1995, capped the Potomac River pound net fishery at 100 licenses. 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.

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. 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 (NCWRC) 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.

South Carolina

In South Carolina, the South Carolina Division 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 fishermen 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

The take of blueback herring is illegal in freshwater in 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.

Tribal and First Nation Fisheries

We have identified thirteen federally recognized East Coast tribes from Maine to South Carolina that have tribal rights to sustenance and ceremonial fishing, and which may harvest river herring for sustenance and ceremonial purposes and/or engage in other river herring conservation and management activities. The Mashpee Wampanoag tribe is the only East Coast tribe that voluntarily reported harvest numbers to the State of MA that were incorporated into the ASMFC Management Plan as subsistence harvest. The reported harvest for 2006 and 2008 ranged between 1,200 and 3,500 fish per year, with removals coming from several rivers. Aside from the harvest reported by ASMFC for the Mashpee Wampanoag tribe, information as to what tribes may harvest river herring for sustenance and/or ceremonial purposes is not available. Letters have been sent to all 13 potentially affected tribes to solicit any input they may have on the conservation status of the species and/or health of particular riverine populations, tribal conservation and management activities for river herring, biological data for either species, and comments and/or concerns regarding the status review process and potential implications for tribal trust resources and activities. To date, we have not received any information from any tribes.

Summary and Evaluation for Factor D

As described in Factor A, there are multiple threats to habitat that have affected and may continue to affect river herring including dams/culverts, dredging, water quality, water withdrawals and discharge. However, many of these threats are being addressed to some degree through existing Federal legislation such as the Federal Water Pollution Control Act, also known as the Clean Water Act, the Coastal Zone Management Act, the Rivers and Harbors Act, the FPA, Marine Protection, Research and Sanctuaries Act of 1972, the Shore Protection Act of 1988, EFH designations for other species and ESA listings for Atlantic salmon and Atlantic sturgeon.

Commercial harvest of alewife and blueback herring is occurring in Canada with regulations, closures, and quotas in effect. In the United States, commercial harvest of alewife and blueback herring is also 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. However, river herring are incidentally caught in several commercial fisheries, but the extent to which this is occurring has not been fully quantified. 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. In the United States, thirteen federally recognized East Coast tribes from Maine to South Carolina have tribal rights to sustenance and ceremonial fishing, and may harvest river herring for sustenance and ceremonial purposes and/or engage in other river herring conservation and management activities. We have further evaluated the existing international, Federal, and state management measures in the qualitative threats assessment section below.

E. Other Natural or Manmade Factors Affecting the Continued Existence of the Species

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.

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 (Bentzen, 2012, unpublished data); 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 2011 forward) is 150,000 fish. Adult river herring are trapped at a 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). The New Hampshire Fish and Game stocks river herring into the Nashua River, the Pine Island Pond, and the Winnisquam Lake using fish from various rivers which have included the Connecticut, Cocheco, Lamprey, Kennebec, and Androscoggin Rivers. MA Division of Marine Fisheries (DMF) conducts a trap and transport stocking program for alewife and blueback herring. Prior to the moratorium in the state, the program transported between 30,000 and 50,000 fish per year into 10–15 different systems. Since the moratorium, effort has been reduced to protect donor populations and approximately 20,000 fish per year have been deposited into five to ten systems. Many of the recent efforts have been within system, moving fish upstream past multiple obstructions to the headwater spawning habitat. Rhode Island's Department of Environmental Management (DEM) has been stocking the Blackstone River with adult broodstock which was acquired from existing Rhode Island river herring runs and other sources out of state. In April 2012, over 2,000 river herring pre-spawned adults were stocked into the Blackstone River. A small number of alewife (200–400 fish) were stocked in the Bronx River, NY, in 2006 and 2007 from Brides Brook in East Lyme, CT. Furthermore, an experimental stocking program exists in Virginia where hatchery broodstock are marked and stocked into the Kimages Creek, a tributary to the James River. A total of 319,856 marked river herring fry were stocked in this creek in 2011.

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. This is a pilot project to see if hatchery contribution makes a significant improvement in runs of returning adults (S. Jackson, USFWS, Pers. comm., 2012). Artificial propagation through the Edenton NFH for the pilot program in the Chowan River watershed is intended for restoration purposes, and it is not thought that negative impacts to anadromous blueback herring populations will be associated with these efforts.

Landlocked Alewife and Blueback Herring

As noted above, 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 & 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 back to an anadromous life history if they had the opportunity to do so (Gephard and Jordaan, Pers. comm., 2012). 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.

Interbreeding Among Alewife and Blueback Herring (Hybridization)

Recent genetic studies indicate that hybridization may be occurring in some instances among alewife and blueback herring where populations overlap (discussed in the River Herring Stock Structure Working Group Report, NMFS, 2012a). Though interbreeding among closely related species is uncommon, it does occasionally occur (Levin, 2002). Most often, different reproductive strategies, home ranges, and habitat differences of closely related species either 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, intermediate environmental conditions can provide an environment where hybrids can thrive, and 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).

Though evidence has come forward that indicates that some hybridization may be 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. Most importantly, there is not enough evidence to show whether hybrids survive to maturity and, if so, whether they are capable of breeding with each other or breeding with either of the parent species.

Summary and Evaluation of Factor E

The potential for inter- and intra-specific competition has been investigated with respect to alewife and blueback herring. Differences have been observed in the diel activity patterns and in spawning times of anadromous alosids, and this may reduce inter- and intra- specific competition. However, it is possible that competition is occurring, as similarities in prey choice have been identified. Stocking is a tool that managers have used for hundreds of years with many different species of fish. This tool has been used as a means of supporting restoration (e.g., passing fish above barriers into suitable spawning and rearing habitat, expanding populations into other watersheds, and introducing fish to newly accessible spawning habitat). In addition, stocking has been used to introduce species to a watershed for recreational purposes. Stocking of river herring has occurred for many years in Maine watersheds, but is less common throughout the rest of the range of both species. Stocking in the United States has consisted primarily of trap and truck operations that move fish from one river system to another or over an impassible dam. Artificial propagation of river herring is not occurring to a significant extent, though blueback herring are being reared on a small scale for experimental stocking in North Carolina.

We have considered natural or manmade factors that may affect river herring, including competition, artificial propagation and stocking, landlocked river herring, and hybrids. Several potential natural or manmade threats to river herring were identified, and we have considered the effects of these potential threats further in the qualitative threats assessment described below.

Threats Evaluation for Alewife and Blueback Herring

During the course of the Status Review for river herring, 22 potential threats to alewife and blueback herring were identified that relate to one or more of the five ESA section 4(a)(1) factors identified above. The SRT conducted a qualitative threats assessment (QTA) to help evaluate the significance of the threats to both species of river herring now and into the foreseeable future. NMFS has used qualitative analyses to estimate extinction risk in previous status reviews on the West Coast (e.g., Pacific salmon, Pacific herring, Pacific hake, rockfish, and eulachon) and East Coast (e.g., Atlantic sturgeon, cusk, Atlantic wolffish), and the River Herring SRT developed a qualitative ranking system that was adapted from these types of qualitative analyses. The results from the threats assessment have been organized and described according to the above mentioned section 4(a)(1) factors. They were used in combination with the results of the extinction risk modeling to make a determination as to whether listing is warranted.

When ranking each threat, Team members considered how various demographic variables (e.g., abundance, population size, productivity, spatial structure and genetic diversity) may be affected by a particular threat. While Factor D, "inadequacy of existing regulatory mechanisms," is a different type of factor, the impacts on the species resulting from unregulated or inadequately regulated threats should be evaluated in the same way as the other four factors.

QTA Methods

All nine SRT members conducted an independent, qualitative ranking of the severity of each of the 22 identified threats to alewives and blueback herring. NERO staff developed fact sheets for the SRT that contained essential information about the particular threats under each of the five ESA section 4(a)(1) factors, attempts to ameliorate these threats, and how the threats are or may be affecting both species. These fact sheets were reviewed by various experts within NMFS to ensure that they contained all of the best available information for each of the factors.

Team members ranked the threats separately for both species at a rangewide scale and at the individual stock complex level. Each Team member was allotted five likelihood points to rank each threat. Team members ranked the severity of each threat through the allocation of these five likelihood points across five ranks ranging from "low" to "high." Each Team member could allocate all five likelihood points to one rank or distribute the likelihood points across several ranks to account for any uncertainty. Each individual Team member distributed the likelihood points as he/she deemed appropriate with the condition that all five likelihood points had to be used for each threat. Team members also had the option of ranking the threat as "0" to indicate that in their opinion there were insufficient data to assign a rank, 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 Team member chose either N/A (Not Applicable) or 0 (Unknown) for a threat, all 5 likelihood points had to be assigned to that rank only. Qualitative descriptions of ranks for the threats listed for alewife and blueback herring (Table 1, 2) are:

- N/A—Not Applicable.
- 0—Unknown.
- 1 Low—It is likely that this threat is not significantly affecting the species now and into the foreseeable future, and that this threat is limited in geographic scope or is localized within the species/stock complex' range.
- 2 Moderately Low—Threat falls between rankings 1 and 3.
- 3 Moderate—It is likely that this threat has some effect on the species now and into the foreseeable future, and it is widespread throughout the species/stock complex' range.
- 4 Moderately High—Threat falls between rankings 3 and 5.
- 5 High—It is likely that this threat is significantly affecting the species now and into the foreseeable future, and it is widespread in geographic scope and pervasive throughout the species/stock complex' range.

The SRT identified and ranked 22 threats to both species both rangewide and for the individual stock complexes. Threats included dams and barriers, dredging, water quality and water withdrawals, climate change/variability, harvest (both directed and incidental), disease, predation, management internationally, federally, and at the state level, competition, artificial propagation and stocking, hybrids, and from landlocked populations.

QTA Results

The SRT unequivocally identified dams and barriers as the most important threat to alewife and blueback herring populations both rangewide and across all stock complexes (the qualitative ranking for dams and barriers was between moderately high and high). Incidental catch, climate change, dredging, water quality, water withdrawal/outfall, predation, and existing regulation were among the more important threats after dams for both species, and for all stock complexes (qualitative rankings for these threats ranged between moderately low and moderate). Water quality, water withdrawal/outfall, predation, climate change and climate variability were generally seen as greater threats to both species in the southern portion of their ranges than in the northern portion of their ranges. In addition, the Team identified commercial harvest as being notably more important in Canada than in the United States. The results of the threats analysis for alewives are presented in Tables 1–5 and Figure 3. The results of the threats analysis for blueback herring are presented in Tables 6–10 and Figure 4.

QTA Conclusion

The distribution of rankings across threat levels provides a way to evaluate certainty in the threat level for each of the threats identified. The amount of certainty for a threat is a reflection of the amount of evidence that links a particular threat to the continued survival of each species. For threats with more data, there tended to be more certainty surrounding the threat level, whereas threats with fewer data tended to have more uncertainty. The same holds true for datasets that were limited over space and/or time.

The results of the threats assessment rangewide and for all stock complexes reveal strong agreement and low uncertainty among the reviewers that dams and barriers are the greatest threat to both alewives and blueback herring. There was also strong agreement that tribal fisheries, scientific monitoring, and educational harvest currently pose little threat to the species. For the threats of state, Federal and international management, dredging, climate change, climate variability, predation, and incidental catch, there was more uncertainty.

Among alewife and blueback stock complexes, Canada, the Mid-Atlantic, and South Atlantic diverged the most from the other stock complexes with respect to certainty of threats. In Canada there was more certainty surrounding the threats of climate change and climate variability for both species, and less certainty surrounding the threat of directed commercial harvest and incidental catch for alewives compared to the certainty surrounding these threats for the other stock complexes. In the mid-Atlantic for alewives and South-Atlantic for bluebacks, there was more uncertainty surrounding climate variability and climate change compared to the certainty surrounding these threats for the other stock complexes.

Based on the Team member rankings, dams and other barriers present the greatest and most persistent threat rangewide to both blueback herring and alewife (Tables 12–13). Dams and culverts block access to historical migratory corridors and spawning locations, in some instances, even when fish passage facilities are present. Centuries of blocked and reduced access to spawning and rearing habitat have resulted in decreased overall production potential of watersheds along the Atlantic coast for alewives and blueback herring (Hall *et al.*, 2012). This reduced production potential has likely been one of the main drivers in the decreased abundance of both species. The recent ASMFC Stock Assessment (2012) attempted to quantify biomass estimates for both alewife and blueback herring but was unable to develop an acceptable model to complete a biomass estimate. Therefore, it is difficult to accurately quantify the declines from historical biomass to present-day biomass, though significant declines have been noted. Studies from Maine show that dams have reduced accessible habitat to a fraction of historical levels, 5 percent for alewives and 20 percent for blueback herring (Hall *et al.*, 2011).

Rangewide, for alewife and blueback herring, no other threats rose to the level of dams, but several other stressors ranked near the moderate threat level. The Team ranked incidental catch, water quality, and predation as threats likely to have some effect on the species now and into the foreseeable future that are widespread throughout the species' range. Incidental catch is primarily from fisheries that use small-mesh mobile gear, such as bottom and midwater trawls. Sources of water quality problems vary from river to river and are therefore unique to each of the stock complexes. And finally, predation by striped bass, seals, double-crested cormorants (and other fish-eating avian species, e.g., northern gannets) and other predators is known to exist, but data are lacking on the overall magnitude. Overall, the degree of certainty associated with these mid-level threats is much lower, primarily due to lack of information on how these stressors are affecting both species.

The SRT's qualitative rankings and analysis of threats for alewife rangewide and for each stock complex:

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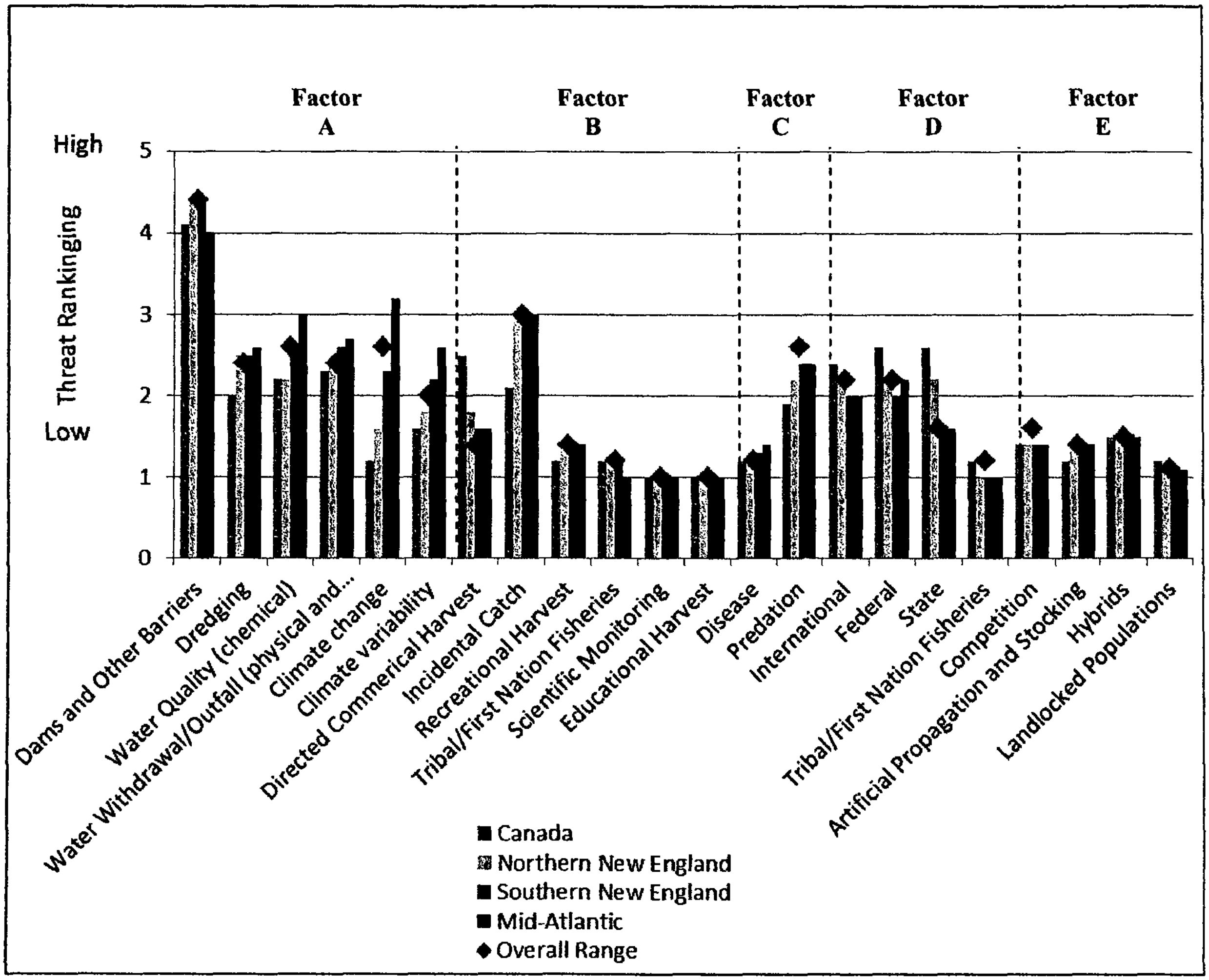

Figure 3. Median qualitative ranking of threats to alewives range-wide and for each stock complex.

Table 1. Qualitative ranking of threats for the alewife rangewide. Status Review Team members ranked threats by distributing 5 likelihood points among 5 ranks: 1- low, 2- medium/low, 3- medium, 4-medium/high, 5-high. The mean represents the overall Team average rank, mode represents the rank which received the most likelihood points, and range represents the range of ranks that were assigned likelihood points for each threat. N=number of Team members who ranked the threat between 1 and 5; likelihood points for threats that Team members ranked as either unknown or not applicable are not included.

Threats	Mean	SD	Mode	Range	N
Dams and Other Barriers	4.3	0.7	5	3-5	9
Water Quality (chemical)	2.8	1.0	3	1-5	9
Incidental Catch	2.7	0.9	3	1-5	9
Predation	2.6	1.1	3	1-5	9
Water Withdrawal/Outfall (physical and temp.)	2.4	0.8	2	1-5	9
Dredging	2.4	1.0	2	1-4	9
Climate change	2.4	0.9	3	1-4	8
Climate variability	2.3	1.1	2	1-5	9
Federal Management	2.3	1.1	2	1-5	9
International Management	2.3	1.1	2	1-5	9
State Management	2.2	1.2	1	1-5	9
Directed Commercial Harvest	1.8	0.8	2	1-3	9
Competition	1.6	0.7	1	1-4	9
Artificial Propagation and Stocking	1.5	0.7	1	1-3	9
Hybrids	1.5	0.7	1	1-3	2
Recreational Harvest	1.4	0.6	1	1-3	9
Tribal/First Nation Fisheries Management	1.3	0.5	1	1-3	7
Disease	1.3	0.4	1	1-2	8
Landlocked Populations	1.2	0.5	1	1-3	8
Tribal/First Nation Fisheries Utilization	1.2	0.4	1	1-2	8
Scientific Monitoring	1.0	0.2	1	1-2	9
Educational Harvest	1.0	0.1	1	1-2	9

Table 2. Qualitative ranking of threats for the Canadian stock complex of alewife. Status Review Team members ranked threats by distributing 5 likelihood points among 5 ranks: 1- low, 2-medium/low, 3- medium, 4-medium/high, 5-high. The mean represents the overall Team average rank, mode represents the rank which received the most likelihood points, and range represents the range of ranks that were assigned likelihood points for each threat. N=number of Team members who ranked the threat between 1 and 5; likelihood points for threats that Team members ranked as either unknown or not applicable are not included.

Threats	Mean	SD	Mode	Range	N
Dams and Other Barriers	4.0	0.9	5	2-5	8
State Management	2.4	0.9	2	1-4	6
Incidental Catch	2.4	1.2	1	1-5	6
Federal Management	2.4	0.9	2	1-4	6
Water Withdrawal/Outfall (physical and temp.)	2.3	0.7	2	1-3	6
Directed Commercial Harvest	2.2	0.9	2	1-4	8
International Management	2.2	0.9	2	1-4	8
Water Quality (chemical)	2.1	0.7	2	1-3	7
Predation	2.1	1.0	2	1-5	8
Dredging	2.0	0.7	2	1-4	6
Climate variability	1.9	0.9	2	1-5	8
Climate change	1.6	0.7	1	1-4	8
Hybrids	1.5	0.7	1	1-3	2
Competition	1.4	0.5	1	1-3	9
Disease	1.3	0.5	1	1-2	7
Artificial Propagation and Stocking	1.3	0.5	1	1-3	7
Tribal/First Nation Fisheries Management	1.2	0.4	1	1-2	5
Recreational Harvest	1.2	0.4	1	1-2	6
Tribal/First Nation Fisheries Utilization	1.2	0.4	1	1-2	6
Landlocked Populations	1.1	0.3	1	1-2	7
Scientific Monitoring	1.0	0.2	1	1-2	6
Educational Harvest	1.0	0.0	1	1	6

Table 3. Qualitative ranking of threats for the Northern New England stock complex of alewife. Status Review Team members ranked threats by distributing 5 likelihood points among 5 ranks: 1- low, 2-medium/low, 3- medium, 4-medium/high, 5-high. The mean represents the overall Team average rank, mode represents the rank which received the most likelihood points, and range represents the range of ranks that were assigned likelihood points for each threat. N=number of Team members who ranked the threat between 1 and 5; likelihood points for threats that Team members ranked as either unknown or not applicable are not included.

Threats	Mean	SD	Mode	Range	N
Dams and Other Barriers	4.3	0.7	5	3-5	9
Incidental Catch	2.9	0.8	3	1-5	7
Water Withdrawal/Outfall (physical and temp.)	2.5	0.9	3	1-5	8
Dredging	2.4	0.9	2,3	1-4	8
State Management	2.4	1.1	2	1-5	9
Predation	2.4	1.2	2	1-5	9
Federal Management	2.4	1.1	2	1-5	9
International Management	2.2	0.9	2	1-4	9
Water Quality (chemical)	2.1	1.0	1	1-5	9
Climate variability	2.0	1.0	2	1-5	9
Directed Commercial Harvest	1.9	0.9	1	1-4	9
Climate change	1.8	0.8	1	1-4	8
Artificial Propagation and Stocking	1.6	0.7	1	1-3	9
Hybrids	1.5	0.7	1	1-3	2
Competition	1.5	0.6	1	1-3	9
Recreational Harvest	1.3	0.5	1	1-3	9
Disease	1.3	0.5	1	1-2	8
Landlocked Populations	1.2	0.4	1	1-2	8
Tribal/First Nation Fisheries Management	1.2	0.4	1	1-2	7
Tribal/First Nation Fisheries Utilization	1.1	0.3	1	1-2	8
Scientific Monitoring	1.0	0.1	1	1-2	9
Educational Harvest	1.0	0.0	1	1	9

Table 4. Qualitative ranking of threats for the Southern New England stock complex of alewife. Status Review Team members ranked threats by distributing 5 likelihood points among 5 ranks: 1- low, 2-medium/low, 3- medium, 4-medium/high, 5-high. The mean represents the overall Team average rank, mode represents the rank which received the most likelihood points, and range represents the range of ranks that were assigned likelihood points for each threat. N=number of Team members who ranked the threat between 1 and 5; likelihood points for threats that Team members ranked as either unknown or not applicable are not included.

Threats	Mean	SD	Mode	Range	N
Dams and Other Barriers	4.2	0.7	4	3-5	9
Incidental Catch	2.9	0.8	3	1-5	7
Water Withdrawal/Outfall (physical and temp.)	2.7	0.8	3	1-5	8
Water Quality (chemical)	2.5	0.9	3	1-5	9
Predation	2.5	1.1	2	1-5	9
Dredging	2.5	0.9	3	1-4	8
Federal Management	2.2	1.1	2	1-5	9
Climate variability	2.2	1.0	2	1-5	9
State Management	2.2	1.1	2	1-5	9
Climate change	2.2	1.0	1,3	1-4	8
International Management	2.0	0.8	2	1-4	9
Directed Commercial Harvest	1.7	0.8	1	1-3	9
Hybrids	1.5	0.7	1	1-3	2
Artificial Propagation and Stocking	1.5	0.6	1	1-3	9
Competition	1.4	0.6	1	1-3	9
Disease	1.3	0.5	1	1-2	8
Recreational Harvest	1.3	0.5	1	1-3	9
Landlocked Populations	1.2	0.4	1	1-2	8
Tribal/First Nation Fisheries Management	1.2	0.4	1	1-2	7
Tribal/First Nation Fisheries Utilization	1.2	0.4	1	1-2	8
Scientific Monitoring	1.0	0.1	1	1-2	9
Educational Harvest	1.0	0.0	1	1	9

Table 5. Qualitative ranking of threats for the Mid-Atlantic stock complex of alewife. Status Review Team members ranked threats by distributing 5 likelihood points among 5 ranks: 1- low, 2-medium/low, 3- medium, 4-medium/high, 5-high. The mean represents the overall Team average rank, mode represents the rank which received the most likelihood points, and range represents the range of ranks that were assigned likelihood points for each threat. N=number of Team members who ranked the threat between 1 and 5; likelihood points for threats that Team members ranked as either unknown or not applicable are not included.

Threats	Mean	SD	Mode	Range	N
Dams and Other Barriers	3.8	1.0	4	3-5	9
Incidental Catch	2.9	0.8	3	1-5	7
Water Quality (chemical)	2.9	0.9	3	1-5	9
Water Withdrawal/Outfall (physical and temp.)	2.8	0.8	3	1-5	8
Climate change	2.7	1.2	3	1-5	8
Climate variability	2.6	1.2	2	1-5	9
Predation	2.5	1.1	2	1-5	9
Dredging	2.5	0.9	3	1-4	8
Federal Management	2.3	1.1	2	1-5	9
State Management	2.2	1.1	2	1-5	9
International Management	1.8	0.8	1	1-4	9
Directed Commercial Harvest	1.7	0.8	1	1-3	9
Hybrids	1.5	0.7	1	1-3	2
Artificial Propagation and Stocking	1.5	0.7	1	1-3	9
Competition	1.4	0.6	1	1-3	9
Disease	1.4	0.5	1	1-3	8
Recreational Harvest	1.3	0.5	1	1-3	9
Landlocked Populations	1.2	0.4	1	1-2	8
Tribal/First Nation Fisheries Management	1.2	0.4	1	1-3	7
Tribal/First Nation Fisheries Utilization	1.1	0.3	1	1-2	7
Scientific Monitoring	1.0	0.1	1	1-2	9
Educational Harvest	1.0	0.0	1	1	9

The SRT's qualitative rankings of threats for blueback herring rangewide and for each stock complex:

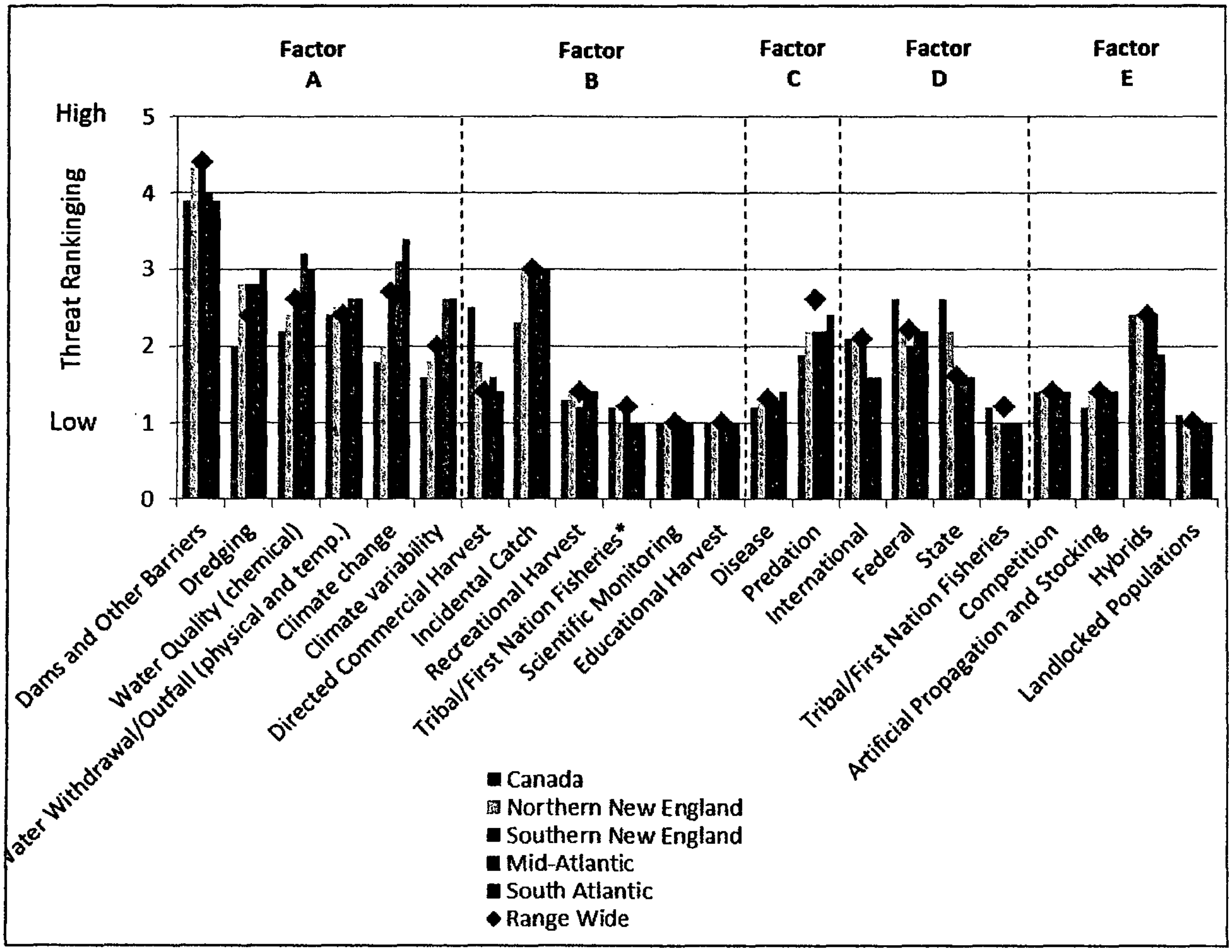

Figure 4. Median qualitative ranking of threats to blueback herring rangewide and for each stock complex.

Table 6. Qualitative ranking of threats for blueback herring rangewide. Status Review Team members ranked threats by distributing 5 likelihood points among 5 ranks: 1- low, 2-medium/low, 3- medium, 4-medium/high, 5-high. The mean represents the overall Team average rank, mode represents the rank which received the most likelihood points, and range represents the range of ranks that were assigned likelihood points for each threat. N=number of Team members who ranked the threat between 1 and 5; likelihood points for threats that Team members ranked as either unknown or not applicable are not included.

Threats	Mean	SD	Mode	Range	N
Dams and Other Barriers	4.2	0.8	4,5	3-5	9
Water Quality (chemical)	2.8	1.0	3	1-5	9
Incidental Catch	2.7	0.9	3	1-5	9
Climate change	2.7	1.2	3,4	1-5	8
Predation	2.6	1.1	3	1-5	9
Climate variability	2.4	1.2	1,2,3	1-5	9
Water Withdrawal/Outfall (physical and temp.)	2.4	0.8	2	1-5	9
Dredging	2.4	1.0	2	1-4	9
Hybrids	2.4	1.0	3	1-4	2
Federal Management	2.3	1.1	2	1-5	9
International Management	2.3	1.1	2	1-5	8
State Management	2.2	1.1	1	1-5	9
Directed Commercial Harvest	1.8	0.8	1	1-3	9
Competition	1.5	0.6	1	1-3	9
Artificial Propagation and Stocking	1.5	0.7	1	1-3	9
Tribal/First Nation Fisheries Management	1.3	0.5	1	1-3	7
Recreational Harvest	1.3	0.5	1	1-3	9
Disease	1.3	0.5	1	1-2	8
Landlocked Populations	1.2	0.5	1	1-3	7
Tribal/First Nation Fisheries Utilization	1.2	0.4	1	1-2	8
Scientific Monitoring	1.0	0.2	1	1-2	9
Educational Harvest	1.0	0.1	1	1-2	9

Table 7. Qualitative rankings of threats for the Canadian stock complex of blueback herring. Status Review Team members ranked threats by distributing 5 likelihood points among 5 ranks: 1- low, 2-medium/low, 3- medium, 4-medium/high, 5-high. The mean represents the overall Team average rank, mode represents the rank which received the most likelihood points, and range represents the range of ranks that were assigned likelihood points for each threat. N=number of Team members who ranked the threat between 1 and 5; likelihood points for threats that Team members ranked as either unknown or not applicable are not included.

Threats	Mean	SD	Mode	Range	N
Dams and Other Barriers	3.9	0.9	4	2-5	8
Incidental Catch	2.4	1.2	1,3	1-5	6
State Management	2.4	0.9	2	1-4	6
Hybrids	2.4	1.0	3	1-4	2
Water Withdrawal/Outfall (physical and temp.)	2.4	0.6	2	1-3	6
Federal Management	2.4	0.9	2	1-4	6
Directed Commercial Harvest	2.4	0.8	3	1-4	8
Water Quality (chemical)	2.2	0.7	2	1-3	7
Climate variability	2.2	1.2	1	1-5	8
Predation	2.1	1.0	2	1-4	8
International Management	2.1	0.9	2	1-4	8
Dredging	2.0	0.7	2	1-3	6
Climate change	2.0	1.0	1	1-4	8
Competition	1.5	0.6	1	1-4	9
Recreational Harvest	1.3	0.5	1	1-2	6
Disease	1.3	0.5	1	1-2	7
Artificial Propagation and Stocking	1.3	0.5	1	1-3	7
Tribal/First Nation Fisheries Utilization	1.2	0.4	1	1-2	6
Tribal/First Nation Fisheries Regulation	1.2	0.4	1	1-3	5
Landlocked Populations	1.1	0.3	1	1-2	6
Scientific Monitoring	1.0	0.2	1	1-2	6
Educational Harvest	1.0	0.0	1	1	6

Table 8. Qualitative ranking of threats for the Northern New England stock complex of blueback herring. Status Review Team members ranked threats by distributing 5 likelihood points among 5 ranks: 1- low, 2-medium/low, 3- medium, 4-medium/high, 5-high. The mean represents the overall Team average rank, mode represents the rank which received the most likelihood points, and range represents the range of ranks that were assigned likelihood points for each threat. N=number of Team members who ranked the threat between 1 and 5; likelihood points for threats that Team members ranked as either unknown or not applicable are not included.

Threats	Mean	SD	Mode	Range	N
Dams and Other Barriers	4.3	0.7	5	3-5	9
Incidental Catch	2.8	0.9	3	1-5	7
Dredging	2.6	1.0	3	1-4	8
Water Withdrawal/Outfall (physical and temp.)	2.5	0.9	3	1-5	8
State Management	2.4	1.1	2	1-5	9
Hybrids	2.4	1.0	3	1-4	2
Water Quality (chemical)	2.4	1.1	3	1-5	9
Predation	2.4	1.2	2	1-5	9
Federal Management	2.4	1.1	2	1-5	9
Climate variability	2.2	1.2	2	1-4	9
Climate change	2.1	1.0	2	1-4	8
International Management	2.0	0.9	2	1-4	9
Directed Commercial Harvest	1.9	0.9	1	1-3	9
Artificial Propagation and Stocking	1.6	0.7	1	1-3	9
Competition	1.5	0.7	1	1-3	9
Recreational Harvest	1.3	0.5	1	1-3	9
Disease	1.3	0.5	1	1-2	8
Landlocked Populations	1.2	0.4	1	1-2	7
Tribal/First Nation Fisheries Management	1.1	0.4	1	1-2	7
Tribal/First Nation Fisheries Utilization	1.1	0.3	1	1-2	8
Scientific Monitoring	1.0	0.1	1	1-2	9
Educational Harvest	1.0	0.0	1	1	9

Table 9. Qualitative ranking of threats for the Southern New England stock complex of blueback herring. Status Review Team members ranked threats by distributing 5 likelihood points among 5 ranks: 1- low, 2-medium/low, 3- medium, 4-medium/high, 5-high. The mean represents the overall Team average rank, mode represents the rank which received the most likelihood points, and range represents the range of ranks that were assigned likelihood points for each threat. N=number of Team members who ranked the threat between 1 and 5; likelihood points for threats that Team members ranked as either unknown or not applicable are not included.

Threats	Mean	SD	Mode	Range	N
Dams and Other Barriers	4.3	0.7	4,5	3-5	9
Incidental Catch	2.8	0.9	3	1-5	7
Water Withdrawal/Outfall (physical and temp.)	2.6	0.8	2,3	1-5	8
Dredging	2.6	1.0	3	1-4	8
Water Quality (chemical)	2.6	1.0	3	1-5	9
Predation	2.4	1.1	2	1-5	9
Hybrids	2.4	1.0	3	1-4	2
Climate change	2.3	1.0	2	1-4	8
Climate variability	2.3	1.1	2	1-5	9
Federal Management	2.2	1.1	2	1-5	9
State Management	1.9	1.1	1	1-5	9
International Management	1.9	0.8	2	1-4	9
Directed Commercial Harvest	1.6	0.8	1	1-3	9
Artificial Propagation and Stocking	1.6	0.7	1	1-3	9
Competition	1.5	0.7	1	1-4	9
Disease	1.3	0.5	1	1-2	8
Recreational Harvest	1.2	0.4	1	1-2	9
Landlocked Populations	1.2	0.4	1	1-2	7
Tribal/First Nation Fisheries Management	1.1	0.4	1	1-2	7
Tribal/First Nation Fisheries Utilization	1.1	0.3	1	1-2	8
Scientific Monitoring	1.0	0.1	1	1-2	9
Educational Harvest	1.0	0.0	1	1	9

Table 10. Qualitative ranking of threats for the Mid-Atlantic stock complex of blueback herring. Status Review Team members ranked threats by distributing 5 likelihood points among 5 ranks: 1- low, 2-medium/low, 3- medium, 4-medium/high, 5-high. The mean represents the overall Team average rank, mode represents the rank which received the most likelihood points, and range represents the range of ranks that were assigned likelihood points for each threat. N=number of Team members who ranked the threat between 1 and 5; likelihood points for threats that Team members ranked as either unknown or not applicable are not included.

Threats	Mean	SD	Mode	Range	N
Dams and Other Barriers	3.9	1.0	4	3-5	9
Water Quality (chemical)	3.0	0.9	3	1-5	9
Incidental Catch	2.8	0.9	3	1-5	7
Water Withdrawal/Outfall (physical and temp.)	2.7	0.8	3	1-5	8
Climate change	2.7	1.2	3	1-5	8
Dredging	2.6	1.0	3	1-4	8
Climate variability	2.6	1.2	2,3	1-5	9
Predation	2.4	1.1	2	1-5	9
Hybrids	2.4	1.0	3	1-4	2
Federal Management	2.3	1.1	2	1-5	9
State Management	2.2	1.1	2	1-5	9
Directed Commercial Harvest	1.9	0.9	1	1-4	9
International Management	1.7	0.8	1	1-4	9
Competition	1.5	0.7	1	1-3	9
Artificial Propagation and Stocking	1.5	0.7	1	1-3	9
Disease	1.4	0.5	1	1-3	8
Recreational Harvest	1.3	0.5	1	1-3	9
Landlocked Populations	1.2	0.4	1	1-2	7
Tribal/First Nation Fisheries Management	1.1	0.4	1	1-2	7
Tribal/First Nation Fisheries Utilization	1.1	0.3	1	1-2	7
Scientific Monitoring	1.0	0.1	1	1-2	9
Educational Harvest	1.0	0.0	1	1	9

Table 11. Qualitative ranking of threats for the Southern Atlantic stock complex of blueback herring. Status Review Team members ranked threats by distributing 5 likelihood points among 5 ranks: 1- low, 2-medium/low, 3- medium, 4-medium/high, 5-high. The mean represents the overall Team average rank, mode represents the rank which received the most likelihood points, and range represents the range of ranks that were assigned likelihood points for each threat. N=number of Team members who ranked the threat between 1 and 5; likelihood points for threats that Team members ranked as either unknown or not applicable are not included.

Threats	Mean	SD	Mode	Range	N
Dams and Other Barriers	3.8	1.1	4	3-5	8
Water Quality (chemical)	3.0	0.9	3	1-5	9
Climate change	3.0	1.3	4	1-5	8
Climate variability	2.8	1.4	2,4	1-5	9
Water Withdrawal/Outfall (physical and temp.)	2.8	0.8	3	1-5	8
Dredging	2.7	1.0	3	1-4	8
Incidental Catch	2.6	1.0	3	1-5	7
Predation	2.6	1.2	3	1-5	9
Federal Management	2.3	1.1	2	1-5	9
State Management	2.2	1.1	2	1-5	9
Hybrids	1.9	0.7	2	1-3	2
Directed Commercial Harvest	1.8	0.8	1	1-3	9
International Management	1.7	0.8	1	1-4	9
Competition	1.6	0.7	1	1-3	9
Disease	1.5	0.6	1	1-3	8
Artificial Propagation and Stocking	1.5	0.7	1	1-3	9
Recreational Harvest	1.3	0.5	1	1-3	9
Landlocked Populations	1.2	0.4	1	1-2	7
Tribal/First Nation Fisheries Management	1.1	0.3	1	1-2	7
Tribal/First Nation Fisheries Utilization	1.1	0.3	1	1-2	7
Scientific Monitoring	1.0	0.1	1	1-2	9
Educational Harvest	1.0	0.0	1	1	9

Table 12. Summary table of threat ranking for alewife rangewide.

Threat	Threat Level	Section 4 Factor
Dams and Other Barriers	Medium High	A
Water Quality (chemical)	Medium	A
Incidental Catch	Medium	B
Predation	Medium	C
Dredging	Medium Low	A
Water Withdrawal/Outfall (physical and temp.)	Medium Low	A
Climate change	Medium Low	A
Climate variability	Medium Low	A
Directed Commercial Harvest	Medium Low	B
International Management	Medium Low	D
Federal Management	Medium Low	D
State Management	Medium Low	D
Competition	Medium Low	E
Artificial Propagation and Stocking	Medium Low	E
Recreational Harvest	Low	B
Tribal/First Nation Fisheries Management	Low	B
Scientific Monitoring	Low	B
Educational Harvest	Low	B
Disease	Low	C
Tribal/First Nation Fisheries Utilization	Low	D
Hybrids	Low	E
Landlocked Populations	Low	E

Table 13. Summary table of threat ranking for blueback herring rangewide.

Threat	Threat Level	Section 4 Factor
Dams and Other Barriers	Medium High	A
Climate change	Medium	A
Water Quality (chemical)	Medium	A
Incidental Catch	Medium	B
Predation	Medium	C
Water Withdrawal/Outfall (physical and temp.)	Medium Low	A
Dredging	Medium Low	A
Climate variability	Medium Low	A
Directed Commercial Harvest	Medium Low	B
International Management	Medium Low	D
Federal Management	Medium Low	D
State Management	Medium Low	D
Competition	Medium Low	E
Hybrids	Medium Low	E
Recreational Harvest	Low	B
Tribal/First Nation Fisheries Management	Low	B
Scientific Monitoring	Low	B
Educational Harvest	Low	B
Disease	Low	C
Tribal/First Nation Fisheries Utilization	Low	D
Artificial Propagation and Stocking	Low	E
Landlocked Populations	Low	E

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Extinction Risk Analysis

In order to assess the risk of extinction for alewife and blueback herring, trends in the relative abundance of alewife and blueback herring were assessed for each species rangewide, as well as for each species-specific stock complex. As noted previously, for alewife, the stock complexes include Canada, Northern New England, Southern New England and the mid-Atlantic. For blueback herring, the stock complexes are Canada, Northern New England, Southern New England, mid-Atlantic and Southern.

Criteria Established by SRT for Evaluating Risk

Prior to conducting the trend analysis modeling, the SRT established criteria that would be used to evaluate the risk to both species as well as to the individual stock complexes. At the SRT's request, the NEFSC conducted modeling to develop trends in relative abundance by estimating the population growth rate for both species both rangewide and for each individual stock complex. The SRT established two tiers that could be used separately or in combination to interpret the results of the modeling in order to assess risk to alewife and blueback herring rangewide and for the individual stock complexes. We concur that these tiers are appropriate. Tier A relates to what is known about the geographic distribution, habitat connectivity and genetic diversity of each species, and Tier B relates to the risk thresholds established for the trend analysis that was conducted by the NEFSC. These tiers are subject to change in the future as more information becomes available. For example, Tier A is based on preliminary genetic data addressing possible stock complexes, which could change in the future. Data related to both tiers were assessed to determine if sufficient information was available to make a conclusion under one or both of the tiers. The SRT decided that, because of significant uncertainties associated with the available data and a significant number of data deficiencies for both species, it was not necessary to have information under both tiers in order to make a risk determination, and we concur with this decision.

The goal of Tier A was to maintain three contiguous stock complexes that are stable or increasing as this: (1) Satisfies the need to maintain both geographic closeness and geographic distance for a properly functioning metapopulation (see McElhany *et al.*, 2000); (2) ensures that the recovered population does not include isolated genetic groups that could lead to genetic divergence (McDowall, 2003, Quinn, 1984); (3) provides some assurance that the species persists across a relatively wide geographic area supporting diverse environmental conditions and diverse habitat types; and (4) ensures that the entire population does not share the same risk from localized environmental catastrophe (McElhany *et al.*, 2000).

Tier B information was used to directly interpret the results of the trends in relative abundance modeling conducted by the NEFSC. As described below, relative abundance of both alewife and blueback herring was used to estimate growth rate (along with the 95 percent confidence intervals for the growth rates) for each species rangewide and for each stock complex. Tier B established risk criteria depending on the outcomes of the population growth rate modeling. As indicated in the foreseeable future section above, a 12- to 18-year timeframe (e.g., 2024–2030) for each species was determined to be appropriate. After subsequent discussions, the SRT decided that the projections into the foreseeable future would not provide meaningful information for the extinction risk analysis. As noted previously, the trend analysis provides a steady population growth rate. If the population growth rate is positive and everything else remains the same into the foreseeable future (e.g., natural and anthropogenic mortality rates do not change), the abundance into the foreseeable future will continue to increase. If the population growth rate is negative, then the abundance into the foreseeable future will continue to decline. Currently, there is insufficient information available to modify any of the factors that may change the growth rates into the foreseeable future, and thus, performing these projections will not provide meaningful information for the extinction risk of either of these species.

The baseline for the overall risk assessment assumes that there has already been a significant decline in abundance in both species due to a reduction in carrying capacity and overfishing as indicated in various publications (Limburg and Waldman, 2009; Hall *et al.,* 2012), as well as other threats. The estimated population growth rates reflect the impacts from the various threats to which the species are currently exposed. The SRT recommended that NEFSC use data from 1976 through the present to minimize the overfishing influence from distant water fleets that occurred in earlier years but has since been curtailed by fisheries management measures. The SRT recommended that the NEFSC also run a trajectory using a plus/minus 10-percent growth rate to test model sensitivity with respect to changes in the model variables. This approach has been used in analyses for other species (e.g., Atlantic croaker, Atlantic cod) and can serve as a means of showing sensitivities in the model to potential variables (e.g., population growth rate changes, climate change) (Hare and Able, 2007; Hare, NMFS Pers. comm., 2012). Following completion of the model results, we determined that the plus/minus 10-percent change in population growth rate would not provide additional information that would change the conclusions as to whether the populations are significantly increasing, stable or decreasing. Without the projections of the population growth rate into the foreseeable future, the plus/minus 10-percent would merely provide an additional set of bounds around the population growth rate estimate, and, therefore, we determined that running the model with the plus/minus 10-percent was not necessary.

The population growth rates derived from the analysis help identify whether stability exists within the population. Mace *et al.* (2002) and Demaster *et al.* (2004) recognized that highly fecund, short generation time species like river herring may be able to withstand a 95 to 99 percent decline in biomass. Both alewives and blueback herring may already be at or less than two percent of the historical baseline (e.g., Limburg and Waldman, 2009), though these estimates are based on commercial landings data, which are dependent upon management and are not a reliable estimate of biomass. However, recognizing historical declines for both species, the modeled population growth rates were used to gauge whether these stock complexes are stable, significantly increasing or decreasing. Relative abundance of a stock is considered to be significantly increasing or decreasing if the 95-percent confidence intervals of the population growth rate do not include zero. In contrast, if the 95-percent confidence intervals do contain zero, then the population is considered to be stable, as the increasing or decreasing trend in abundance is not statistically significant.

The SRT determined and we agree that a stable or significantly increasing trajectory suggests that these species may be within the margins of being self-sustainable and thus, if all of the growth rates for the coast-wide distribution and the stock complexes are stable or significantly increasing, the species is at low risk of extinction (the risk categories were defined by adapting the categories described above for the QTA—Low risk—it is likely that the threats to the species' continued existence are not significant now and/or into the foreseeable future; Moderately Low—risk falls between low and moderate rankings; Moderate—it is likely that the threats are having some effect on the species continued existence now and/or into the foreseeable future; Moderately High—the risk falls between moderate and high; High—it is likely that the threats are significantly affecting the species' continued existence now and/or into the foreseeable future). If the coast wide population growth rate is stable or significantly increasing and one stock complex is significantly decreasing but all others are stable or significantly increasing, the species is at a moderate-low risk. A significantly decreasing population growth rate for several stock complexes would be an indicator that the current abundance may not be sustainable relative to current management measures and, therefore, may warrant further protections. Thus, if the population growth rates for two of the stock complexes are significantly decreasing but the coast-wide index is significantly increasing, the species is at moderate-high risk. If the growth rates for three or more of the stock complexes are significantly decreasing and/or the coast-wide index is significantly decreasing, the species is at high risk.

Risk Scenarios

- Low risk
  - Coast wide trajectory—Stable to significantly increasing
  - Stock complex trajectories—All stable to significantly increasing
- Moderate-Low risk
  - Coast wide trajectory—Stable to significantly increasing
  - Stock complex trajectories—One significantly decreasing, all others stable to significantly increasing
- Moderate-High risk
  - Coast wide trajectory—Stable to significantly increasing
  - Stock complex trajectories—Two or more significantly decreasing
- High risk
  - Coast wide trajectory—Significantly decreasing
  - Stock complex trajectories—Three or more significantly decreasing

Trend Analysis Modeling

The sections below include summaries/excerpts from the NEFSC Report to the SRT, "Analysis of Trends in Alewife and Blueback Herring Relative Abundance," June 17, 2013, 42 pp. (NEFSC, 2013). For detailed information on the modeling conducted, please see the complete report which can be found at *http://www.nero.noaa.gov/prot_res/CandidateSpeciesProgram/RiverHerringSOC.htm* or see **FOR FURTHER INFORMATION CONTACT** section above for contacts.

Data Used in the Trend Analysis Modeling

Rangewide Data

Relative abundance indices from multiple fishery-independent survey time series were considered as possible data inputs for the rangewide analysis. These time series included the NEFSC spring, fall, and winter bottom trawl surveys as well as the NEFSC shrimp survey. For alewife, two additional time series were available: Canada's DFO summer research vessel (RV) survey of the Scotian Shelf and Bay of Fundy (1970–present), and DFO's Georges Bank RV survey (1987–present, conducted during February and March).

For the NEFSC spring and fall bottom trawl surveys, inshore strata from 8 to 27 m depth and offshore strata from 27 to 366 m depth have been most consistently sampled by the RV *Albatross IV* and RV *Delaware II* since the fall of 1975 and spring of 1976. Prior to these time periods, either only a portion of the survey area was sampled or a different vessel and gear were used to sample the inshore strata (Azarovitz, 1981). Accordingly, seasonal alewife and blueback herring relative abundance indices were derived from these trawl surveys using both inshore and offshore strata for 1976–2012 in the spring and 1975–2011 in the fall. Additional relative abundance indices were derived using only offshore strata for 1968–2012 in the spring and 1967–2011 in the fall (from 1963–1967 the fall survey did not extend south of Hudson Canyon). These time series were developed following the same methodology used in the ASMFC river herring stock assessment (ASMFC, 2012).

Through 2008, standard bottom trawl tows were conducted for 30 minutes at 6.5 km/hour with the RV *Albatross IV* as the primary survey research vessel (Despres-Patanjo *et al.*, 1988). However, vessel, door and net changes did occur during this time, resulting in the need for conversion factors to adjust survey catches for some species. Conversion factors were not available for net and door changes, but a vessel conversion factor for alewife was available to account for years where the RV *Delaware II* was used. A vessel conversion factor of 0.58 was applied to alewife weight-per-tow indices from the RV *Delaware II*. Alewife number-per-tow indices did not require a conversion factor (Byrne and Forrester, 1991).

In 2009, the survey changed primary research vessels from the RV *Albatross IV* to the RV *Henry B. Bigelow*. Due to the deeper draft of the RV *Henry B. Bigelow*, the two shallowest series of inshore strata (8–18 m depth) are no longer sampled. Concurrent with the change in fishing vessel, substantial changes to the characteristics of the sampling protocol and trawl gear were made, including tow speed, net type and tow duration (NEFSC, 2007). Calibration experiments, comprising paired standardized tows of the two fishing vessels, were conducted to measure the relative catchability between the two vessel-gear combinations and develop calibration factors to convert Bigelow survey catches to *RV Albatross* equivalents (Miller *et al.*, 2010). In the modeling, the NEFSC developed species-specific calibration coefficients which were estimated for both catch numbers and weights using the method of Miller *et al.* (2010) (Table 14). The calibration factors were combined across seasons due to low within-season sample sizes from the 2008 calibration studies (fewer than 30 tows with positive catches by one or both vessels).

Table 14. Coefficients and associated standard errors used to convert RV Bigelow catches of alewife and blueback herring to RV Albatross IV equivalents for the 2009-2011 NEFSC bottom trawl surveys.

	Number		Biomass	
Species	**Coefficient**	**SE**	**Coefficient**	**SE**
Alewife	1.05	0.16	0.72	0.11
Blueback herring	0.87	0.17	1.59	0.45

Bottom trawl catches of river herring tend to be higher during the daytime due to diel migration patterns (Loesch *et al.*, 1982; Stone and Jessop, 1992). Accordingly, only daytime tows were used to compute relative abundance and biomass indices. In addition, the calibration factors used to convert RV *Bigelow* catches to RV *Albatross* equivalents were estimated using only catches from daytime tows. Daytime tows, defined as those tows between sunrise and sunset, were identified for each survey station based on sampling date, location, and solar zenith angle using the method of Jacobson *et al.* (2011). Although there is a clear general relationship between solar zenith and time of day, tows carried out at the same time but at different geographic locations may have substantially different irradiance levels that could influence survey catchability (NEFSC, 2011). Preliminary analyses (Lisa Hendrickson, NMFS, 2012—unpublished data) confirmed that river herring catches were generally greater during daylight hours compared to nighttime hours.

In addition to the NEFSC spring and fall trawl surveys, the NEFSC winter and shrimp surveys were considered for inclusion in the analysis. For the winter survey (February), the sampling area extended from Cape Hatteras, NC, through the southern flank of Georges Bank, but did not include the remaining portion of Georges Bank or the Gulf of Maine. With the arrival of the RV *Bigelow* in late 2007, the NEFSC winter survey was merged with the NEFSC spring survey and discontinued. Alewife and blueback herring indices of relative abundance were developed for the winter survey from 1992–2007 using daytime tows from all sampled inshore and offshore strata. The shrimp survey is conducted during the summer (July/August) in the western Gulf of Maine during daylight hours. Relative abundance indices were derived for alewife and blueback herring from 1983–2011 using all strata that were consistently sampled across the survey time series in the NEFSC winter and shrimp surveys.

Stratified mean indices of relative abundance of alewife from Canada's summer RV survey and Georges Bank RV survey were provided by Heath

Stone of Canada's DFO. In these surveys, alewife is the predominant species captured; however, some blueback herring are likely included in the alewife indices because catches are not always separated by river herring species (Heath Stone, DFO Pers. comm., 2012). Furthermore, some Georges Bank strata were not sampled in all years of the survey due to inclement weather and vessel mechanical problems (Stone and Gross, 2012).

Due to the restricted spatial coverage of the winter, shrimp and Canadian Georges Bank surveys, these surveys were not used in the final rangewide analyses. Accordingly, relative abundance (number-per-tow) from the NEFSC spring and fall surveys was used in the rangewide models for blueback herring, and number-per-tow from the NEFSC spring survey, NEFSC fall survey, and the Canadian summer survey were used in the rangewide models for alewife.

Data from 1976 through the present were incorporated into the trend analysis. This time series permitted the inclusion of the spring and fall surveys' inshore strata. In addition, with this time series, the required assumption that the population growth rate will remain the same was reasonable. Prior to 1976, fishing intensity was much greater due to the presence of distant water fleets on the East Coast of the United States.

Years with zero catches were treated as missing data. For alewife, there were no years with zero catches in the spring, fall and Scotian shelf surveys. Zero catches of blueback herring occurred in the fall survey in 1988, 1990, 1992 and 1998.

Stock-Specific Data

Stock-specific time series of alewife and blueback herring relative abundance were obtained from the ASMFC and Canada's DFO. Available time series varied among stocks and included run counts, as well as young-of-year (YOY), juvenile and adult surveys that occurred solely within the bays or sounds of the stock of interest (for alewife see Table 15 in the NEFSC's "Analysis of Trends in Alewife and Blueback Herring Relative Abundance," and for blueback herring, see Table 16). All available datasets were included in the stock-specific analyses, with the exception of run counts from the St. Croix and Union Rivers. These datasets were excluded due to the artificial impacts of management activities on run sizes. The closure of the Woodland Dam and Great Falls fishways in the St. Croix River prevented the upstream passage of alewives to spawning habitat. In contrast, fluctuations in Union River run counts were likely impacted by lifting and stocking activities used to maintain a fishery above the Ellsworth Dam. In the southern Gulf of St. Lawrence trawl survey, all river herring were considered to be alewife because survey catches were not separated by river herring species (Luc Savoie DFO, Pers. comm., 2012). No blueback herring abundance indices were available for the Canadian stock. Select strata were not used to estimate stock-specific indices from the NEFSC trawl surveys because mixing occurs on the continental shelf. Accordingly, any NEFSC trawl survey indices, even estimated using only particular strata, would likely include individuals from more than one stock.

Each available dataset in the stock-specific analyses represented a particular age or stage (spawners, young-of-year, etc.) of fish. Consequently, each time series was transformed using a running sum over 4 years. The selection of 4 years for the running sum was based on the generation time of river herring. For age- and stage-specific data, a running sum transformation is recommended to obtain a time series that more closely approximates the total population (Holmes, 2001). In order to compute the running sums for each dataset, missing data were imputed by computing the means of immediately adjacent years. For both species 4 years were imputed for the Monument River, and 1 year was imputed for the DC seine survey. For alewife, 1 year was also imputed for the Mattapoisett River, Nemasket River, and the southern Gulf of St. Lawrence trawl survey. For blueback herring, 1 year was also imputed for the Long Island Sound (LIS) trawl survey and Santee-Cooper catch-per-unit-effort (CPUE).

If possible data from 1976 through the present were incorporated into each stock-specific model, with the first running sum incorporating data from 1976 through 1979. However, for some stocks, observation time series began after 1976. In these cases, the first modeled year coincided with the first running sum of the earliest survey.

MARRS Model Description

Multivariate Autoregressive State-Space models (MARSS) were developed using the MARSS package in R (Holmes *et al.*, 2012a). This package fits linear MARSS models to time series data using a maximum likelihood framework based on the Kalman smoother and an Expectation Maximization algorithm (Holmes *et al.*, 2012b).

Each MARSS model is comprised of a process model and an observation model (Holmes and Ward, 2010; Holmes *et al.*, 2012b). The model is described in detail in the NEFSC (2013) final report to the SRT (posted on the Northeast Regional Office's Web site—*http://www.nero.noaa.gov/prot_res/CandidateSpeciesProgram/RiverHerringSOC.htm*). *Population projections and model analysis.*

For each stock complex, the estimated population growth rate and associated 95 percent confidence intervals were used to classify whether the stock's relative abundance was stable, significantly increasing or decreasing. As noted previously, relative abundance of a stock was considered to be significantly increasing or decreasing if the 95 percent confidence intervals of the population growth rate did not include zero. In contrast, if the 95 percent confidence intervals included zero, the population was considered to be stable because the increasing or decreasing trend in abundance was not significant.

Model Results

Rangewide Analyses

For the rangewide analysis, as shown in Table 15 below, the preferred model run for alewife indicates that the 95-percent confidence intervals spanning the estimated population growth rate do not include 0 and are statistically significantly increasing. For blueback herring rangewide, however, the 95-percent confidence intervals do include 0, and thus, it is not possible to state that the trend rangewide for this species is increasing. We, therefore, conclude based on our criteria described above that blueback herring rangewide are stable.

Table 15. Population growth rate maximum likelihood estimates (ML.Est), associated standard errors (Std.Err) and lower and upper 95 percent confidence intervals (low.CI, up.CI) for each rangewide model run. The preferred model run (lowest AIC) for each species is highlighted in grey.

Species	Run	ML.Est	Std.Err	low.CI	up.CI
Alewife	Independent with equal variances	0.034	0.006	0.022	0.046
	Independent with unequal variances	0.032	0.006	0.020	0.043
	Unconstrained	0.030	0.005	0.020	0.041
	Unequal variances with one covariance term	0.035	0.013	0.009	0.062
	Equal variance and covariance	0.034	0.005	0.023	0.045
Blueback herring	Independent with equal variances	0.039	0.040	-0.040	0.119
	Independent with unequal variances	0.022	0.036	-0.047	0.093
	Unconstrained	0.026	0.045	-0.063	0.112
	Equal variance and covariance	0.040	0.052	-0.064	0.144

Stock-Specific Analyses

As shown in Table 16 below, the 95-percent confidence intervals spanning the estimated population growth rate for the Canadian stock complex do not include 0 and are statistically significantly increasing. For the other three stock complexes, however, the confidence intervals do include 0, and thus, the Northern New England, Southern New England and mid-Atlantic alewife stock complexes are stable.

As Canada does not separate alewife and blueback herring in their surveys (e.g., they indicate that all fish are alewife), we were unable to obtain data from Canada specifically for blueback herring. For three of the remaining four stock complexes, the 95-percent confidence intervals spanning the estimated population growth rate do include 0 and thus, the trend for these stock complexes is stable. For the mid-Atlantic stock complex, the population growth rate and both 95-percent confidence intervals are all statistically significantly decreasing. Thus, we conclude that this stock complex is significantly decreasing.

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Table 16. Population growth rate maximum likelihood estimates (ML.Est), associated standard errors (Std.Err) and lower and upper 95-percent confidence intervals (low.CI, up.CI) for each stock-specific model run. The preferred model run (lowest AIC) for each stock is highlighted in grey.

Species	Stock	Run	ML.Est	Std.Err	low.CI	up.CI
Alewife	Mid Atlantic	Independent with equal variances	0.004	0.034	-0.061	0.073
		Independent with unequal variances	-0.021	0.036	-0.092	0.048
		Unconstrained	-0.013	0.029	-0.071	0.044
		Unequal variances with one covariance term	-0.021	0.035	-0.088	0.054
		Equal variance and covariance	-0.004	0.046	-0.092	0.088
	Southern New England	Independent with equal variances	0.008	0.032	-0.052	0.072
		Independent with unequal variances	0.017	0.028	-0.038	0.071
		Equal variance and covariance	0.005	0.032	-0.057	0.069
	Northern New England	Independent with equal variances	0.036	0.038	-0.041	0.109
		Unconstrained	0.038	0.036	-0.034	0.108
		Equal variance and covariance	0.036	0.041	-0.048	0.114
	Canada	Independent with equal variances	0.111	0.031	0.050	0.170
Blueback herring	Southern	Independent with equal variances	-0.004	0.047	-0.091	0.091
		Independent with unequal variances	0.022	0.041	-0.058	0.102
		Unconstrained	0.024	0.042	-0.058	0.103
		Equal variance and covariance	-0.001	0.046	-0.091	0.092
	Mid Atlantic	Independent with equal variances	-0.070	0.008	-0.085	-0.055
		Independent with unequal variances	-0.048	0.003	-0.054	-0.042
		Equal variance and covariance	-0.072	0.013	-0.097	-0.046
	Southern New England	Independent with equal variances	-0.033	0.035	-0.101	0.036
	Northern New England	Independent with equal variances	-0.076	0.058	-0.185	0.041

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Model Assumptions and Limitations

The available data for each analysis varied considerably among species and stocks. Some stocks such as Southern New England blueback herring had only one available data set; however, other stocks such as Southern New England alewife and mid-Atlantic blueback herring had eight or more available time series. Within each analysis, all input time series must be weighted equally, regardless of the variability in the dataset. Furthermore, only the annual point estimates of relative abundance are inputs to the model; associated standard errors for the time series are not inputted.

However, some observation time series may be more representative of the stock of interest than other time series. For example, for Northern New England alewife, available datasets included run counts from five rivers and Maine's juvenile alosine seine survey. Each time series of run counts represents the spawning population in one particular river, whereas the juvenile seine survey samples six Maine rivers including Merrymeeting Bay (ASMFC, 2012). Accordingly, it is possible that the juvenile seine survey provides a better representation of Northern New England alewife than the run counts from any particular river because the seine survey samples multiple populations. Likewise, for Southern New England alewife, available datasets included the Long Island Sound (LIS) trawl survey, New York juvenile seine survey, and run counts from six rivers. The LIS trawl survey samples Long Island Sound from New London to Greenwich Connecticut with stations in both Connecticut and New York state waters, including the mouths of several rivers including the Thames, Connecticut, Housatonic, East and Quinnipiac (CTDEP, 2011; ASMFC, 2012). The NY juvenile seine survey samples the Hudson River estuary (ASMFC, 2012), and run counts are specific to particular rivers. As a consequence, the LIS trawl survey may be more representative of the Southern New England alewife stock because it samples not only a greater proportion of the stock, but also samples LIS where mixing of river-specific populations likely occurs.

Several sources of uncertainty are described in detail in the modeling report. It is important to understand and document these sources of uncertainty. However, even with several assumptions and these sources of uncertainty, we are confident that the model results are useful in determining the population growth rates both coast-wide and for the individual stock complexes, and thus, for providing information to be used in assessing the risk to these species and stock complexes.

Extinction Risk Conclusion

In performing our analysis of the risk of extinction to the species, we considered the current status and trends and the threats as they are impacting the species at this time. Currently, neither species is experiencing high rates of decline coast-wide as evidenced by the rangewide trends (significantly increasing for alewife and stable for blueback herring). Thus, using the extinction risk tiers identified by the SRT, we have concluded the following:

Alewife—

• Tier A: There is sufficient information available to conclude that there are at least three contiguous populations that are stable to significantly increasing.

• Tier B: The species is at "Low risk" as the coast-wide trajectory is significantly increasing and all of the stock complexes are stable or significantly increasing.

Blueback herring—

• Tier A: There is insufficient information available to make a conclusion under Tier A as we were unable to obtain data from Canada to determine the population growth rate for rivers in Canada. Thus, we were only able to obtain information for four of the five stock complexes identified for the species.

• Tier B: The species is at "Moderate-low risk "as the coast-wide trajectory is stable and three of the four stock complexes are stable. The estimated population growth rate of the mid-Atlantic stock complex is significantly decreasing based on the available information. However, the relative abundance of the species throughout its range (as demonstrated through the coast-wide population growth rate) is stable, and thus, the SRT concluded that the mid-Atlantic stock complex does not constitute a significant portion of the species range. We concur with this conclusion. In other words, the data indicate that the mid-Atlantic stock complex does not contribute so much to the species that, without it, the entire species would be in danger of extinction.

Many conservation efforts are underway that may lessen the impact of some of these threats into the foreseeable future. One of the significant threats identified for both species is bycatch in Federal fisheries, such as the Atlantic herring and mackerel fisheries. The New England and Mid Atlantic Fishery Management Councils have recommended management measures under the MSA that are expected to decrease the risk from this particular threat. Under both the Atlantic Herring Fishery Management Plan and the Mackerel/Squid/Butterfish Fishery Management Plan, the Councils have recommended a suite of reporting, vessel operation, river herring catch cap provisions, and observer provisions that would improve information on the amount and extent of river herring catch in the Atlantic herring and mackerel fisheries. NMFS has partially approved the measures as recommended by the New England Council and will be implementing the measures in September or October 2013. Another threat that has been identified for both species is loss of habitat or loss of access to spawning habitats. We have been working to restore access to spawning habitats for river herring and other diadromous fish species through habitat restoration projects. While several threats may lessen in the future, given the extensive decline from historical levels, neither species is thought to be capable of withstanding continued high rates of decline.

Research Needs

As noted above, 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); NMFS Stock Structure, Climate Change and Extinction Risk Workshop/Working Group Reports (NMFSa, 2012; NMFSb, 2012; NMFSc, 2012) and associated peer reviews; and New England and Mid-Atlantic Fishery Management Council documents (NEFMC, 2012; MAFMC, 2012). We have identified below some of the most critical and immediate research needs to conserve river herring taking the recently identified needs into consideration, as well as information from this determination. However, these are subject to refinement as a coordinated and prioritized coast-wide approach to continue to fill in data gaps and conserve river herring and their habitat is developed (see "Listing Determination" below).

• Gather additional information on life history for all stages and habitat areas using consistent and comprehensive coast-wide protocols (i.e., within and between the United States and Canada). This includes information on movements such as straying rates and migrations at sea. Improve methods to develop biological benchmarks used in assessment modeling.

- Continue genetic analyses to assess genetic diversity, determine population stock structure along the coast (U.S. and Canada) and determination of river origin of incidental catch in non-targeted ocean fisheries. Also, obtain information on hybridization and understand the effects of stocking on genetic diversity.
- Further assess human impacts on river herring (e.g., quantifying bycatch through expanded observer and port sampling coverage to quantify fishing impact in the ocean environment and improve reporting of commercial and recreational harvest by waterbody and gear, ocean acidification)
- Continue developing models to predict the potential impacts of climate change on river herring. This includes, as needed to support these efforts, environmental tolerances and thresholds (e.g., temperature) for all life stages in various habitats.
- Develop and implement monitoring protocols and analyses to determine river herring population responses and targets for rivers undergoing restoration (e.g., dam removals, fishways, supplemental stocking). Also, estimate spawning habitat by watershed (with and without dams).
- Assess the frequency and occurrence of hybridization between alewife and blueback herring and possible conditions that contribute to its occurrence (e.g., occurs naturally or in response to climate change, dams, or other anthropogenic factors).
- Continue investigating predator prey relationships.

Listing Determination

The ESA defines an endangered species as any species in danger of extinction throughout all or a significant portion of its range, and a threatened species as any species likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. Section 4(b)(1) of the ESA requires that the listing determination be based solely on the best scientific and commercial data available, after conducting a review of the status of the species and after taking into account those efforts, if any, that are being made to protect such species.

We have considered the available information on the abundance of alewife and blueback herring, and whether any one or a combination of the five ESA factors significantly affect the long-term persistence of these species now or into the foreseeable future. We have reviewed the information received following the positive 90-day finding on the petition, the reports from the stock structure, extinction risk analysis, and climate change workshops/working groups, the population growth rates from the trends in relative abundance estimates and qualitative threats assessment, the Center for Independent Experts peer reviewers' comments, other qualified peer reviewer submissions, and consulted with scientists, fishermen, fishery resource managers, and Native American Tribes familiar with river herring and related research areas, and all other information encompassing the best available information on river herring. Based on the best available information, the SRT concluded that alewife are at a low risk of extinction from the threats identified in the QTA (e.g., dams and other barriers to migration, incidental catch, climate change, dredging, water quality, water withdrawal/outfall, predation, and existing regulation), and blueback herring are at a moderate-low risk of extinction from similar threats identified and discussed in the QTA discussion above. We concur with this conclusion, and we have determined that as a result of the extinction risk analysis for both species, these two species are not in danger of extinction or likely to become so in the foreseeable future. Therefore, listing alewife and blueback herring as either endangered or threatened throughout all of their ranges is not warranted at this time.

Significant Portion of the Range Evaluation

Under the ESA and our implementing regulations, a species warrants listing if it is threatened or endangered throughout all or a significant portion of its range. In our analysis for this listing determination, we initially evaluated the status of and threats to the alewife and blueback herring throughout the entire range of both species. As stated previously, we have concluded that there was not sufficient evidence to suggest that the genetically distinct stock complexes of alewife or blueback constitute DPSs. We also then assessed the status of each of the individual stock complexes in order to determine whether either species is threatened or endangered in a significant portion of its range.

As noted above in the QTA section, the SRT determined that the threats to both species are similar and the threats to each of the individual stock complexes are similar with some slight variation based on geography. Water quality, water withdrawal/outfall, predation, climate change and climate variability were generally seen as greater threats to both species in the southern portion of their ranges than in the northern portion of their ranges. In light of the potential differences in the magnitude of the threats to specific areas or populations, we next evaluated whether alewife or blueback herring might be threatened or endangered in any significant portion of its range. In accordance with our draft policy on "significant portion of its range," our first step in this evaluation was to review the entire supporting record for this listing determination to "identify any portions of the range[s] of the species that warrant further consideration" (76 FR 77002; December 9, 2011). Therefore, we evaluated whether there is substantial information suggesting that the hypothetical loss of any of the individual stock complexes for either species (e.g., portions of the species' ranges) would reasonably be expected to increase the demographic risks to the point that the species would then be in danger of extinction, (i.e., whether any of the stock complexes within either species' range should be considered "significant"). As noted in the extinction risk analysis section, all of the alewife stock complexes as well as the coastwide trend are either stable or increasing. For blueback herring, 3 of the stock complexes and the coastwide trend are all stable, but the mid-Atlantic stock complex is decreasing. The SRT determined that the mid-Atlantic stock complex is not significant to the species, given that even though it is decreasing, the overall coastwide trend is stable. Thus, the loss of this stock complex would not place the entire species at risk of extinction. We concur with this conclusion. Because the portion of the blueback herring stock complex residing in the mid-Atlantic is not so significant that its hypothetical loss would render the species endangered, we conclude that the mid-Atlantic stock complex does not constitute a significant portion of the blueback herring's range. Consequently, we need not address the question of whether the portion of the species occupying this portion of the range of blueback herring is threatened or endangered.

Conclusion

Our review of the information pertaining to the five ESA section 4(a)(1) factors does not support the assertion that there are threats acting on either alewife or blueback herring or their habitat that have rendered either species to be in danger of extinction or likely to become so in the foreseeable future, throughout all or a significant portion of its range. Therefore, listing alewife or blueback herring as threatened or endangered under the ESA is not warranted at this time.

While neither species is currently endangered or threatened, both species are at low abundance compared to historical levels, and monitoring both species is warranted. We agree with the SRT that there are significant data deficiencies for both species, and there is uncertainty associated with available data. There are many ongoing restoration and conservation efforts and new management measures that are being initiated/considered that are expected to benefit the species; however, it is not possible at this time to quantify the positive benefit from these efforts. Given the uncertainties and data deficiencies for both species, we commit to revisiting both species in 3 to 5 years. We have determined that this is an appropriate timeframe for considering this information in the future as a 3- to 5-year timeframe equates to approximately one generation time for each species, and it is therefore unlikely that a detrimental impact to either species could occur within this period. Additionally, it allows for time to complete ongoing scientific studies (e.g., genetic analyses, ocean migration patterns, climate change impacts) and for the results to be fully considered. Also, it allows for the assessment of data to determine whether the preliminary reports of increased river counts in many areas along the coast in the last 2 years represent sustained trends. During this 3- to 5-year period, we intend to coordinate with ASMFC on a strategy to develop a long-term and dynamic conservation plan (e.g., priority activities and areas) for river herring considering the full range of both species and with the goal of addressing many of the high priority data gaps for river herring. We welcome input and involvement from the public. Any information that could help this effort should be sent to us (see **ADDRESSES** section above).

References Cited

A complete list of all references cited in this rulemaking can be found on our Web site at *http://www.nero.noaa.gov/prot_res/CandidateSpeciesProgram/RiverHerringSOC.htm* and is available upon request from the NMFS office in Gloucester, MA (see **ADDRESSES**).

Authority: The authority for this action is the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*).

Dated: August 6, 2013.

Alan D. Risenhoover,

Director, Office of Sustainable Fisheries, performing the functions and duties of the Deputy Assistant Administrator for Regulatory Programs National Marine Fisheries Service.

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*NOTE: This is a **REVISED** version of the plan, originally posted to the DEC website in August 2011. Changes were made as a result of public comment received by Sept 22, 2011.*

New York State
Department of Environmental Conservation

Sustainable Fishing Plan for New York River Herring Stocks

Kathryn A. Hattala, Andrew W. Kahnle
Bureau of Marine Resources, Hudson River Fisheries Unit

and

Robert D. Adams
Hudson River Estuary Program

September 2011

Submitted for review
to the
Atlantic State Marine Fisheries Commission

REVISED VERSION: September 2011, based on public comment received.

EXECUTIVE SUMMARY

Amendment 2 to the Atlantic States Marine Fisheries Commission Shad and river Herring Interstate Fishery Management Plan requires member states to demonstrate that fisheries for river herring (alewife and blueback herring) within their state waters are sustainable. A sustainable fishery is defined as one that will not diminish potential future reproduction and recruitment of herring stocks. If states cannot demonstrate sustainability to the Atlantic States Marine Fisheries Commission (ASMFC), they must close their herring fisheries.

New York State proposes to maintain a restricted river herring (alewife and blueback herring) fishery in the Hudson River and tributaries and to close river herring fisheries elsewhere in the State. This proposal conforms to Goal 1 of the New York State Hudson River Estuary Action Agenda.

Stock Status

Blueback herring and alewife are known to occur and spawn in New York State in the Hudson River and tributaries, the Bronx River, and several streams on Long Island. The Hudson River is tidal to the first dam at Troy, NY (rkm 245). Data on stock status are available for the Hudson River and tributaries. Few data are available on river herring in streams in Bronx County, southern Westchester County, or on Long Island. River herring are absent in the New York portion of the Delaware River.

Hudson River: Commercial and recreational fisheries exploit the spawning populations of river herring in the Hudson River and tributaries. Fixed and drifted gill, cast and scap/lift nets are used in the main stem Hudson, while scap/lift and cast nets are used in the tributaries. Recreational fishers often use commercial net gears because permit fees remain at 1911 levels. Anglers also are allowed take of river herring with variety of small nets and hook and line. In the last ten years, about 250 fishers annually purchased commercial gill net permits and approximately 240 purchased commercial scap net permits. However only 84 gill net and 93 scap/lift fishers reported using the gear licensed. Fishers using commercial gears are required to report landings annually. Most river herring taken in the Hudson and tributaries are used as bait in the recreational striped bass fishery. Anglers and subsistence fishers take a few river herring from Long Island streams.

Data on commercial harvest of river herring are available since the early 1900s. Landings peaked in the early 1900s and in the 1930s and then declined through the 1980s. Landings increased again through 2003, but have since declined. Reported commercial harvest has remained below 50,000 river herring per year since the early 1990s. A series of creel surveys and estimates since 2001 indicated substantial and increasing harvest of river herring by recreational anglers from the Hudson River and tributaries. We estimated that approximately 240,000 river herring were harvested by recreational anglers in 2007. The extent of the loss of river herring through bycatch in ocean commercial fisheries remains largely unknown but is expected to be significant.

Fishery dependent data on river herring status since 2000 are available from commercial reports and from on-board monitoring. Catch per unit effort (CPUE) in fixed (anchored) gill nets fished in the main stem river has increased. Conversely, CPUE in scap nets fished in tributaries initially declined, but then varied without trend. Mean length of river herring observed in the commercial harvest has declined slightly since 2000. We feel that the CPUE in fixed gear below the Bear Mountain Bridge provides the best annual measure of abundance because it intercepts river herring migrating past the gear to upriver spawning locations..

Fishery independent data on size and age composition of river herring spawning in the Hudson River Estuary are available from 1936 and intermittently since the late 1970s. Sample size has been small in most years. The largest fish were collected in the 1930s. Size of both blueback herring and alewife has declined over the last 30 years. Age data were obtained from scales in 1936 and the late 1980s. Since then, ages were estimated from age length keys developed by Maine, Massachusetts, and Maryland. Observed and estimated age at length of Hudson River fish varied substantially among methods and thus age can only be used for trends within method. Annual mean age since the late 1980s has remained stable in blueback herring and female alewife, but declined in male alewife. Because of the uncertainty with estimated ages, we estimated annual mortality with length-based methods. Estimates varied substantially depending on assumed model inputs and therefore actual total mortality on the stocks remains unknown. However, we should emphasize that mortality on stocks must have been high in the last 30 years to have so consistently reduced mean size and presumably mean age. Within method, estimates of total mortality generally increased for both species since 1980. This increase was most pronounced in alewife.

Young of year production has been measured annually by beach seine since 1980. CPUE of alewife remained low through the late 1990s and has since increased erratically. CPUE of young of year blueback herring has varied with a very slight downward trend since 1980.

Streams on Long Island, Bronx and south shore of Westchester County: Limited data have been collected for some of the river herring populations in these areas. The data are not adequate to characterize stock condition.

Delaware River in New York: No records exist to document the presence of river herring in this portion of the river.

Proposed Fishery for the Hudson River

Given the inconsistent measures of stock status described above, we do not feel that the data warrant a complete closure of the Hudson River fishery at this time. New York State proposes a five year restricted fishery in the main-stem Hudson River, a partial closure of the fishery in tributaries, and annual stock monitoring. We set a sustainability target for juvenile indices. We will monitor, but not set targets for mean length from fishery independent spawning stock sampling and CPUE in the commercial fixed gill net fishery in the lower river below the Bear Mountain Bridge. We will also monitor age structure, frequency of repeat spawning, and total mortality from fishery independent sampling if we can resolve problems with age determination and mortality estimation.

A summary of existing and proposed restrictions is provided. Proposed restrictions to the recreational fishery include: a ten fish per day creel limit for individual anglers with a boat limit of 50, and a 10 fish creel limit per day for paying customers with a boat limit of 50 for charter vessels, no fishing within 825 ft (250m) of any man made or natural barrier in the main river and tributaries, no use of nets in tributaries, and the continuation of various small nets in the main river. Proposed restrictions to the commercial fishery and use of commercial gears include: a commercial verification requirement; a net ban in the upper 28 km of the main-stem estuary, shad spawning flats, or tributaries; gill net mesh and size restrictions; a ban on fixed gears or night fishing above the Bear Mountain Bridge; seine and scap/lift net size restrictions; extension of existing 36 hour lift period to all commercial net gears; increased net fees to account for inflation since 1911 when fees were set or the preferred option of creation of a new Hudson River Commercial Fish Permit; extension of the current Marine and Coastal District Charter /Party boat license to the tidal Hudson and tributaries at a cost of $250.00 annually; and monthly mandatory reporting of catch and harvest.

We should note that Draft Addendum 3 to Amendment 6 of the ASMFC Interstate Management Plan for striped bass stipulates that states should reduce fishing mortality on spawning stocks by 50%. If this draft is approved by the ASMFC Striped Bass Management Board, we may have to restrict effort in the recreational striped bass fishery. Restrictions may include a reduction in use of bait such as river herring. Any reduction in effort will likely reduce demand for river herring and thus reduce losses in the Hudson stocks.

<u>Proposed Moratorium for streams on Long Island, Bronx County, the southern shore of Westchester County, and the Delaware River and its tributaries north of Port Jervis NY</u>. Due to the inability to determine stock condition for these areas, the ASMFC Amendment 2 requires that a moratorium on river herring fishing be implemented.

This SFP does not directly address ocean bycatch but focuses on fisheries in New York State waters. New York is working with the National Marine Fisheries Service, the New England Fishery Management Council and the Mid-Atlantic Fishery Management Council to deal with this issue. Both councils are in the process of amending the Atlantic Herring and the Atlantic Mackerel, Squid and Butterfish Plans to reduce bycatch of river herring.

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2 INTRODUCTION

Amendment 2 to the Atlantic States Marine Fisheries Commission Shad and River Herring Interstate Fishery Management Plan was adopted in 2009. It requires member states to demonstrate that fisheries for river herring (alewife and blueback herring) within state waters are sustainable. A sustainable fishery is defined as one that will not diminish potential future reproduction and recruitment of herring stocks. If states cannot demonstrate sustainability to ASMFC, they must close their herring fisheries.

The following proposes a plan for a sustainable fishery for river herring in waters of New York State. The goal of this plan is to ensure that river herring resources in New York provide a source of forage for New York's fish and wildlife and provide opportunities for recreational and commercial fishing now and in the future.

The fisheries that existed back in colonial days in the Hudson Valley of New York undoubtedly included river herring among the many species harvested. River herring, comprised of both alewife (*Alosa pseudoharengus*), and blueback herring (*Alosa aestivalis*) were among the fish mentioned by early explorers and colonists – the French Jesuits, Dutch and English. Archaeological digs along the Hudson in Native American middens indicates that the fishery resources in the river provided an important food source to Native Americans.

Written records for river herring harvest in New York begin in the early 1900. Landings peaked in the early 1900s and in the 1930s and then declined through the 1980s. Landings increased again through 2003, but have since declined. Factors in addition to fishing have affected the stocks: habitat destruction (filling of shallow water spawning habitat) and water quality problems associated with pollution that caused oxygen blocks in major portions of the river (Albany and New York City). Water quality has improved over the last 30 years.

New York State does not augment wild river herring stocks with hatchery progeny. The New York City Parks Department initiated an experimental restoration program in which alewife were captured in a Long Island Sound tributary in Connecticut and released in the Bronx River above the first barrier. Limited returns to the river suggest that some reproduction has occurred from these stockings. A variety of non-governmental organizations along with state and federal agencies are working on development of fish passage for alewife in Long Island streams

3 MANAGEMENT UNITS

The management unit for river herring stocks in New York State comprises three sub-units. All units extend throughout the stock's range on the Atlantic coast.

- The largest consists of the Hudson River Estuary from the Verrazano Narrows at New York City to the Federal Dam at Troy including numerous tributary streams (Figure 1).
- The second is made up of all Long Island streams that flow into waters surrounding Long Island and streams on the New York mainland (Bronx and Westchester Counties) that

flow into the East River and/or Long Island Sound (Figure 2).

- The third subunit consists of the non-tidal Delaware River and tributaries upriver of Port Jervis, NY.

Range of the New York river herring along the Atlantic coast is from the Bay of Fundy, Canada and Gulf of Maine south to waters off Virginia (NAI 2008).

A listing of most Hudson River tributaries, and streams on Long Island, and the Bronx and southern Westchester Counties are in Appendix Table A.

3.1 Description of the Management Unit Habitat

3.1.1 Hudson River and tributaries

Habitat Description

The Hudson River Estuary is tidal its entire length of 246 km from the Battery (tip of Manhattan Island) in New York City to the Federal Dam at Troy (Figure 1). The estuary is fresh water above Newburgh (km 90).

The estuarine portion of the Hudson River is considered a "drowned" river valley in that the valley slopes steeply into the river. Many of the tributaries below the Troy Dam are tidal for a short distance (usually about a kilometer) ending at a natural or man-made barrier, often built on a natural barrier. There are approximately 67 primary and secondary, both named and unnamed, tributaries to the tidal portion of the Hudson River Estuary (Figure 1). Schmidt and Cooper (1996) catalogued 62 of these tributaries for the presence or absence of barriers to migratory fish. They found that only one had no barrier for migratory fish, 31 were blocked (either partially or completely) by natural barriers, and the remaining 30 had artificial barriers, dams or culverts, that reduced or eliminated access for fish. We estimated stream length of all these tributaries to be about 97 km that is accessible to river herring below the first impassable man-made or natural barrier.

The Mohawk River is the largest tributary to the Hudson River. It enters the Hudson 2 km north of the Troy Dam. Cohoes Falls, a large scenic waterfall of 20 m is the first natural barrier on the Mohawk just upriver of the confluence with the Hudson. Access into the Mohawk system was created through the Waterford Flight – a series of five locks and dams, built as part of the Erie Canal to circumvent the falls. The canal lock and dam system was built in 1825, to connect the Hudson to central New York and Lakes Ontario and Erie. The Canal parallels and/or is part of the Mohawk River for the river's entire length to Rome, a distance of 183 km. A series of permanent and seasonal pools make up the canal where it intertwines with the Mohawk River. Permanent pools created from hydro-power dams are found in the Waterford section. Temporary pools are created each year in early spring by removable dams (series of gates) that increase water levels to 14 feet (4.3 m) while the canal is in operation (May through November). During the winter months, the river is returned to its natural state of riffles and pools.

Habitat Use

Hudson River alewife, blueback herring and American shad are spring spawners. Alewives are the first of the herring to enter the estuary, arriving as early as mid-March with continued spawning through early May. Blueback herring prefer slightly warmer temperatures and arrive later, usually in April.

Adults of both species spawn in Hudson River tributaries and in the shallow waters of the main stem Hudson. Alewife prefer to spawn over gravel, sand and stone in back water and eddies whereas bluebacks tend to spawn in fast moving water over a hard bottom. Herring spawn in the tidal freshwater Hudson from Kingston (km 144) to Troy (km 256) (Figure 1) and its tributaries for approximately six to ten weeks, dependent on water temperature (Smith 1985, Hattala et al. 2011). Once spawning ends, most mature fish quickly return to ocean waters. The nursery area includes the spawning reach and extends south to Newburgh Bay (km 90), encompassing the freshwater portion of the Estuary.

Some blueback herring of the Hudson River migrate above the Federal Dam at Troy. A few continue upriver in the non-tidal Hudson as far as Lock 4 on the Champlain Canal (NAI 2007). However, most fish turn west into the Mohawk River. This larger portion migrates as far inland as Rome (439 km inland), via the Erie Canal and the Mohawk River. The canal system opens in New York on or about May 1st. Since most alewives are already spawning by then, they do not move into the system (J. Hasse, NYSDEC retired, personal communication).

Blueback herring began colonizing the Mohawk River in the 1970s. By 1982, they had migrated into Oneida Lake in the Great Lakes drainage. The number of herring using the Mohawk increased through the 1990s, but since 2000 herring have rarely occurred in the upper end of the River. Blueback herring were historically unable to access the Mohawk River until the locks of the Erie Canal provided upstream passage into the system. Now that they are established, however, they have become important forage for local sport fish populations.

3.1.2 Long Island and Westchester County

The herring runs in streams on Long Island are comprised almost exclusively of alewife (B. Young, NYSDEC retired, personal communication). Most streams are relatively short runs to saltwater from either head ponds (created by dammed streams) or deeper kettle-hole lakes. Either can be fed by a combination of groundwater, run-off or area springs. Spawning occurs in April through May in the tidal freshwater below most of the barriers. Natural passage for spawning adults into the head ponds or kettle lakes is present in very few streams.

There have been limited efforts to understand river herring runs on Long Island since 1995. Several known runs of alewives on Long Island occur in East Hampton, Southampton, Riverhead and Brookhaven. With the advent of a more aggressive restoration effort in Riverhead on the Peconic River other runs have come to light. Since 2006, an annual volunteer alewife spawning run survey has been conducted. This volunteer effort basically documents the presence or absence of alewives in Long Island Coastal Streams. In 2010 a volunteer investigation was initiated to quantify the Peconic River alewife run. Size and sex data have been collected for 2010 and 2011. A crude estimate of the runs size was also made in 2010, this effort was improved during 2011 with the placement of a video camera for recording alewife passage through the fish passage. These efforts have been undertaken to understand the Long Island Coastal streams and to improve the runs that exist there.

We have no record of river herring in any of the streams in southern Westchester County. In the Bronx River (Bronx County) alewives were introduced to this river in 2006 and 2008 and some adult fish returned in 2010. Monitoring of this run is in its early stages.

3.1.3 Delaware River

No records exist to document the presence of river herring in the New York portion of the Delaware River.

3.2 Habitat Loss and Alteration

Hudson River: Much spawning and nursery habitat in the upper half of the tidal Hudson was lost due to dredge and fill operations to maintain the river's shipping channel to Albany. Most of this loss occurred between the end of the 19th century (NYS Department of State 1990) and the first half of the 20th century. Preliminary estimates are that approximately 57% of the shallow water habitat (1,821 hectares or 4,500 acres) north of Hudson (km 190) was lost to filling (Miller and Ladd 2004). Work is in progress to map the entire bottom of the Hudson River. Data from this project will be used to characterize and quantify existing spawning and nursery habitat. While most of the dredge and fill loss affected American shad, it is suspected that herring were also affected as they spawn along the shallow water beaches in the river.

Very little, or no, habitat has been lost due to dam construction. The first major dam was constructed in 1826 at Rkm 256 at Troy. Prior to the dam, the first natural barrier occurred at Glens Falls, 32 km above the Troy Dam. The construction of the dam is not known to have reduced spawning or nursery habitat.

The introduction of zebra mussels in the Hudson in 1991, and their subsequent explosive growth in the river, quickly caused pervasive changes in the phytoplankton (80% drop) and micro- and macro- zooplankton (76% and 50% drop respectively) communities (Caraco et al. 1997). Water clarity improved dramatically (up by 45%) and shallow water zoobenthos increased by 10%. Given these massive changes, (Strayer et al. 2004) explored potential effects of zebra mussel impact on young-of-year (YOY) fish species. Most telling was a decrease in observed growth rate and abundance of YOY fishes, including both alewife and blueback herring. It is not yet clear how this constraint affects annual survival and subsequent recruitment.

Long Island: Most all streams on Long Island have been impacted by human use as the population expanded. Many streams were blocked off with dams to create head ponds, initially used to contain water for power or irrigation purposes. The dams remain; only a few with passage facilities. Many streams were also impacted by the construction of highways, with installations of culverts or other water diversions which impact immigrating fish.

Recent efforts at restoration look to provide fish passage over or around these barriers, or even removal of small obstructions. Permanent fish passage was recently installed on the Carmans River in the South Shore Estuary near Shirley, NY. This project was the result of advocacy and cooperation by environmental groups and local, state and federal agencies. Additional protections for the River are assured due to legislation enacted in 2011, and community awareness is building. An earlier cooperative effort resulted in the installation of a rock ramp passage in the Peconic River within the Peconic Bays Estuary. Local citizens monitor the spring alewife run in this river. As awareness of these successful efforts spreads, interest in replicating that success on other systems grows.

3.3 Habitat Water Quality

The Hudson has a very long history of abuse by pollution. New York City Department of Environmental Protection recognized pollution, primarily sewage, as a growing problem as early as 1909. By the 1930s over a billion gallons a day of untreated sewage were dumped into New York Harbor. (NYCDEP http://home2.nyc.gov/html/dep/html/news/hwqs.shtml)

New York City was not the only source of sewage. Most major towns and cities along the Hudson added their share. It was so prevalent that the Hudson was often referred to as an open sewer. Biological demand created by the sewage created oxygen blocks that occurred seasonally (generally mid to late summer) in some sections of the river. One of the best known blocks occurred near Albany in the northern section of the tidal estuary in the 1960s through the 1970s. This block often developed in late spring and remained through the summer months. It essentially cut off the upper 40 km of the Hudson for use as spawning and nursery habitat. A second oxygen block occurred in the lower river in the vicinity of New York City in late summer. This block could potentially have affected emigrating age zero river herring. This summer oxygen-restricted area occurred for decades until 1989 when a major improvement in a sewage treatment plant came on line in upper Manhattan. It took decades, but water quality in general has greatly improved in both areas since the implementation of the Clean Water Act in the 1970s and subsequent reduced sewage loading to the river.

4 STOCK STATUS

Following is a description of all available data for the Hudson's river herring stocks, plus a brief discussion of their usefulness as stock indicators. Sampling data are summarized in Tables 1 and 2. Sampling was in support of Goal 1 of the Hudson River Estuary Action Agenda and has been partially funded by the Hudson River Estuary Program.

4.1 Fisheries Dependent Data

4.1.1 Commercial Fishery

Commercial fisheries for river herring in New York State waters occur in the Hudson River Estuary and in marine waters around Long Island. Current commercial fishing restrictions for New York waters are listed in Appendix Table B.

The present commercial fishery in the Hudson River and tributaries exploits the spawning migration of both alewife and blueback herring. The primary use of commercially caught herring is for bait in the recreational striped bass fishery. The herring fishery occurs from March into early June annually, although some fishers report catching herring as late as July.

Ocean bycatch

River herring occur as bycatch in many commercial fisheries which are in the known migratory range of the Hudson stock from North Carolina up to the Gulf of Maine. Fishery bycatch is mostly un-documented but has the potential to harvest Hudson stock and many other stocks along the coast. In some years, estimated bycatch of river herring in the Atlantic herring fishery equaled or exceed the total of all coastal in-river landings (Cieri et al. 2008). More recent analyses by the National Marine Fisheries Service's Northeast Fisheries Science Center (2011) indicated that total annual incidental catch of river herring in all fishing fleets sampled by the Northeast Fisheries Observer Program during 1989-2010 ranged from 108 to 1867 mt. It is not known how much of current ocean river herring bycatch consists of Hudson River fish.

This SFP does not directly address ocean bycatch but focuses on fisheries in New York State waters. New York is working with the National Marine Fisheries Service, the New England Fishery Management Council (www.nefmc.org) and the Mid-Atlantic Fishery Management Council (www.mafmc.org) to deal with this issue. Both councils are in the process of amending the Atlantic Herring (Amendment 5) and the Atlantic Mackerel, Squid and Butterfish (Amendment 14) Plans to reduce bycatch of river herring.

Gear Use in the Hudson River and Tributaries

The fixed gill net fishery occurs in the mainstem river from km 40 to km 75 (Piermont to Bear Mountain Bridge, Figure 1). In this stretch, the river is fairly wide (up to 5.5 km) with wide, deepwater (~ six to eight m) shoals bordering the channel. Fishers use particular locations within this section away from the main shipping channel. Over the past ten years, an average of 22 active fishers participated in this lower river fixed gill net fishery annually. Nets are 3.7 to 183 m (12 to 600 ft) long. Above the Bear Mountain Bridge gill net fishers use both drift (~58%) and fixed gill nets (~42%). These gears are used up to km 225 (Castleton) where the river is much narrower (1.6 to 2 km wide). Approximately 60 fishers participate in this mid river gill net fishery. Nets range in size from 7.6 to 183 m (25 to 600 ft).

The other major gear used in the river herring fishery is scap nets (also known as lift and/or dip nets). The scap/lift net fishery occurs from km 70 to km 130 (Peekskill to New Baltimore), primarily in the major river herring spawning tributaries. Scap/lift nets range in size from 0.2 to 121.9 m^2 (0.5 to 400ft^2). On average, about 96 fishers participate annually.

Marine permits are required of fishers to use seines or scap nets greater than 36 ft^2, dip or scoop nets exceeding 14 in. in diameter, and all gill nets. Marine permit holders are required to report effort and harvest annually to the Department. Many marine permit holders are recreational anglers taking river herring for personal use as bait or food. It should be noted that over the last ten years, an average of over 260 gill net and 260 scap nets permits were sold annually. According to the required annual reports, however, only 36% of the permitees actively catch fish.

In addition to Marine permits, New York has a bait license that allows the take and sale of bait fish (river herring included) using seines and cast nets. As no reporting is required for this license, harvest of river herring using this license is unknown.

Commercial Landings and License Reporting

Recorded landings of river herring in New York State began in the early 1900s. Anecdotal reports indicate that herring only played a small part in the historic commercial fishing industry in the Hudson River. Total New York commercial landings for river herring include all herring caught in all gears and for both marine and inland waters. Several different time series of data are reported including several state sources, National Marine Fisheries Service (NMFS), and more currently Atlantic Coastal Cooperative Statistics Program (ACCSP). NMFS data do not specify river or ocean source(s) and landings are often reported as either alewife or blueback herring, but not both in a given year. It is unlikely that only one species was caught. From 1995 to the present, the Department has summarized landings and fishing effort information from mandatory state catch reports required for Hudson River marine permits. Full compliance for this reporting started in 2000. All Hudson River data are sent to NMFS and ACCSP for incorporation into the national databases.

Because of the discrepancies among the data series and the lack of information to assign the landings to a specific water body source, only the highest value from all sources is used to avoid double counting. Several peaks occur in the river herring landings for New York (Figure 3). The first peak occurred in the early 1900s followed by a lull (with some gaps) until the period prior to, during, and after World War II when landing peaked a second time. By the 1950s landings were in a serious decline. A few unusual peaks occurred in the NMFS data series. In 1966, 1.9 million kg were landed (omitted on Figure 3), followed by a series of years of low landings with another peak in 1982. Landings were low, with some data gaps during the rest of the 1980s through 1994.

Hudson River landings

Since 1995, landings have been separated between the Hudson and other water (marine). Harvest in the river was relatively low in 1995, but grew in response to the need for bait for the expanding striped bass recreational fishery. In-river landings peaked in 2003 and have slowly declined since then (Figure 4). The reason for the decline is unknown. The striped bass fishery and the need for bait have not diminished. It is possible that recreational fishers have shifted harvest to non commercial gears which do not have a mandatory reporting requirement. The landings from these "personal use" gears are unknown. Reporting rate from fishers using commercial gear is unknown.

The primary outlet for harvest taken by Hudson River marine permits is for the in-river bait industry. Since 2000, most commercially caught river herring have been taken by scap/lift nets (10 year mean of 48% of the catch) (Figure 5). The remaining 52% was split between drift and fixed gill nets.

Commercial Discards

From 1996 to 2010, river herring were not reported as discards on any mandatory reports targeting herring in the Hudson River or tributaries. Our commercial fisheries monitoring data, however, (See program description below) suggests otherwise. Since 1995, we have observed a 0.12% rate of discard in the anchored gill net fishery. Reasons for discards are unspecified. Discard rates are unknown for ocean fisheries.

Hudson River Commercial Catch Rates – Mandatory Reports

Relative abundance of river herring is tracked through catch per unit effort (CPUE) statistics of fish taken from the targeted river herring commercial fishery in the Estuary. All commercial fishers annually fill out mandatory reports. Data reported include catch, discards, gear, effort, and fishing location for each trip. Data within week is summarized as total catch divided by total effort (square yards of net x hours fished), separately by gear type (fixed gill nets, drift gill nets, and scap nets). Annual means are summarized in two ways. Above the Bear Mountain Bridge and within the spawning reach, annual CPUE is calculated as total catch/total effort. Below the Bear Mountain Bridge (km 75) and thus below the spawning reach, annual CPUE is calculated as an annual sum of weekly CPUE. Here, nets capture fish moving through to reach upriver spawning locations and run size is determined by number (density) of spawners each week as well as duration (number of weeks) of the run. The sum of weekly CPUE mimics area under the curve calculations where sampling occurs in succeeding time periods. The downside of using reported CPUE to monitor relative abundance is that results can be influenced by inter-annual, location, and inter-gear differences in reporting rate.

We use the CPUE of the fixed gear fishery below the Bear Mountain Bridge for estimating relative abundance because effort expended by the fishery below this bridge is much greater (~70% of fixed gill net effort) than in the river above this point (remaining 30%). Moreover, fixed gear below the bridge (rkm 40 to 75) is always fished in relatively the same location each year, is passive in nature, and intercepts fish that pass by. Annual CPUE for the lower river fixed gill net remained relatively flat until 2006 and has since increased (Figure 6).

We do not consider the CPUE of gears fished above the Bear Mountain Bridge and within the spawning reach as reliable an annual abundance indicator as that from fixed gill nets below the bridge. Upriver gears catch fish that are either staging (getting ready to spawn) or moving into areas to spawn and gears are generally not employed until fish are present. The gears include drift gill nets, scap nets and some fixed gill nets (Figure 5). Drift gill net CPUE is also more variable as it can be actively fished – set directly into a school of fish. Drifted gill net CPUE varied widely without trend through the time period. Scap net CPUE declined slightly from 2000 through 2003, and has since remained relatively stable (Figure 6). Fixed gill nets fished within the spawning reach show the same recent increasing trend as lower in the river, but effort expended is much less than below Bear Mountain Bridge.

Hudson River Commercial Catch Rates – Monitoring Program

Up until the mid-1990s, the Department's commercial fishery monitoring program was directed at the American shad gill net fishery, a culturally historic and economically important fishery. We expanded monitoring to the river herring fishery in 1996, but were limited by available manpower and the ability to connect with the fishers. Monitoring focused on the lower river fixed gill net fishery since we considered it to be a better measure of annual abundance trends (see section above).

Data were obtained by observers onboard fishing vessels. Technicians recorded data on numbers of fish caught, gear type and size, fishing time and location. Scale samples, lengths and weights are taken from a subsample of the fisher's catch. CPUE was calculated by the method used for summarizing mandatory report data (above).

Since 1996, 66 trips targeting river herring (lower river: 53; mid and upper river: 13) have been monitored. These trips were sporadic and sample size is low, from one to 11 trips per year. Because of these few samples, the resulting CPUE is considered unreliable for tracking relative abundance. However, active monitoring provided the only data on catch composition of the commercial harvest and we consider these data to be useful.

Commercial Catch Monitoring- Size and Age Structure

Commercial fixed gill net fishers use 1 ¾ to 2 ¾ inch stretch mesh sizes to target herring. Catch composition include fish caught in all meshes. For trend analysis of size change, we subset the data to include only fish caught in similar size mesh each year; these include gill nets of 2 ½ and 2 ¾ inch mesh.

Catch composition varied annually most likely due to the low number of monitored trips each year, and the timing of when the trips occurred. Annual sample size was relatively low, ranging from 40 to 185 fish from 2001 to 2007 (Table 3). Alewives were observed more often than blueback herring. The species difference may be the result of when the samples occurred (early or late in the run). The sex ratio of alewife in the observed catch was nearly equal (~ 50:50) in all years; more blueback herring females were caught than males (60:30 ratio). From 2001 to 2010, a slight decline was observed in mean total length (mm) for both alewife and blueback herring (Figure 7).

Age data for samples collected during the commercial monitoring program are yet to be analyzed (see discussion in Age section under FI programs below).

4.1.2 Recreational Fishery

Hudson River and tributaries: The recreational river herring fishery exists throughout the main-stem Hudson River, and its tributaries including those in the tidal section and above the Troy Dam (Mohawk River). Herring are sought from shore and boat by angling (jigging) and multiple net gears (see Appendix B). Boat fishers utilize all allowable gears while shore fishers predominantly use scap/lift nets, or angling (jigging). Some recreational herring fishers use their catch as food (smoking/pickling). However, the recreational herring fishery is driven primarily by the need for bait in the striped bass fishery.

The magnitude of the recreational fishery for river herring is unknown for most years. NYSDEC contracted with Normandeau Associates, Inc. to conduct creel surveys on the Hudson River in 2001 and 2005 (NAI 2003 and 2007). Estimated catch of river herring in 2001 was 34,777 fish with a 35.2% retention rate. When the 2001 data were analyzed, NAI found that the total catch and harvest of herring was underestimated due to the angler interview methods. In the 2001 survey, herring caught by fishers targeting striped bass were only considered incidental catch, and not always included in herring total catch and harvest data. Fishers were actually targeting herring and striped bass simultaneously. Corrections were made to the interview process for the 2005 survey and estimated catch increased substantially to 152,117 herring with an increased retention rate of 75.1% (Table 4). Although some fish were reported as released, we consider these mortalities due to the herring's fragile nature. We also adjusted the 2001 catch using the 2005 survey data. The adjusted catch rose to 93,157 fish.

We also evaluated river herring use by striped bass anglers using data obtained from our Cooperative Angler Program (CAP). The CAP was designed to gather data from recreational striped bass anglers through voluntary trip reports. Volunteer anglers log information for each striped bass fishing trip including fishing time, location, bait use, and fish caught, including length, and weight, and bycatch. In 2006 through 2010, volunteer anglers were asked to provide specific information about herring bait use. The annual proportion of angler days where herring was used for bait ranged from 71% to 93 % with a mean of 77%. The proportion of herring used by anglers that were caught rather than purchased increased through the time period (Table 4). Herring caught per trip varied from 1.6 to 4.8 and with the highest values in the last two years. Herring purchased per trip ranged from 0.63 to 1.5 with the lowest value in 2009. We calculated the total number of herring caught or purchased by striped bass anglers in 2007 as the estimated number of striped bass trips from a statewide creel survey (90,742) * average proportion of angler days using herring in the CAP in 2007 (0.77) * number of herring caught or purchased per trip in the CAP (1.8 and 1.7). The result was 125,502 caught and 115,816 bought for a total of 241,318 herring used.

The number of river herring taken from the Hudson River and tributaries for personal use as food by anglers is unknown.

Long Island: Alewives can be caught in many of the small streams on Long Island, though only the Peconic River sees more than occasional effort. No creel data are available but anecdotal information (B. Young, NYSDEC retired, personal communication) suggests that harvest is rising in the more easily accessible streams. Herring taken are used for personal consumption as well as for bait.

The town of Southampton, on Long Island's East End, has local ordinances in place to prevent fishing (dipping) during the alewife spawning runs.

Bronx and Westchester Counties: We do not know if any fishery occurs in the streams in Bronx and Westchester Counties that empty into the East River and Long Island Sound.

4.2 Fishery Independent Surveys

4.2.1 Spawning Stock Surveys - Hudson River

Several surveys have sampled the alewife and blueback herring spawning stocks of the Hudson River and tributaries. The spawning stocks are made up of the fish which have escaped from coastal and in-river commercial and recreational fisheries.

The earliest data is from a biological survey of the Hudson in 1936 by the then New York State Conservation Department (Greeley 1937). The sample size was small (25 fish) but indicates the fish were relatively large compared to recent data. More recent data on river herring come from several Department surveys. The longest dataset (1975-2000) is from an annual survey of chemical contaminants in fish that targeted multiple species within the Hudson River estuary. Fish were collected by electro-fishing and river herring sample size varied among years. In most years, length data were recorded for a sub sample of herring. The Department also conducted a two-year electro-fishing survey in 1989 and 1990, to examine the population characteristics of blueback herring in the Hudson and the Mohawk River, the Hudson's largest tributary. Data were obtained on length, age, and sex.

Limited data on river herring stock characteristics have also been collected during annual monitoring of American shad and striped bass spawning stocks. Sampling occurs in the main-stem Hudson River between km 145 and 232 from late April through early June. Fish are collected by haul seines and electro-fishing. The 10.2 cm stretch mesh in the haul seines was specifically designed to catch shad and striped bass and avoid river herring, but some large (> 280mm) herring were occasionally retained in these gears. Herring were an incidental catch of the electro-fishing. Data were collected on length, age, and sex of river herring caught in both gears.

In 1987, the Department began to target adult river herring during the spring spawning stock survey. From 1987 to 1990, two small mesh (9.5 mm) beach seines (30.5 and 61m) were occasionally used with some success. In 1998, we specifically designed a small haul seine (91 m) with an appropriate mesh size (5.1 cm) to target herring. It was designed to capture all sizes of herring present with the least amount of size, and age, bias. We have used this gear since 1999. Sampling occurs during the shad and bass survey within the area described above, using the same field crew.

We only use data from the least size-biased gears to describe characteristics of the herring spawning stock: electro-fishing, the beach seine (61m) and the herring haul seine (91m). As sample size varied among years, all data were combined to characterize size and weight composition of the spawning population. Mean total length and weight data are summarized for adults only (>=170mm TL).

4.2.2 Hudson River Spawning Stock - Characteristics

Mean Size and Growth

Mean size of fish has been calculated for all years that samples were obtained (Figure 8). Sample size is relatively small, however, in most years presented (n<34 fish). Adequate samples (n>34), following the method described by Lynch and Kim (2010) to characterize length (depicted with an X over the graph's data point) were collected in the late 1980s, early 1990s, then occasionally since 2001 for both species. Lengths have declined since the early 1980s. Since 2000, mean size of female alewife has been stable, but declined slightly in males (Figure 8). Mean size of blueback herring has declined for both sexes from 1989 to the present.

Age

The Department samples from the 1989-1990 were primarily blueback herring. The aging method used was that of Cating (1954), developed for American shad. More recent scale samples from Department surveys remain un-aged and therefore we have limited age or repeat spawn data directly from scales of Hudson River fish. In attempting to age Hudson River herring scales, we relied on techniques used by other state agencies. As an alternative, and for a very general picture of potential age structure, we estimated annual age structure using length at age keys from datasets provided by Maine, Massachusetts, and Maryland for alewife and Massachusetts and Maryland for blueback herring. We found that three state agencies differ enough in their technique to produce variation in the results.

Blueback herring: Age estimates using length-age keys differed from ages assigned by the Department for the 1989- 1990 samples and from each other for most years (Figure 9). In general, keys from MD and MA were mostly in agreement for male blueback herring in most years, but MA aged females slightly older (Figure 10). Ages from two through eight were present in the spawning stock. Most fish were ages three, four, and five. Mean age remained relatively stable among years within method (Figure 11).

Alewife: Age estimates using length-age keys from the three states differed from each other for alewife (Figure 12). In general, the ME key resulted in the youngest ages, followed by older ages from MA, then MD. Ages from two through eight or nine were present in the spawning stock. Peak age varied with key used and by sex; most fish were ages three or four for males and four or five for females. Mean age was youngest for the ME key, older for MA, and oldest for MD age key (Figure 13). Mean age for males was greater in 2001 and 2003, then dropped and remained relatively stable for 2005 through 2010. Mean age for females was slightly lower in 2008 and 2009 but by 2010 returned to the same level as estimated for 2001 and 2003.

Maximum age that the Hudson River herring stock can attain is unknown. Jessop (B. Jessop DFO retired, personal communication) reported a maximum age of 12 for both alewife and blueback herring for the St. John's River in New Brunswick.

Given current uncertainty about aging methods and age of Hudson River river herring, we suggest that available estimates should only be used for a general discussion of age structure and for trends within estimate method. We do not feel that age estimates should be used to monitor changes in stock status or to set sustainable fishing targets until aging methods can be verified. This issue is currently being discussed in the ongoing ASMFC River Herring stock assessment where resolution to the differences in ageing methods is being sought..

Mortality Estimates

The variation in annual age structure translated into comparable variation in estimates of total mortality when various age-based estimation methods were used. This difficulty in estimating ages precluded the use of age-based mortality estimators. As an alternative, we explored use of the Beverton-Holt length-based method (Gedamke and Hoenig 2006) using growth parameters for length calculated from the 1936 length at age data (see section above). Since the definition of length at full recruitment (Lc) given by Nelson et al. (2010) seemed arbitrary, we estimated total mortality using the Nelson et al. (2010) and two additional Lc values. Results from the length based method were also influenced by L_∞. The Beverton-Holt method also relies on several population assumptions including continuous recruitment to the stock that the population is in equilibrium. Neither of these assumptions are true for Hudson herring stocks.

Total mortality estimates for alewife of both sexes varied tremendously within and among years depending on assumed model inputs (Figure 14). Estimates increased until 2006, after which a decline occurred to 2010. An even greater variation occurred for blueback herring (Figure 15) with a series of very high peaks followed by low values. Given this demonstrated sensitivity to model inputs, we suggest that total mortality of Hudson River river herring stocks remains unknown. However, we should emphasize that mortality on stocks must have been high in the last 30 years to have so consistently reduced mean size and presumably mean age. We do not feel that estimates of total mortality should be used to monitor stock change during the proposed experimental fishery unless uncertainty in estimation methodology can be resolved. Current uncertainty precludes use of total mortality to set sustainability targets.

4.2.3 Spawning Stock Surveys - Long Island

Young (2011) sampled alewife in the Peconic River 32 times throughout the spawning season in 2010. Sampling occurred by dip net just below the second barrier to migration at the lower end of a tributary stream. A rock ramp fish passage facility was completed at the first barrier near the end of February 2010. The author collected data on total length and sex and estimated the number of fish present based on fish that could be seen below the barrier. Peak spawning occurred during the last three weeks of April. The minimum estimate of run size was 25,000 fish and was the total of the minimal visual estimates made during each sample event. Males ranged from 243- 300 mm with a mean length of 263 mm. Females ranged from 243-313 mm with a mean of 273 mm.

4.2.4 Volunteer and Other river herring monitoring

The Department's Hudson River Fisheries Unit (HRFU), Hudson River Estuary Program and the Environmental Defense's South Shore Estuary Reserve Diadromous Fish Workgroup (SSER) have begun to incorporate citizen volunteers into the collection of data on temporal variation of and physical characteristics associated with spawning of river herring in tributaries. These data were not provided by the fishery dependent and independent sample programs discussed above. The volunteer programs also bring public awareness to environmentally important issues.

Long Island Streams

The SSER began a volunteer survey of alewife spawning runs on the south shore of Long Island in 2006. The survey is designed to identify alewife spawning in support of diadromous fish restoration projects. The survey also evaluates current fish passage projects (i.e. Carmans River fish ladder), and sets a baseline of known spawning runs. Data were available for surveys in 2006 – 2008. Monitoring occurred on six to nine targeted streams annually, with volunteer participation ranging from 24 to 68 individuals. Monitoring takes place from March through May. Alewife were seen as early as March 5 (2006) and as late as May 31 (2008). Data indicated that alewife use multiple streams in low numbers. It is not clear whether each stream supports a spawning population since total sightings were very low. The Carmans and Swan Rivers showed the most alewife activity and likely support yearly spawning migrations. The first permanent fish ladder on Long Island was installed in 2008 on the Carmans River. Information gathered during this study will aid in future construction of additional fish passage (Kritzer et al. 2007a, 2007b and Hughes and O'Reilly 2008).

In addition to the SSER, other interested individuals have also monitored Long Island runs (see Appendix Table A). Anecdotal data provides valuable information on tracking existing in-stream conditions, whether streams hold active or suspected runs, interaction with human land uses and suggestions for improvement (L. Penney, Town of East Hampton, personal communication). A rock ramp was constructed around the first barrier to migration on the Peconic River in early

2010 (B. Young, retired, NYS Dept of Environmental Conservation, personal communication). The Peconic River Fish Restoration Commission set up an automated video counting apparatus at the upriver end of this ramp. Data are still being analyzed.

The Department has conducted a similar river herring volunteer monitoring program annually since 2008 for tributaries of the Hudson River Estuary (Dufour et al. 2009, NYSDEC 2010, Hattala et al. 2011). We designed this project to gather presence–absence and temporal information about river herring spawning runs from the lower, middle and upper tributaries of the Estuary. Between nine and 11 tributaries were monitored annually by 70 to 213 volunteers in 2008, 2009, and 2010. Herring were seen as early as 31 March and as late as 1 June. River herring were observed in all but one of the tributaries. However, several tributaries with known strong historical runs had very few sightings. Water temperature seemed to be the most important factor determining when herring began to run up a given tributary. Sightings of herring were most common at water temperature above 50 F. Tributaries in the middle part of the estuary warmed the fastest each spring and generally had the earliest runs.

4.2.5 Young-of-the-Year Abundance

Since 1980, the Department has obtained an annual measure of relative abundance of young-of-the-year (YOY) alewife and blueback herring in the Hudson River Estuary. Although the program was designed to sample YOY American shad, it also provides data on the two river herring species. Blueback herring appear more commonly than alewife. In the first four years of the program, sampling occurred river-wide (rkm 0-252), bi-weekly from August through October, beginning after the peak in YOY abundance occurred. The sampling program was altered in 1984 to concentrate in the freshwater middle and upper portions of the Estuary (km 88-225), the major nursery area for young herring. Timing of samples was changed to begin in late June or early July and continue biweekly through late October each year. Gear is a 30.5 m by 3.1 m beach seine of 6.4 mm stretch mesh. Collections are made during the day at approximately 28 standard sites in preferred YOY herring habitat. Catch per unit effort is expressed as annual geometric and arithmetic means of number of fish per seine haul for annual weeks 26 through 42 (July through October). This period encompasses the major peak of use in the middle and upper estuary.

From 1980 to 1998, the Department's geometric mean YOY annual index for alewife was low, with only one year (1991) over one fish per haul. Since 1998, the index has increased erratically (Figure 16).

From 1980 through 1994, the Department's geometric mean YOY annual index for blueback herring averaged about 24 fish per haul, with only one year (1981) dropping below 10 fish per haul (Figure 16). After 1994, the mean dropped to around 17 fish per haul, and then began the same high-low pattern observed for alewife.

The underlying reason for the wide inter-annual variation in YOY river herring indices is not clear. The same erratic trend that occurred since 1998 has also occurred in American shad

(Hattala and Kahnle 2007). The increased inter-annual variation in relative abundance indices of all three Alosines may indicate a change in overall stability in the system.

4.2.6 Conclusion

Over the last 30 years, the Hudson River stocks of alewife and blueback herring have shown inconsistent signs in stock status trends. Calculated CPUE for commercial gill net gears has increased in recent years, while CPUE in scap nets fished in tributaries initially declined, but has remained relatively stable since 2003. Apparent mortality increased on mature fish and as mortality rose, mean total length and weight declined. Similar trends occur in the both the fishery dependent and independent data. Recruitment has become extremely variable since the mid-1990s for both species. Some decline is occurring for YOY blueback herring while, counter-intuitively, there has been an increasing trend for YOY alewife. Anecdotal evidence from anglers and commercial fishermen suggest a decline in abundance in tributaries yet a dramatic increase of herring in the main-stem river in the last few years.

The upsurge in river herring used as bait for striped bass has placed herring in a tenuous position. With this continuing demand, declining size, and increasing mortality, careful management is needed despite variable but stable recruitment.

5 PROPOSED FISHERY CLOSURES

5.1 Long Island, Bronx County and Westchester County

Limited data that have been collected for Long Island river herring populations are not adequate to characterize stock condition or to choose a measure of sustainability. Moreover, there are no long-term monitoring programs in place that could be used to monitor future changes in stock condition. In 2010, the Peconic River Fish Restoration Commission installed a rock ramp to provide fish passage at the first dam on the Peconic River system. In the spring of 2011, a fish counting apparatus was installed upriver of this ramp. In addition, the Commission initiated biological fish sampling of species, sex, length and scales. If these operations continue in the future and if these provide information that could be used to set and monitor a sustainability target, we will consider a fishery for this river. Little data have been collected for river herring populations in the Bronx and Westchester Counties.

For the above reasons, New York State will close all fisheries for river herring in Long Island streams and in the Bronx and Westchester County streams that empty into the East River and Long Island Sound.

5.2 Delaware River

We have no data that suggest river herring occur in New York waters of the Delaware River. New York State proposes to close fishing for river herring in New York waters of the Delaware River to prevent future harvest should the Delaware stock rebound and expand upriver. This closure conforms to similar closures planned for the Delaware River and Bay by Pennsylvania, New Jersey, and Delaware.

6 PROPOSED SUSTAINABLE FISHERY

6.1 Hudson River and Tributaries

Given the mixed picture of stock status provided by available data on Hudson River herring, New York State proposes a restricted fishery in the main-stem Hudson River coupled with a partial closure of the fishery in all tributaries. We do not feel that the data warrant a complete closure of all fisheries. We propose that the restricted fishery would continue for five years concurrent with annual stock monitoring. We propose a five-year period because the full effect of our proposed restrictions will not become apparent until all age classes in the population have been exposed to the change. Most of the fish in the Hudson River herring spawning stocks are estimated to be three through seven years old and these ages predominate in the fishery. Sustainability targets would be set juvenile indices. We would monitor, but not yet set targets for mean length from fishery independent spawning stock sampling and CPUE in the commercial fixed gill net fisheries in the lower river below Bear Mountain Bridge. We will also monitor age structure, frequency of repeat spawning, and total mortality (Z) if we can resolve uncertainties about aging methods and mortality estimate methodology. Stock status would be evaluated during and after the five year period and a determination made whether to continue or change restrictions. Moreover, we do not know how much of the apparent high mortality is caused by bycatch in ocean fisheries and thus outside current scope of restrictions proposed in this plan.

Recreational harvest of river herring is much greater than reported harvest from commercial gears. Data from a creel survey in 2005 estimated approximately 152,000 herring were taken in the recreational fishery (NAI 2007) while some 31,000 herring were reported from commercial gears (Table 2). For this reason, we feel that restrictions to the recreational fishery will likely have a greater impact on take of herring than commercial restrictions.

We should note that Draft Addendum 3 to Amendment 6 of the ASMFC Interstate Management Plan for striped bass stipulates that states should reduce fishing mortality on spawning stocks by 50%. If this draft is approved by the ASMFC Striped Bass Management Board, we may have to restrict effort in the recreational striped bass fishery. Restrictions may include a reduction in use of bait such as river herring. Any reduction in effort will likely reduce demand for river herring and thus reduce losses in the Hudson stocks.

A summary of the following fishery restrictions are contained in Tables 5 and 6. These restrictions were based on public comments received from public information meetings held in the Hudson valley in 2010 in addition to the need to reduce harvest. Public suggestions for restrictions are listed in Appendix C.

6.1.1 Proposed Restrictions - Recreational Fishery

Recreational fishing season

Currently none; proposed season is March 15 to June 15.

Recreational Creel Limit

Currently there are no restrictions on daily take of river herring in the Hudson and its tributaries. To reduce harvest and waste, we propose to implement a restrictive recreational creel limit of ten river herring per day, or a total maximum boat limit of 50 per day for a group of boat anglers, whichever is less. A Charter boat captain (see Commercial Fishery Restrictions) will be responsible for a possession limit of 10 river herring per paying customer or a total maximum boat limit of 50 herring per day, whichever is less. Charter boat captains are required, at minimum, to hold a US Coast Guard "six pack" license, i,e. a maximum number of six passengers can be on board. However, most vessels fishing the Hudson relatively small (20 to 30 ft) with an average of four fares maximum.

Most of the river herring harvest is driven by striped bass fishermen catching herring for bait. Anecdotal reports and comments at public meetings suggest that many anglers take many more herring than they need for a day's fishing. The proposed creel limit will prevent such overharvest and avoid waste. We obtained an idea of potential harvest reduction from the proposed creel survey from data in the Cooperative Angler Program described in Section 2.1.3. Data were available on herring harvest during 502 trips. Since trip level reports often included more than one angler, we divided the reported herring catch by the number of anglers for an estimate of catch per angler trip. These data indicated that 56 percent of the catch per angler trips caught six or more herring suggesting that a five fish limit could reduce harvest by 56 percent.

To track harvest, New York will implement the on line creel survey/ diary program coordinated by ACCSP. It is scheduled to go live by Jan. 1, 2012. New York will increase public outreach to encourage angler use of this program. We will also continue the Cooperative Angler Program for comparison and for individuals not savvy with on-line tools.

Prohibit Harvest by Nets in Tributaries

Recreational anglers generally use hook and line (jigging) in the main-stem river and are allowed to use personal use gears (without a license) of scap/lift nets (36 sq ft or less), small dip nets, and cast nets. They are not required to report this catch and the number of herring taken by these gears is unknown. Anecdotal reports and observations suggest tributaries are popular locations for recreational harvest by these net gears, especially in the middle section of the estuary (Figure 1).

Information from the volunteer angler program along with anecdotal data on recreational harvest suggests that abundance of river herring, mostly alewife, has declined in some spawning tributaries. This may be due to the increased vulnerability to harvest as herring often concentrate in these tributaries in large schools to spawn. Tributaries with an impassable barrier close to the mouth confine fish to even smaller areas. For these reasons, we feel it prudent to close recreational harvest by nets from tributaries until measures of stock condition improve. We did not feel that it was feasible or desirable to enforce a closure on angling for river herring in tributaries.

In the main-stem Hudson, personal use nets will be allowed to continue but with a reduced size for scap/ lift nets (16 sq ft instead of 36 sq ft); seine, cast, and dip nets sizes will remain the same (Table 5).

Closed areas

Although personal-use net fishing by recreational anglers will not be allowed in tributaries, angling will continue. However, to further relieve fishing pressure in areas of fish concentration, in addition to the net ban, no fishing will be allowed within the River Herring Conservation Area (RHCA) defined as stream length within 250 m (825 feet) of any type of barrier, natural or man-made. This is similar to a fishing ban within 50 rods of fishways instituted in New York in 1895. Many of the Hudson's tributaries have natural (rapids) or man-made barriers a short distance in from the main river. River herring concentrate in great numbers below these barriers making them very vulnerable to any fishing. This closed area will allow them to spawn in this undisturbed stretch. The RHCA closure will effectively end all fishing in the eight smallest tributaries, or 14% of the tributaries in the estuary.

Above the Troy Dam, an area closure is already in effect for the "Waterford Flight", Lock 2 to Guard Gate 2, a series of dams and locks at the entrance to the Mohawk River. Within the Mohawk, a RHCA will be in effect below any of the remaining locks and dams up to Lock 21 in Rome.

Escapement period

None are proposed.

Licensing and reporting

In 2011, New York State implemented a recreational marine fishing registration. All anglers fishing for anadromous fish must register prior to fishing for migratory fish of the sea. For the Hudson this includes river herring and striped bass. The recreational and commercial fisheries for American shad were closed in the Hudson River in 2010.

By Jan 1 2012 New York, in cooperation with ACCSP, will start up an online angler survey. The Department will increase public outreach to strongly encourage fishers to use this new tool to aid in understanding recreational catch and harvest.

6.1.2 Proposed Restrictions - Commercial Fishery

License Required:

Currently, fishers using commercial, non-personal use size gears to take and /or sell fish must be in possession of a Marine Permit for that gear. Marine permits have an annual reporting requirement, but no requirements for proof that harvest was for commercial purposes. Recreational fishermen commonly purchase marine permits and use commercial gears because of the low cost. We propose to strengthen the commercial aspects of these gears by requiring proof that harvest was sold as a requirement for license renewal.

The overlap with gears licensed under the NY bait license will be minimized by requiring a Marine Permit to take river herring. Cast nets will be included under the Marine Permit licensing system.

Closed area

We propose to continue the current closures as listed in Table 6 and implement a new closure:

Prohibit Harvest by Nets in Tributaries: Closing the tributaries to harvest by nets will likely reduce overall harvest, but the actual size of this reduction is not known. We do not know the size of recreational net harvest from tributaries. We can infer current commercial harvest from tributaries by the number of fish taken in scap nets since most river herring taken in tributaries are taken by this gear and most scap nets are fished in tributaries. Mean annual reported harvest by commercial scap nets in the last five years was about 15,000 river herring or 48% of the total reported commercial harvest. The mean number of commercial fishing trips using scap nets during this time period was 611 trips which were about 59% of all reported trips in the estuary and tributaries. Elimination of commercial net harvest from these waters will eliminate commercial fishing in 175 miles, or approximately 65% of linear spawning streams in the Estuary and above the Troy Dam.

Gear Restrictions

All current gear restrictions will remain in place (Table 6). Other changes include:

Gill nets: Currently both anchor and drift gill nets are used in the mid and upper estuary above the Bear Mountain Bridge (> rkm75). Both gears catch herring, but losses can be higher in anchored nets because they are often not tended as frequently as drifted nets. This is especially the case with recreational fishermen who are often not experienced in use of gill nets. We propose to ban use of fixed gill nets in the Hudson River above Bear Mountain Bridge; drift gill nets are required to be tended by owners as they are fished. We don't know what reduction in harvest would result, but some will occur and the change will certainly reduce waste of fish.

Scap /Lift nets: Currently there are no limits on size of scap nets to be used. Mandatory reports indicate that the largest nets in use are 400 sq ft (20 by 20 ft). The proposed maximum net size is 10 ft by 10 ft.

Fyke and Trap nets: Although currently legal for the take of river herring, no commercial harvest is reported from these gears. We propose that their use not be allowed for harvest of river herring.

Commercial Net Permit and Fees

Commercial gears in the main-stem Hudson and tributaries are licensed under a NYSDEC Bureau of Marine Resources Marine Permit. Access to obtain a Marine Permit remains open, with no prior requirements. These commercial gears are often used by recreational fishermen because current permit fees are very low. Most fees were set in 1911 by the then New York Forest, Fish and Game Commission and no fee increases have occurred through the present time. Commercial gears such as gill nets can take high numbers of herring and are not considered to be recreational gear in New York. For the purposes of harvest in ocean waters (Marine and Coastal District), gill nets are considered commercial gear and their use for recreational purposes is not permitted.

We propose regulations to increase fees to account for inflation, to emphasize that nets are commercial gears, and to discourage casual use by recreational anglers. Current fee structure can be found in New York Code of Rules and Regulation- Part 35 (see http://www.dec.ny.gov/regs/4019.html). We considered two alternatives.

1. Increased gear and fishing vessel fees.

    a. In 1911, fees were $5.00 per each trap, seine or gill net, and $1.00 per scap net. These fees would translate to $115.00 per gill net or seine and $25.00 per scap net in today's (2011) dollars.
    b. Gill nets and seines can also be licensed by the linear foot of net rather than as a type of net. We propose that the current $ 0.05 per foot be increased to $1.00 per foot. Data from the mandatory reports indicates that the most recent (2010) licensed gill net lengths ranged from 10 ft ($10 fee) to 600 ft ($600 fee). Seines have no maximum length restriction in place; current use is 50 ft ($50 fee) to 100 ft ($100 fee).
    c. Another way to differentiate between recreational and commercial fishermen is to reinstitute the 1911 fishing vessel registration for the Hudson River, which is still active for other waters of NY. The 1911 fee of $15.00 for the smallest motorized vessel translates to $350.00 per vessel in today's dollars.

2. A single commercial gear permit.

This approach simplifies the above combination of gear fees and is our preferred alternative.

We would create a Hudson River Commercial Fish Gear Permit (HRCFGP): for individuals who want to harvest river herring or Atlantic menhaden; fee of $150. This would be instead of individual gear licenses.

a. Qualifications needed: proof of previous sale to a licensed retail bait shop; if a business (retail bait shop), proof of business incorporation (LLC)
b. If applicant holds a valid New York food fish or crab permit(s); cost of HRCFGP to be offset by valid permit fee(s)
c. To include all restrictions as listed in Table 6.
d. Gears to be used include anchored (fixed) and drifted gill nets, scap/lift nets, seines and cast nets (see Table 6 for size limitations)

Gear restrictions outlined above will still apply to any alternative chosen.

Closed Fishing Days

A 36-hour escapement period per week, from 6 AM prevailing time on Friday to 6 PM prevailing time on Saturday, is in effect for commercial gill nets from March 15 to June 15. We propose to expand this closure to include all commercial nets.

Reporting

Current mandatory reports of daily catch and effort data are submitted annually. We will continue to require these reports, but decrease the time of report submission to monthly.

Charter Boat License

In order to distinguish Charter Boat operators from recreational anglers, we propose to use the existing Marine & Coastal District Party & Charter Boat License (CPBL), as it exists for NY's Marine District. CPBL holders will follow all regulation as established for the Marine District with two exceptions: creel and size limit for striped bass will comply with limits set for the Hudson River above the G. Washington Bridge and the creel limit for a charter boat will be 20 river herring per day. Hudson valley charters can take up to three to six individuals per trip.

7 PROPOSED MEASURES OF SUSTAINABILITY

7.1 Targets

Juvenile Indices

We propose to set a sustainability target for juvenile indices using data from the time period of

1983 through 2010 for both species. We will use a more conservative definition of juvenile recruitment failure than described in section 3.1.1.2 of Amendment 2 to the ASMFC Interstate Fisheries Management Plan for Shad and River herring (ASMFC 2009). Amendment 2's definition is that recruitment failure occurs when three consecutive juvenile index values are lower than 90 % of all the values obtained in the base period. We will use a 75% cut off level. The 75% level for alewife is 0.35 (instead of 0.19) and 11.14 (instead of 2.86) for blueback herring (Figure 16).

The fishery will close system-wide if recruitment failure, defined as three consecutive years below the recruitment failure limit, occurs in either species and will remain closed until we see three consecutive years of recruitment greater than the target values.

7.2 Sustainability Measures

There are several measures of stock condition of Hudson River herring that can be used to monitor relative change among years. However, these measures have limitations (described below) that currently preclude their use as targets. These include mean length in fishery independent samples, catch per unit effort (CPUE) in the reported commercial harvest and age structure. We propose to monitor these measures during the fishery and use them in concert with the sustainability target to evaluate consequences of a continued fishery.

Mean Length

Mean total length reflects age structure of the populations and thus some combination of recruitment and level of total mortality. Mean total lengths of both river herring species in the Hudson River system has declined over the last 20 years and the means are now the lowest of the time series. Since this has been a persistent change in the face of stable recruitment, we suggest that the reduction in length has been caused by excessive mortality of adults within the river and during their ocean residency (bycatch). The bycatch fishery is a large unknown and not solely controlled by New York State to effect a change. Current annual reproduction now relies on a few returning year classes making the populations vulnerable to impacts of poor environmental conditions during the spawning and nursery seasons. We propose to monitor mean total lengths during the proposed fishery.

Catch per Unit Effort in Report Commercial

We suggest that CPUE values of the reported harvest reflect general trends in abundance. However, annual values can be influenced by changes in reporting rate and thus we do not feel that CPUE should be used as a target. Rather, we will follow changes within gear types and fisheries for general trends.

Age structure and Total mortality

We will monitor age structure, frequency of repeat spawning, and total mortality (Z) if we can resolve uncertainties about aging methods and estimate methodology discussed in Status Section 4.2.2.

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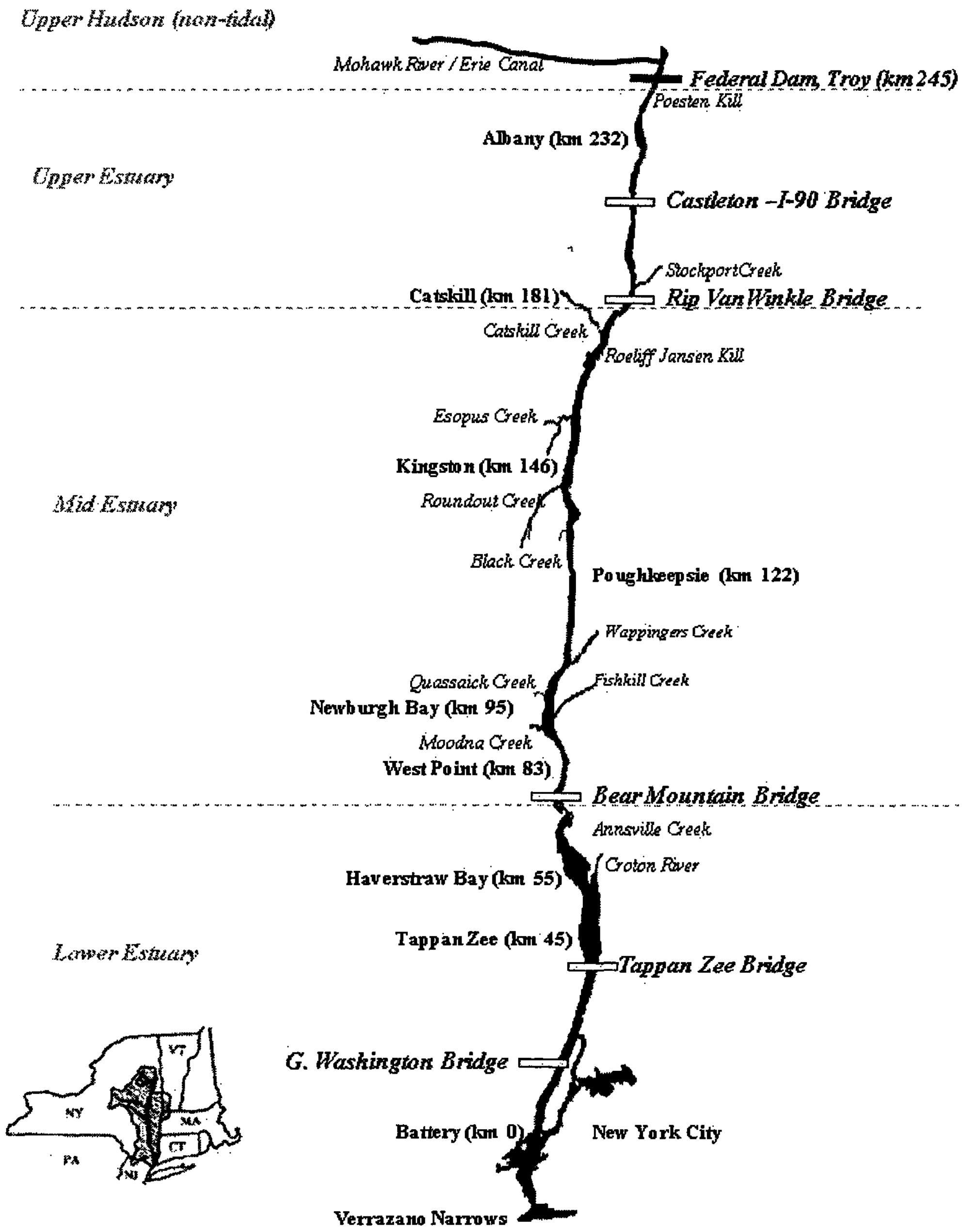

Figure 1 Hudson River Estuary with major spawning tributaries for river herring. (see Appendix Table A for complete list)

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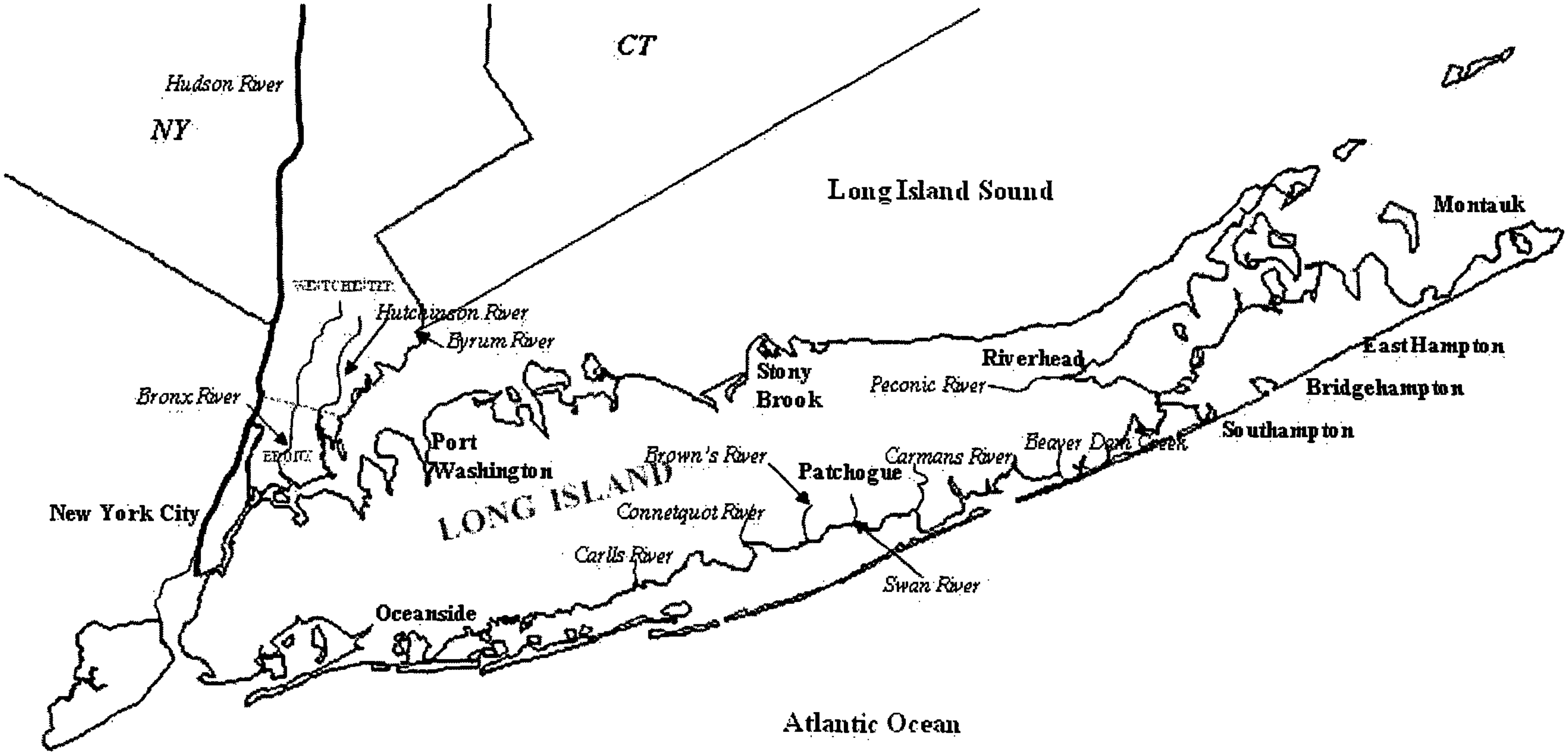


Figure 2 Long Island, Bronx and Westchester Counties, New York, with some river herring (primarily alewife) spawning streams identified (See Appendix Table A for list)

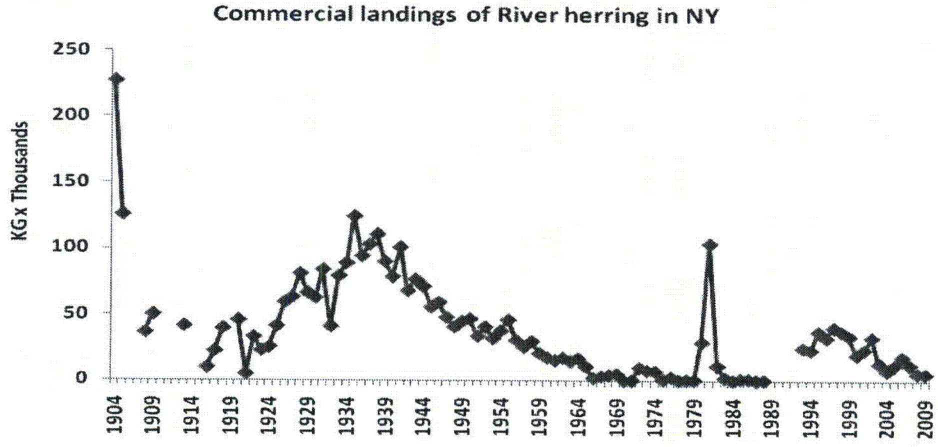


Figure 3 Commercial landings of river herring from all waters of New York State.

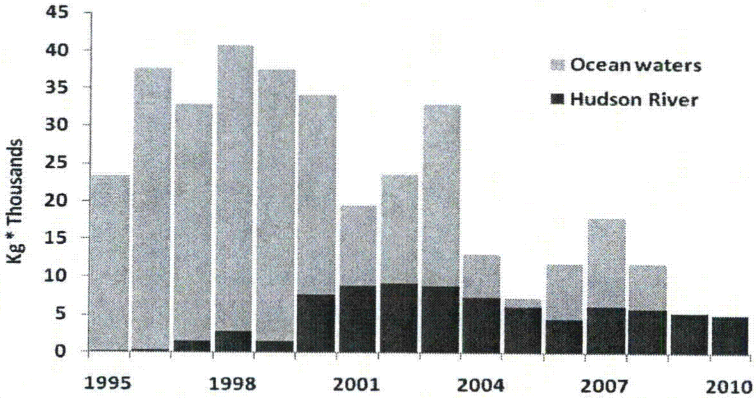


Figure 4 Commercial landings of river herring in the Hudson River and NY Ocean waters.

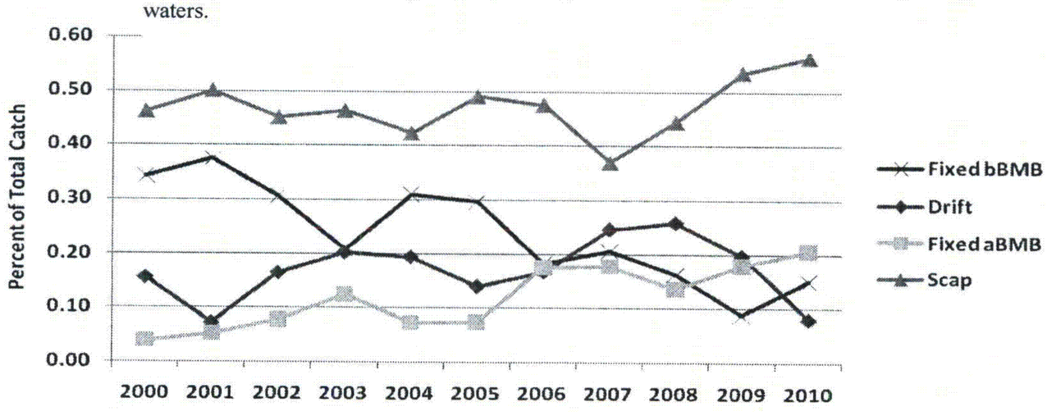


Figure 5 Percent commercial catch by gear of river herring in the Hudson River (a/b BMB=above and below Bear Mountain Bridge).

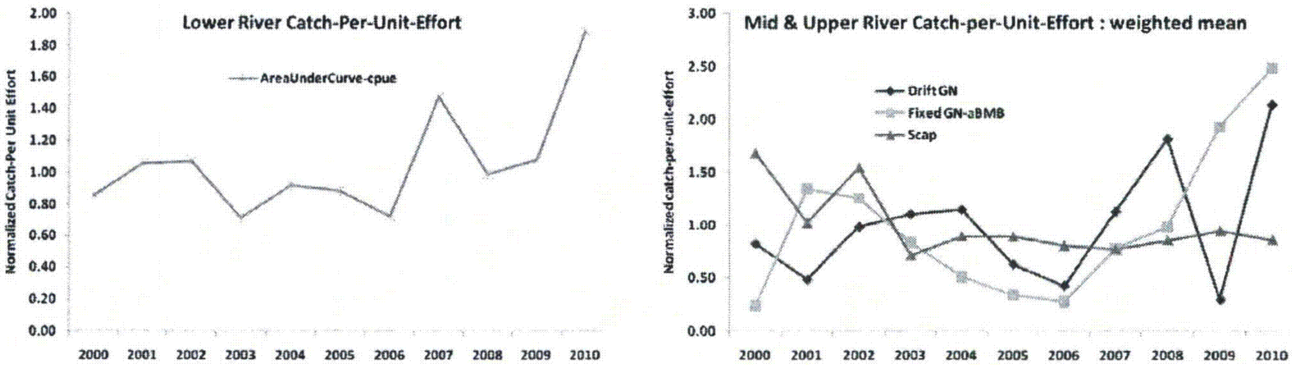


Figure 6 Catch per Unit Effort (number of fish per hours fished) by area of the river and gear. Lower estuary = below Bear Mountain Bridge [rkm 75]; Mid & Upper estuary = above the Bear Mountain Bridge.

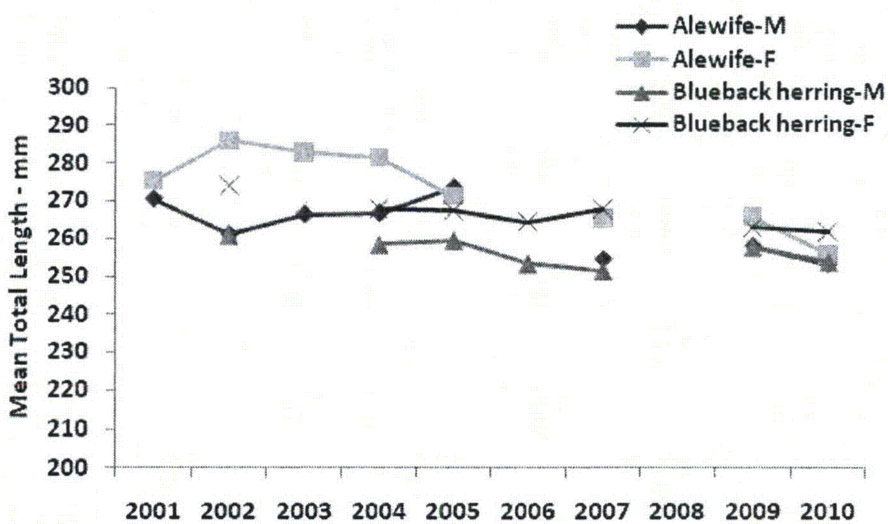


Figure 7 Mean total length of river herring collected from commercial fishery monitoring trips in the Hudson River Estuary

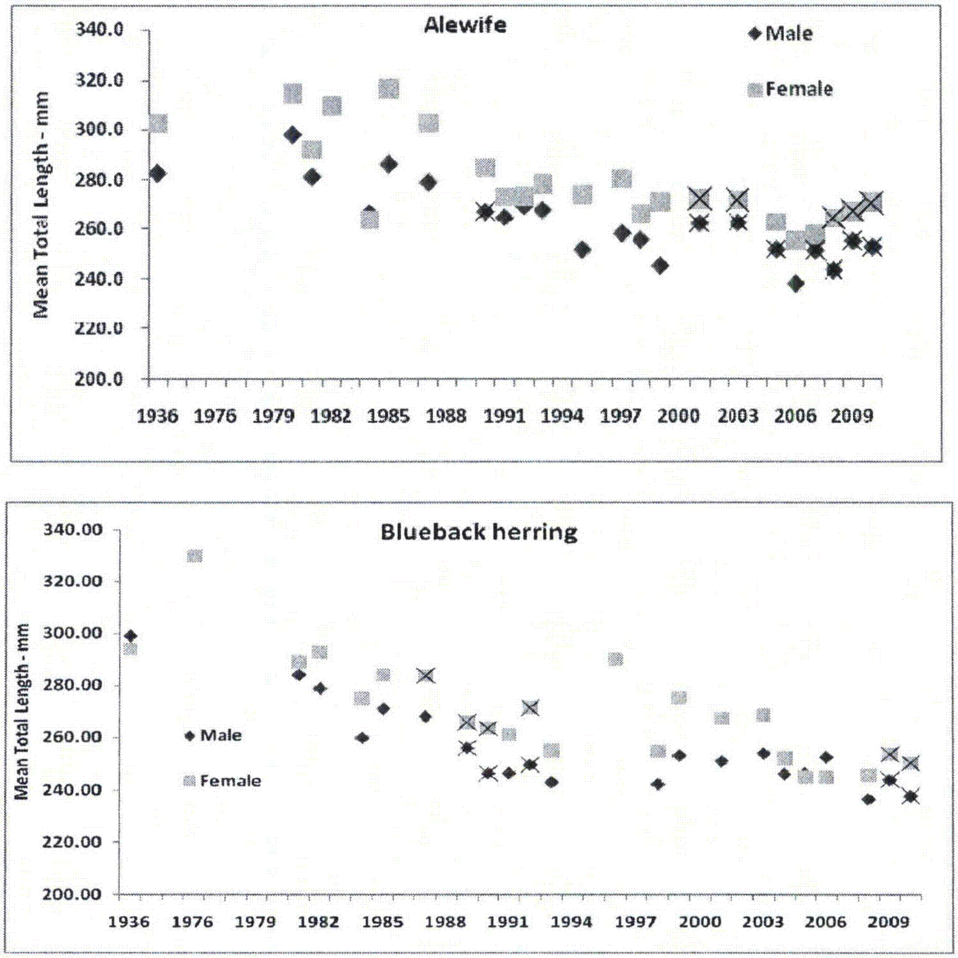


Figure 8 Mean total length of river herring in the Hudson River Estuary. Symbols with an "X" indicate adequate sample size (N>34) to characterize the stock.

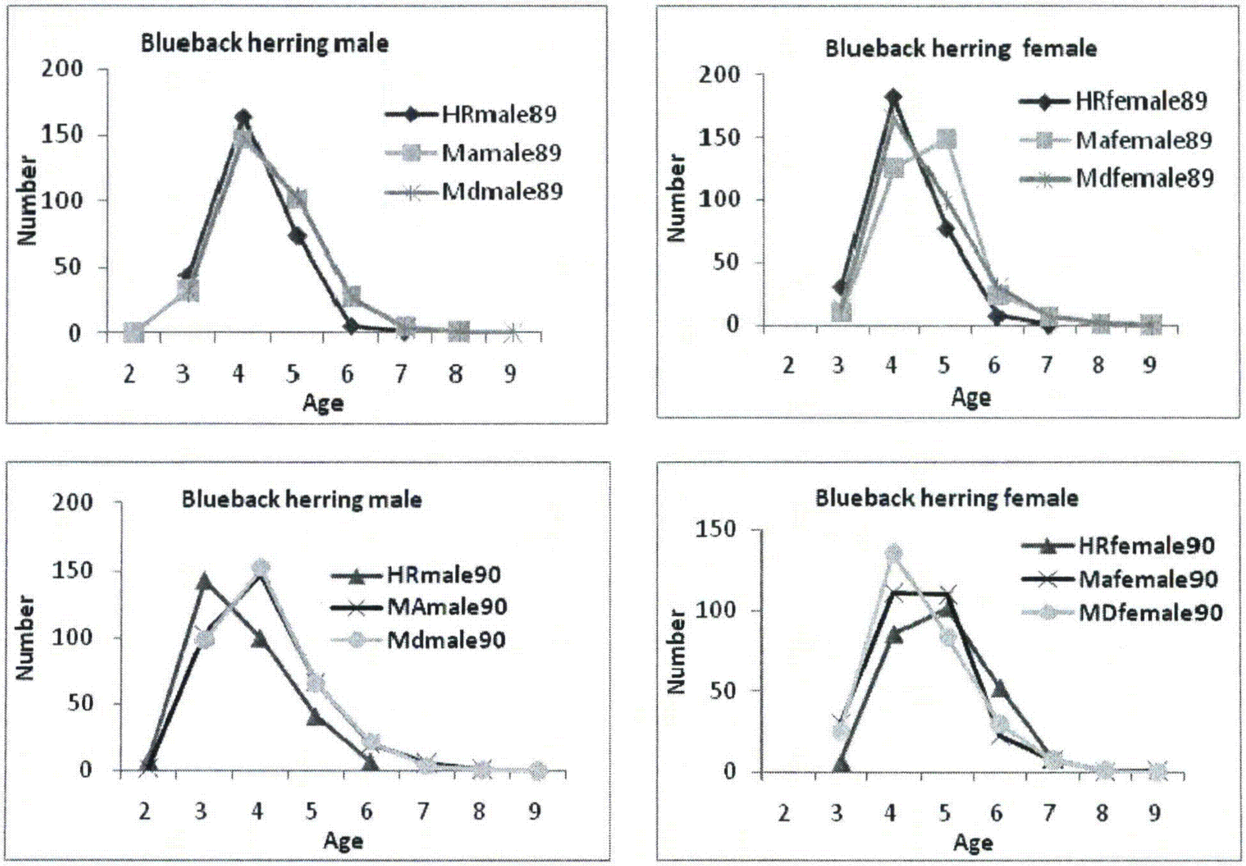


Figure 7 Hudson (HR) age structure and estimated age structure of Hudson River blueback herring based on length-at-age keys from Massachusetts (MA) and Maryland (MD) blueback herring.

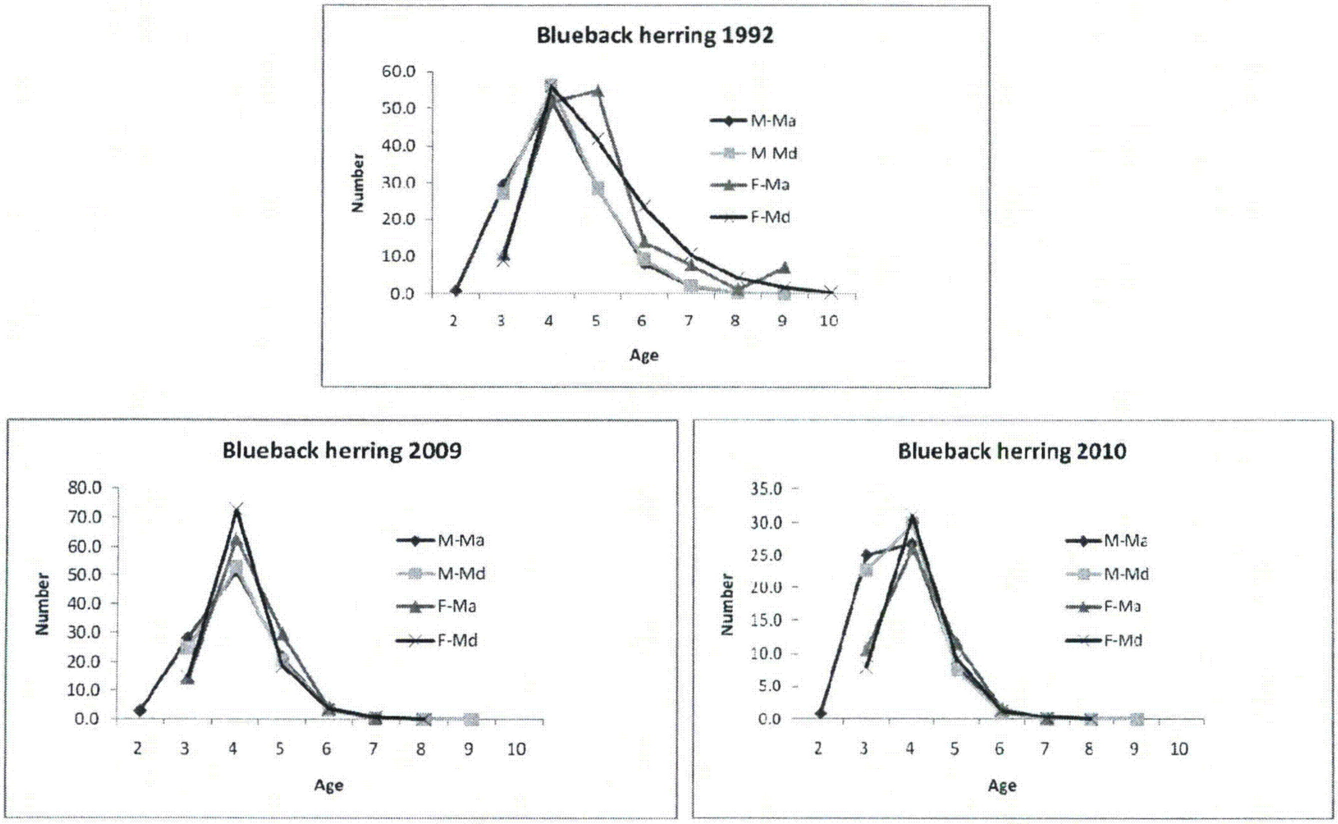


Figure 10 Estimated age structure of Hudson River blueback herring based on length-at-age keys from Massachusetts (MA) and Maryland (MD).

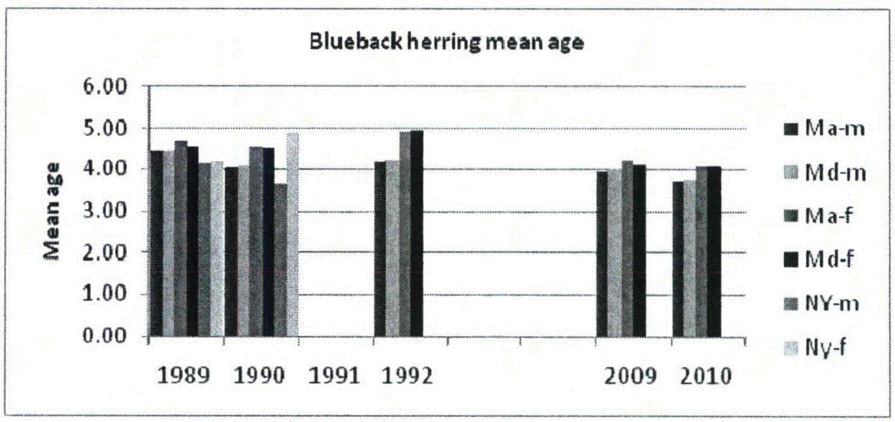


Figure 11 Mean age of Hudson River blueback herring based on length-at-age keys from Massachusetts (MA) and Maryland (MD).

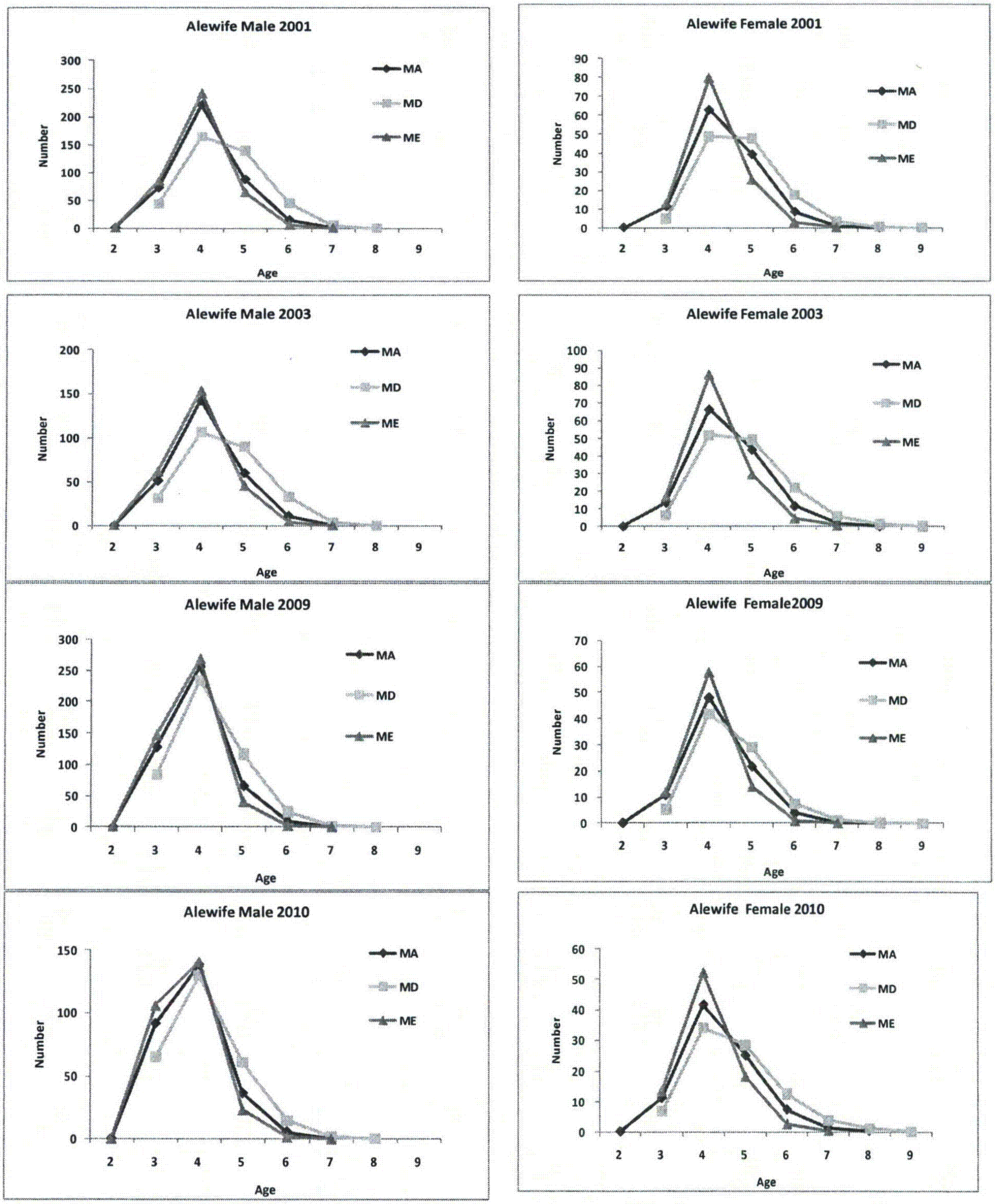
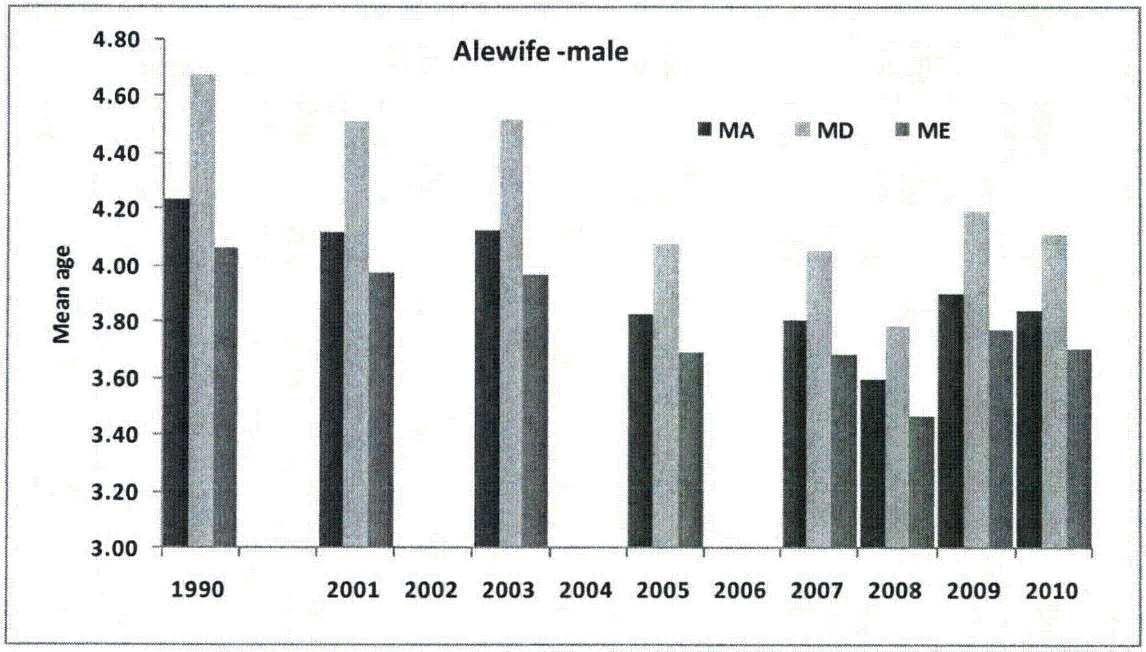


Figure 12. Estimated age structure of Hudson River alewife based on length-at-age keys from Maine (ME), Massachusetts (MA) and Maryland (MD).



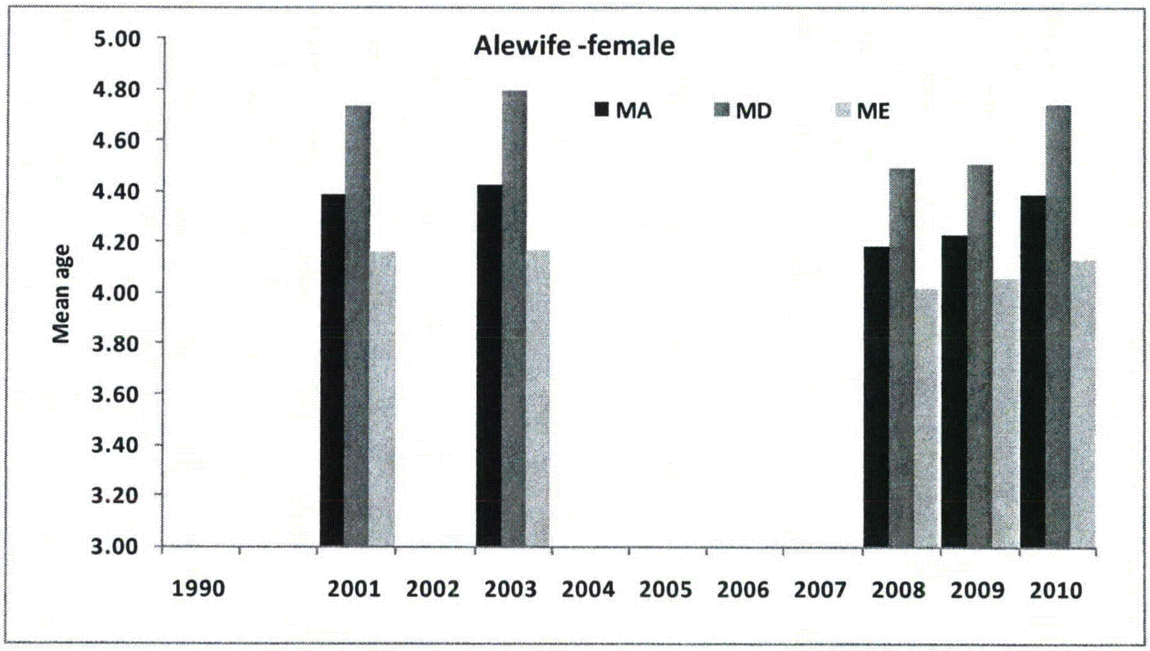
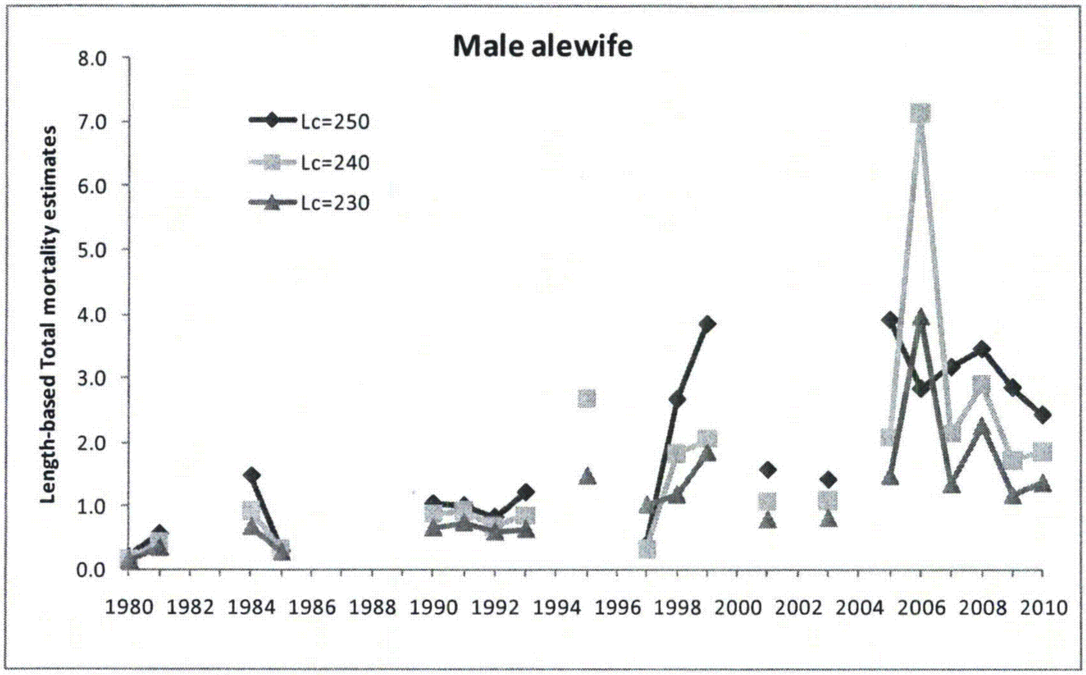


Figure 13. Mean age of Hudson River alewife, ages estimated from age-length keys from Maine (ME), Massachusetts (MA) and Maryland (MD).



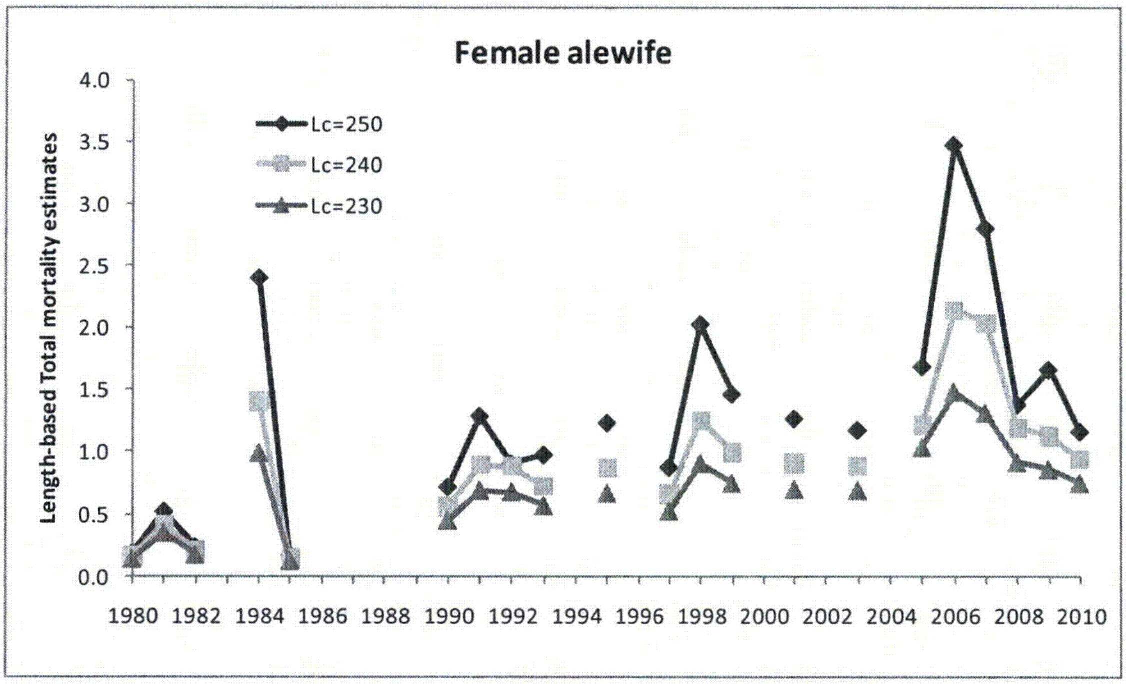
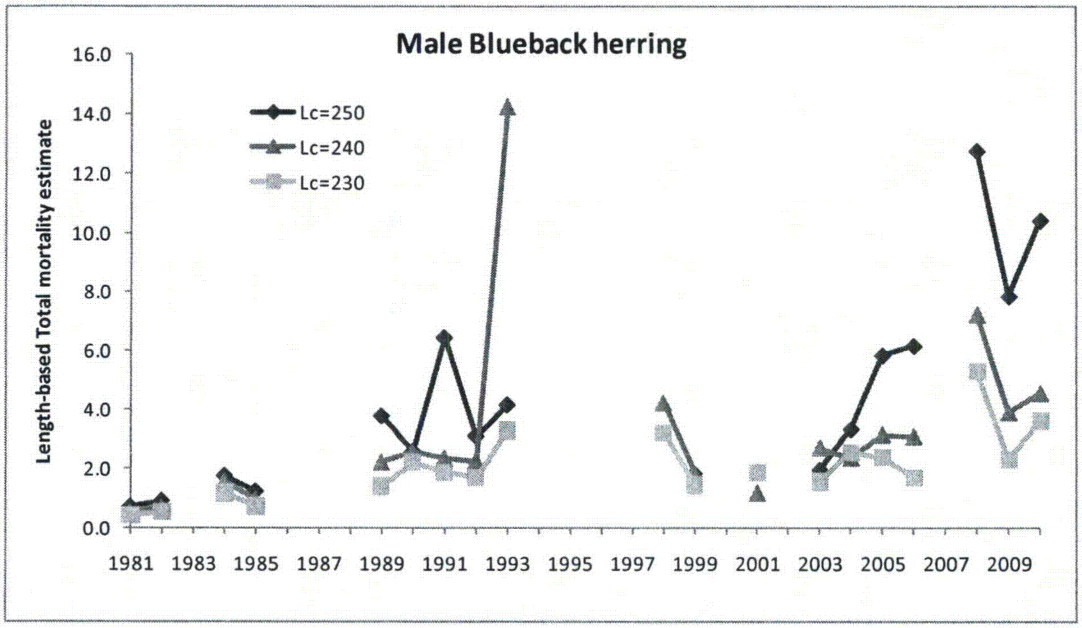


Figure 14. Length-based mortality estimates for Hudson River alewife. Lc =minimum length of fish caught in the sample gear.



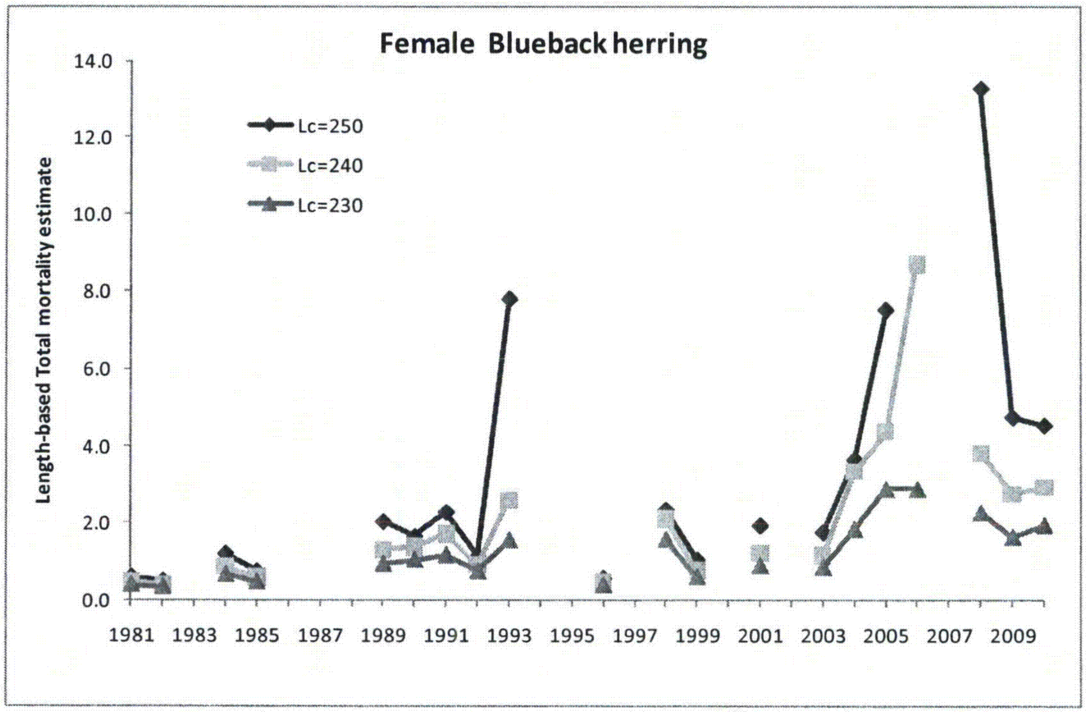
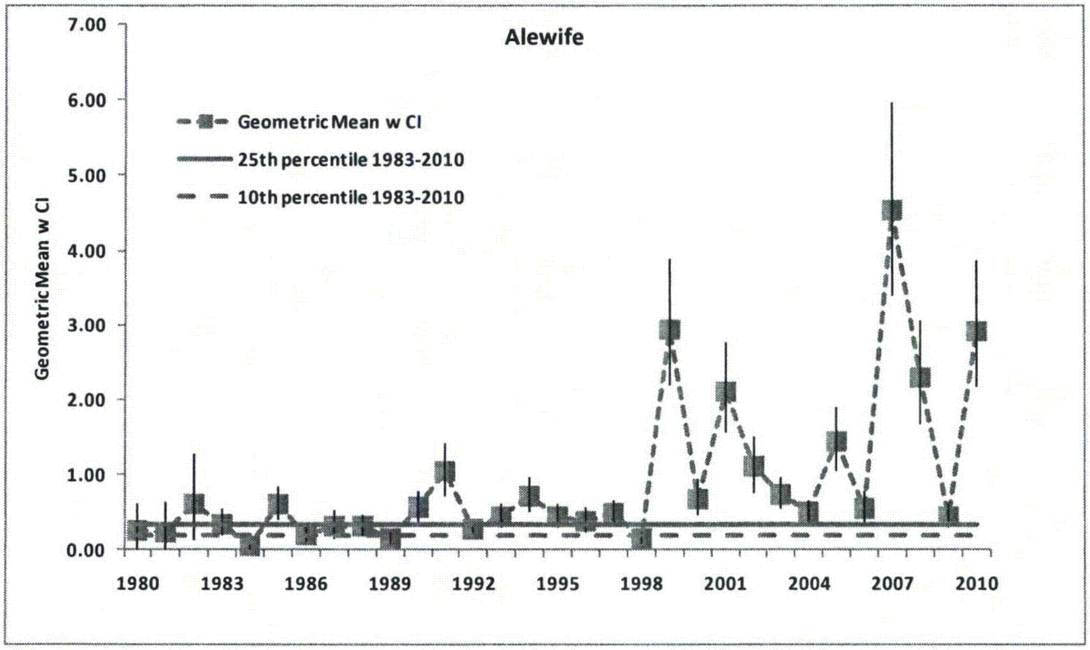


Figure 15 Length-based mortality estimates for Hudson River blueback herring. Lc =minimum length of fish caught in the sample gear.



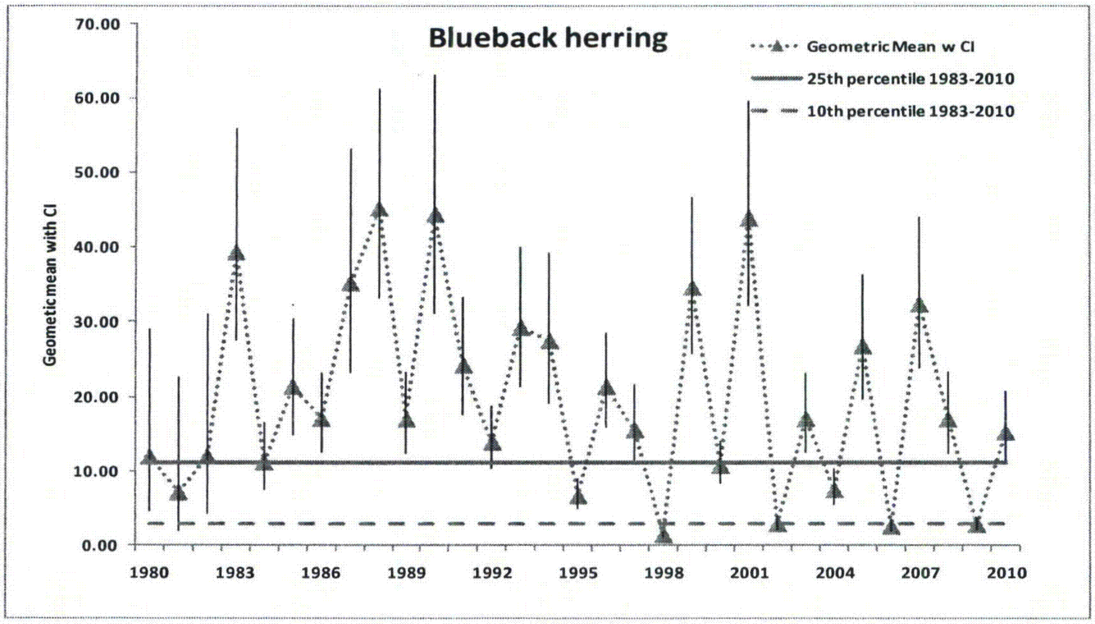


Figure 16. Annual young-of-the-year indices (with 95% CI) for alewife and blueback herring collected in the Hudson River Estuary.

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Table 1. Summary of available fishery-dependent river herring data in Hudson River and Marine District of New York.

Data Type	Time period/ Details	Description	Usefulness as index
Fishery Dependent - Commercial			
Harvest	Historic data: -1904-1994: NMFS -1994-present: Hudson (see below)- NYSDEC; Marine waters- VTR/dealer report since 2002 -1994- present: transfer of historic NMFS data to ACCSP, data available in confidential and non-confidential form	- Provide catch and effort data - Not separated by area (river v marine) - River data reporting rate unknown	- Gives historic perspective - Provides trend data for state as a whole, but does not separate river(s) from ocean until 1994.
Marine monitoring	River herring most likely occur as bycatch in variety of fisheries	No port sampling in NY for 'herring'	
Hudson River Mandatory reports	- Began in 1995 through the present - Enforcement of reports in 2000 - Catch and effort statistics - Licenses are open access with low fees, many recreational fishers purchase and use commercial gears to obtain bait	- Data from 2000 to present good - Reporting rate unknown - Data separated by gear used: - Fixed gill net below Bear Mountain Bridge (BMB); passive gear below spawning area; consistent manner of fishing; weekly sum of CPUE approximating "area under curve" method - In spawning area above BMB - Drift gill (main-stem HR only) - active gear - Fixed gill (main-stem HR only) - less effort than below BMB - Scap/lift net (main-stem HR and tributaries)	Emigration area CPUE - Fixed GN below BMB: o Good indicator of abundance o increasing trend Spawning area CPUE o Drift GN - variable o Scap - Flat o Fixed GN- increasing
Hudson R. Fishery Monitoring	- Began in 1999 through the present - Onboard monitoring - Catch and effort statistics - Catch subsample	- Number of annual trips are low; co-occurs & conflicts with FI sampling - Catch samples low - NEED improved sample size to be useful	- Characterize catch
Fishery Dependent - Recreational			
Harvest (primarily sought as bait for striped bass; some harvest for personal consumption)	Creel surveys: - 2001, river-wide, all year - 2005, spring only - 2007, state-wide angler survey; effort for striped bass	- 2001: provides point estimate of effort for striped bass, ancillary river herring (RH) data - 2005 provides point estimate of RH harvest & effort for striped bass	Combination of effort for striped bass and point estimate of RH harvest; combine with below CAP data to estimate magnitude of recreational harvest for 2005 to the present.
Cooperative Angler Program	Data 2006-present	Diary program for striped bass anglers; includes data for RH catch or purchase, use by trip	Good RH use per trip- used above with rec. harvest to estimate total recreational harvest

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Table 2. Summary of available fishery-independent river herring data in Hudson River, New York.

Data type	Time period/Agency	Description	Usefulness as index
Fishery Independent- Hudson River			
Spawning stock	1936: Biological Survey	Historic data, low sample size of 25 fish, species, sex, length & age	Indication of size change to present
	1975-1985: NYSDEC contaminant sampling	Sample size low and extremely variable by year	Indication of size change to present
	1989-1990 NYSDEC Hudson-Mohawk River.	Focused study, large sample size (1,100 fish): species, sex, length & age	Primarily blueback herring
	1999-2001 Normandeau Assoc. Inc. (NAI)	- Contract to assess gears for spawning stock survey - Developed own age key; not clear how compares to method of other Atlantic coast states	Primary gear used was size selective gill nets; precludes use for length analyses; need adjustment for ages
	2001 to present: NYSDEC spawning stock survey	Focused spawning stock survey; >300 fish collected most years; species, sex, length & scales (ageing not complete)	Sample design precludes use for catch-per-unit-effort data
	Overview of all above	*Problems*	*Ok to use*
		Spotty adequate sample size in most years (>34 per species, sex) to provide trend for length and weight	Good sample size for data 1989-99, 2001,-03,-05, -08 to present
		Ageing technique varies greatly from 1936, 1980s, NAI; techniques appear different from other Atlantic coast states - Mortality estimates from age structure (above) unusable as index	- Used ME, MA & MD age-length keys to estimate Hudson ages; - Results: a slight non-consistent bias of age difference, possibly attributed to ageing technique &/or growth differences (MD fish grow faster than MA) - Suggest use trend in mean age - Mortality estimates from age structure (above) unusable as index - Beverton-Holt length based too dependent on inputs (length at recruitment and age)
	Volunteer River herring surveys	- 2006 to present; documents presence/absence of river herring in Hudson tributaries and in some Long Island streams	- Not yet useful as index; provide a mechanism to improve future sampling for adult runs
Young-of-year Indices	1980 to present: annual yoy sampling standardized since 1984;	- July-Oct sampling within nursery area - Geometric mean number per haul - Catchability may be affected by habitat change	- Both species index variable - Alewife increasing - Blueback slight decreasing trend

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			- Selected conservative target of 25th percentile

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Table 3. Commercial river herring fishery monitoring data for the Hudson River Estuary.

		On-board Observations on Commercial Trips																	
		Alewife					Blueback herring					Unidentified "river herring"							
	N of	Number			Sex ratio		Number			Sex ratio		Number			Sex ratio			Percent	
Year	trips	M	F	U	M	F	M	F	U	M	F	M	F	U	M	F	Total	Alewife	Blueback
1996	1								43								43	0%	100%
1997	5	5	25	178	0.17	0.83											208	100%	0%
1998	1			114													114	100%	0%
1999	4			73										348			421	17%	0%
2000	6	19	18		0.51	0.49	3	32	480	0.09	0.91						552	7%	93%
2001	7	192	178	851	0.52	0.48											1221	100%	0%
2002	8			43			19	41	1225	0.32	0.68						1328	3%	97%
2003	2			171													171	100%	0%
2004	11	124	168	8	0.42	0.58	5	6		0.45	0.55	500	796	297	0.39	0.61	1904	16%	1%
2005	1			428										28			456	94%	0%
2006	3			1					246								247	0%	100%
2007	6			14					53					268			335	4%	16%
2008	1											44			0.50	0.50	44	0%	0%
2009	3	187	179	4	0.51	0.49	37	61		0.38	0.62						468	79%	21%
2010	1	80	42	2	0.66	0.34	33	70	6	0.32	0.68						233	53%	47%

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Table 4. Estimated recreational use and take of river herring by Hudson River anglers.

	Herring Use*							
Year	% of all CAP Trips using herring as bait	N-SB Trips using RH	N bought / trip	N caught / trip	Total RH use/trip	Estimated SB trips**	Trips using herring as bait**	Estimated Herring Use
2001						53,988	39,500	93,157**
2005	89%				2.36	72,568	64,500	152,117**
	Cooperative Angler Program Data							
2006	93%	263	1.47	2.57	4.04			
2007	70%	331	1.66	1.80	3.46	90,742	69,700	241,318***
2008	71%	445	0.86	1.64	2.50			
2009	77%	492	0.63	3.80	4.43			
2010	74%	527	0.67	4.80	5.48			

*Data from NYSDEC - HRFU Cooperative Angler Program (unpublished data)
**Creel survey data: NAI 2003, NAI 2007; 2001 estimated use modified using 2005 RH use per trip* 2001 trips using herring as bait
***Estimate calculated from overall average RH/trip (CAP) and Estimated SB trips from NYSDEC statewide angler survey

Table 5. Current and proposed recreational fishery regulations for a river herring fishery in the Hudson River.

Regulation	**Current 2010 Recreational**	**Proposed change-** ***new***
Season	All year	March 15 to June 15
Creel/ catch limits	None (any size, any number)	- *10 per day per angler or a maximum boat limit of 50 per day for a group of boat anglers (whichever is lower)* - *Charter boats: (see commercial fishing table)*
Closed areas	- None below Troy Dam - Closure from Guard gate 2 to Lock 2 on the Mohawk River	- the *River Herring conservation Area: No fishing within 825 ft (250m) of a man-made or natural barrier* - Closure from Guard gate 2 to Lock 2 on Mohawk River
Gear restrictions	-Angling -Scap/lift net: 36 sq ft or smaller - Dip net: 14" round or 13"x13" square - Seine: 36 sq ft or smaller - Cast net; 10ft diameter	- *All tributaries, including the Mohawk River above Troy: Angling only, no nets* - Main river below Troy Dam: Angling or the use of nets to obtain bait for personal use only as follows: - *Scap/lift net 16 sq ft or less* - Dip net: 14" round or 13"x13" square - Seine 36 sq ft or smaller - Cast net 10 ft diameter
Escapement (no fishing days)	None	None
License	Marine Registry	Marine Registry
Reporting	None	*New York angler diary on ACCSP website*

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Table 6. Current and proposed commercial fishery regulations for a river herring fishery in the Hudson River.

Regulation	**Current 2010 Commercial**	**Proposed change** - *new*
Season	Mar 15 – Jun 15	Mar 15 – Jun 15
Creel/ catch limits	None	*Charter boats: 10 fish per day per paying customer or a maximum boat limit of 50 fish per day,(whichever is lower)**
Closed areas	- No gill nets above I90-Castleton Bridge - No nets on Kingston Flats	- No gill nets above I90 - Castleton Bridge - No nets on Kingston Flats - *No nets in tributaries*
Gear restrictions	Allowed gears - Gill net o 600 ft or less o 3.5 in stretch mesh or smaller o No fishing at night in HR above Bear Mt Bridge - Seine >36 sq ft - No seine >100 ft allowed above I90 bridge - Scap/lift net no size - Fyke or trap net - Cast net not exceeding ten ft diameter	Allowed gears for river herring - Gill net o 600 ft or less o 3.5 in stretch mesh or smaller o No fishing at night in HR above Bear Mt Bridge o *No fixed gill nets above the Bear Mt Bridge* - Seine; no seine >100 ft allowed above I90-Castleton Bridge - *Scap/lift net 10 ft by 10 ft maximum* - Cast net not exceeding ten ft diameter
Escapement (no fishing days)	- 36 hr lift (applies only to gill nets allowed in the main river)	- 36 hr lift - *Applicable to all net gears*
Marine Permit	Marine Permit - Fees implemented in 1911 - Gill net $0.05/foot - Scap net <10 sq ft $1.00 - Scap net>10sq ft $2.00 - Seine $0.05/foot - Trap nets $3 to $10 - Fyke net $1 to $2 Bait license - Cast net $10	- *Marine permit only license to take anadromous river herring*, the only net gears allowed include drift and fixed gill net, scap/lift net,seine and cast net - Fees updated to include any of the following: 1a. Gill or seine net - $115; scap net $25 1b.Gill or seine $1 per foot 1c.Fishing vessel $350 2. Create Hudson River commercial fish permit; includes use of gillnets, scap/lift nets, seines and cast nets with all other restrictions as listed in this table; qualifications needed (see Sec 6.1.2, page 26)
Charter* Boat License	None for Hudson above the Tappan Zee Bridge	Require existing Maine &Coastal District Party boat/ Charter license for tidal Hudson and its tributaries- $250.00
Reporting	Mandatory daily catch& effort; one annual report	Mandatory daily catch& effort; *reports due monthly*

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Appendix A. River herring streams of New York including tributaries of the Hudson River Estuary, and the Mohawk River; streams in the Bronx and Westchester Counties and on Long Island. (This list may not be complete).

Hudson River						
River Mile	County	Primary Tributary	Secondary Trib1	Secondary Trib2	M to barrier	Ft to barrier
18	Westchester	Saw Mill			100	328
24	Rockland	Sparkill Creek			1,620	5,315
25	Westchester	Wicker's Creek			240	787
28	Westchester	Pocantico River			950	3,117
33	Westchester	Sing-Sing			450	1,476
34	Westchester	Croton River			2,860	9,384
38	Westchester	Furnace Brook			820	2,690
38	Rockland	Minisceongo			2,100	6,890
39	Rockland	Cedar Pond Brook			4,500	14,765
43	Westchester	Dickey Brook			2,610	8,563
44	Westchester	Annsville Creek	Peekskill Hollow	Sprout Brook	1,140	3,740
44	Westchester	Annsville Creek	Peekskill Hollow		2,310	7,579
44	Westchester	Annsville Creek			3,000	9,843
46	Orange	Popolopen Creek			840	2,756
52	Putnam	Phillipse Brook			1,160	3,806
52	Putnam	Indian Brook			1,240	4,068
53	Putnam	Foundry Brook			880	2,887
55	Putnam	Breakneck Brook			160	525
57	Orange	Moodna Creek			4,740	15,552
58	Dutchess	Malzingah Brook (Gordon's Brook)			100	328
59	Dutchess	Fishkill Creek			980	3,215
67	Dutchess	Hunters Brook			180	591
67	Dutchess	Wappingers Creek	Hunters Brook		3,380	11,090
69	Ulster	Lattintown Creek	S. Lattintown		550	1,805
69	Ulster	South Lattintown			1,100	3,609
75	Dutchess	Falkill			100	328
76	Ulster	Twaalfskill	Highland Brook		400	1,312
78	Dutchess	Maritje Kill			190	623
81	Dutchess	Crum Elbow			270	886
84	Dutchess	Indian Kill			1,200	3,937
84	Ulster	Black Creek			1,670	5,479
87	Dutchess	Fallsburg Creek			2,000	6,562
87	Dutchess	Landsman Kill			2,100	6,890
91	Ulster	Roundout			3,820	12,533
98	Columbia	South Bay Creek			890	2,920
98	Dutchess	Saw Kill			970	3,183
100	Dutchess	Stony Creek			2,290	7,513
101	Ulster	Esopus Creek			1,850	6,070
105	Columbia	Cheviot Creek			380	1,247
110	Columbia	Roeliff Jansen Kill			9,320	30,579
112	Greene	Catskill Creek	Kaaterskill Creek		4,940	16,208
118	Greene	Murderers Creek			930	3,051
121	Columbia	Stockport Creek	Claverack Creek		1,250	4,101
121	Columbia	Stockport Creek	Claverack Creek	Kinderhook Cree	1,780	5,840
126	Greene	Coxsackie	Sickles Creek (dry)		1,270	4,167
128	Columbia	Mill Creek			1,870	6,135
131	Albany	Hannacroix			1,650	5,414
132	Albany	Coeymans			300	984
135	Renssalaer	Schodack	Muitzes Kill		10,900	35,763
136	Renssalaer	Vlockie Kill			1,880	6,168
137	Albany	Vloman Kill			1,130	3,708
137	Renssalaer	Papscanee	Moordener Kill		1,550	5,086
142	Albany	Normans Kill			2,970	9,745
144	Renssalaer	Mill Creek			210	689
149.5	Renssalaer	Wynants Kill			430	1,411
150	Renssalaer	Poesten Kill			310	1,017
Above Troy Dam		Mohawk River			183,000	600,423

Appendix Table A continued.

County	Stream
Bronx	Bronx River
	Hutchinson River
Westchester	Beaver Swamp Brook
	Blind Brook
	Byram River
	Mamaroneck River
	New Rochelle Creek
	Otter Creek

Long Island			
Shore	Stream &.or Pond with outlet	Tributary	Alewife Present?
South	Beaverdam Creek		Unknown
South	Browns River		Unknown
South	Carlls River		Confirmed
South	Carmans River		Confirmed
South	Connetquot River	Westbrook, Rattlesnake Creek	Unknown
South	Massapequa Creek		Confirmed
South	Mud Creek		Unknown
South	Patchogue River		Unknown
South	Penataquit Creek		Unknown
South	Swan River		Unknown
South	Champlin Creek		Unknown
South	Forge River		Unknown
South	Pipes Creek		Unknown
North	Beaver Brook		Unknown
North	Cold Spring Brook		Unknown
North	Fresh Pond/Baiting Hollow		Confirmed
North	Mill River, Oyster Bay		Unknown
North	Nissequogue River		Confirmed
North	Setauket Mill pond		Unknown
North	Stony Hollow Run, Ctrpt.		Unknown
North	Sunken Meadow Creek		Confirmed
North	Wading River		Unknown
East End	Alewife Brook		Confirmed
East End	Alewife Creek/Big Fresh Pond		Confirmed
East End	Big Reed Pond		Confirmed
East End	Ely Pond		Restoration stocking effort
East End	Gardiner Bay Creeks		Unknown
East End	Georgica Pond		Unknown
East End	Halsey's-Neck Pond		Unknown
East End	Hog Creek		Unknown
East End	Hook Pond		Unknown
East End	Ligonee Brook		Confirmed
East End	Mill Pond - Mecox Bay Ext.		Unknown
East End	Peconic River		Confirmed
East End	Sagaponack Pond - Jeremy's Hole		Unknown
East End	Scoy Pond		Restoration stocking effort
East End	Silver Lake/Moore's Drain		Unknown
East End	Stepping Stones Pond		Unknown

REVISED VERSION: September 2011, based on public comment received.

Appendix Table B. Summary of current (2010) fishery regulations for alewife and blueback herring in New York State.

Fishery / Area

Commercial Harvest:

Inland waters

Hudson River Estuary: G. Washington Bridge north to Troy Dam (River kilometer 19-245)
- Season: 15 March through 15 June
- 36 hour Escapement period (Friday 6 am to Saturday 6pm, prevailing time)
- Net size restriction: limit of 600 ft, mesh size restriction: mesh <3.5 inch stretch mesh
- Net deployment restrictions (distance between fishing gear > 1500 ft)
- Area restrictions (drifted gears allowed in certain portions of the river)

Long Island: No restrictions, except for some towns which have restricted fishing within their township

Marine Waters: Hudson River - G. Washington Bridge south; and waters including NY Harbor and around Long Island
- No limits or season.

Delaware River: NY portion, north of Port Jervis
- No commercial fishery exists in this portion; no rules prohibit it

Baitfish harvest: Take of bait fish (including alewife and blueback herring) are allowed with Bait License in the Inland water of New York State. Allowed gears are seines (all Inland waters) and cast nets in the Hudson River only.

Recreational Harvest:
- No daily limit
- No season
- Harvest can be by hook and line, and some net gears: dip nets (14inches round), scoop nets (13 x 13 inches square), cast net (maximum of 10 feet in diameter) and seine and scap / lift nets 36 square feet or less. Anglers must be registered with the New York Recreational Marine Registry.

REVISED VERSION: September 2011, based on public comment received.

Appendix C. Current regulations for river herring fisheries in the Hudson River watershed, and public suggestions for change summarized from meetings held in April, 2010. Published in the NYSDEC website: http://www.dec.ny.gov/animals/57672.html

Regulation	Current 2010 Commercial	Public suggestions for change
Season	Mar 15 – Jun 15	
Creel/ catch limits	None	- Possession limit of 24 fish for charter boats* - Have a 100 fish daily limit - Have some kind of quota
Closed areas	- No gill nets above I90 Bridge - No nets on Kingston Flats	- Add: Close tributaries to nets
Gear restrictions	- Gill net o 600 ft or less o 3.5 in stretch mesh or smaller o No fishing at night in HR above Bear Mt Bridge - Seine >36 sq ft - No seine >100 ft above I90 bridge	- Gill net o Shorten length to 100 or 200 ft o Add mesh size restriction o Limit net size - Allow no nets
Escapement (no fishing days)	- 36 hr lift (no gill nets allowed in the main river) - does not apply to scap nets in tributaries	- 36 to 72 hr closure - Stay away from the weekend (higher demand for bait)
License	Marine Permit - Varies by gear $1 to $30	- *require a charter boat license - Raise the price of a permit - Increase fee to $75 to $200 Include cast nets as commercial Marine Permit (currently need a bait license) - Make a lottery for obtaining marine permit
Reporting	Mandatory daily catch& effort	

REVISED VERSION: September 2011, based on public comment received.

Regulation	Current 2010 Recreational	Public suggestions for change
Season	All year	- Be more restrictive - Choose a season to protect alewife - Choose closure (season) based on water temperature
Creel/ catch limits	None (any size, any number)	- 5 to 10 a day - Allow a special limit for Charter boats: 24 /day - Need to know difference between creel and possession limit? - Make a slot size &/or size limit
Closed areas	None	- Close all the tributaries to fishing - Close the Mohawk to herring fishing - Have rotating tributary closures (changes every 3 years) - Close parts of tributaries
Gear restrictions	- Angling - 36 sq ft scap or smaller - 14" round or 13"x13" dip net - 36 sq ft seine - Maximum 10 ft diam. Cast net*	- No nets, angling only - No nets in tributaries - No nets or smaller gear
Escapement (no fishing days)	None	- Close fishing 3 or 4 days a week - Allow herring harvest either on odd or even days of the week - Close the run during peak of spawning - Time closures (hours during the day or night) - Opposed to day closures - Make no-fishing days enough to protect spawning - Have sliding closures during the week, i.e. "lure" days
License	Marine License $10	
Reporting	None	- Have a call-in number for harvest (like a HIP #) to get better information - Create a website for anglers to input what they catch

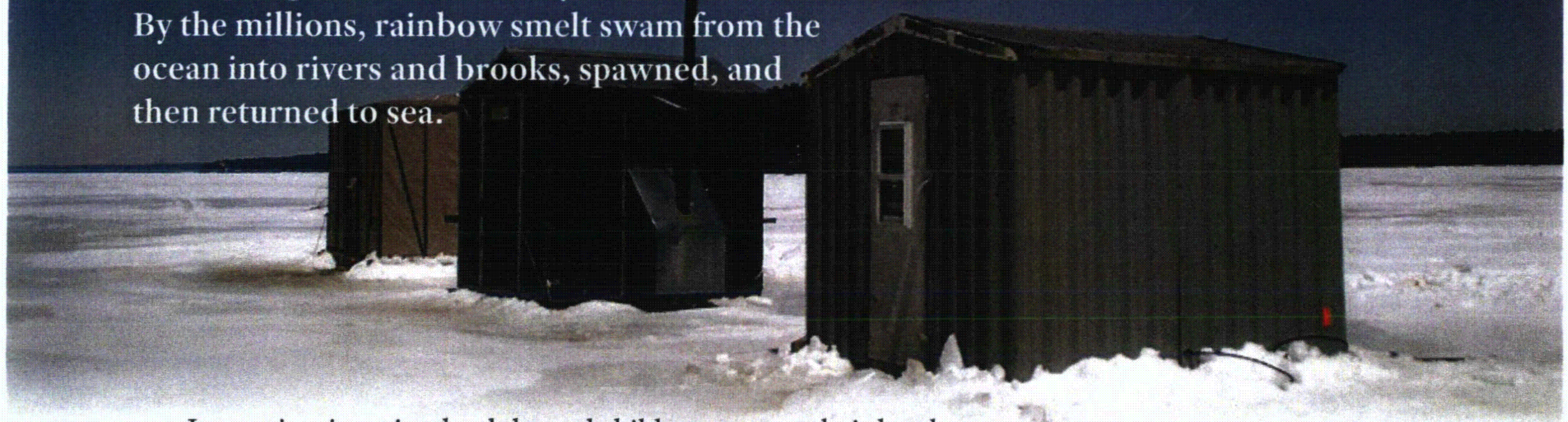
Other issues (other than a fishery) that are creating problems for river herring
- Chlorine discharge problems
- Ocean harvest is the problem- not the river fishery
- Increased silt (covers eggs)

Long Island streams: The lack of data means that no fishery will be allowed under the "sustainable" definition in the ASMFC Amendment 2 . Information on habitat and passage issues will be gathered.

Rainbow Smelt

An Imperiled Fish in a Changing World

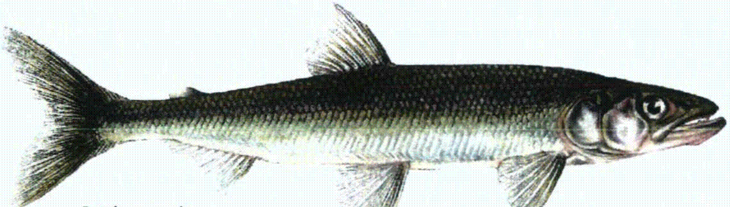
A century ago, streams in coastal New England teemed each spring with small silvery fish called rainbow smelt. By the millions, rainbow smelt swam from the ocean into rivers and brooks, spawned, and then returned to sea.



In a springtime ritual, adults and children went to their local streams and caught great quantities of the small fish. Prized as one of the best-tasting fried fish, smelt were brought home for dinner, sold locally, and shipped to distant markets. Many animals—seals, striped bass, codfish, great blue herons, and others—feasted on rainbow smelt during the springtime bonanza. Although small in size, this fish played a big role in the ecosystem and economy.

Now rainbow smelt are declining, even in streams that once hosted abundant runs each spring. The diminishing numbers have become evident in the Gulf of Maine. Recognizing the plight of the rainbow smelt, the U.S. government listed it in 2004 as a federal Species of Concern.

The state governments of Maine, Massachusetts, and New Hampshire are working together to understand the rainbow smelt's status and threats, and to plan a regional conservation effort for the species. Scientific research by the three-state collaborative focuses on the status of the smelt population and the condition of spawning areas in streams, which may be a key factor in the rainbow smelt's decline.



Rainbow smelt
Osmerus mordax

Ice-fishing shacks (above) are evidence of New England's long tradition of fishing for rainbow smelt. Scientists (below) from three states are studying causes of the smelt's recent decline, including loss of suitable stream habitats (bottom) for spawning.

Joyce Grondin; Mike Timberlake (top)

Tom Watson

State and local governments, community groups, and individual citizens can take immediate action to resolve some of the threats and to restore the rainbow smelt as an icon of spring in New England.

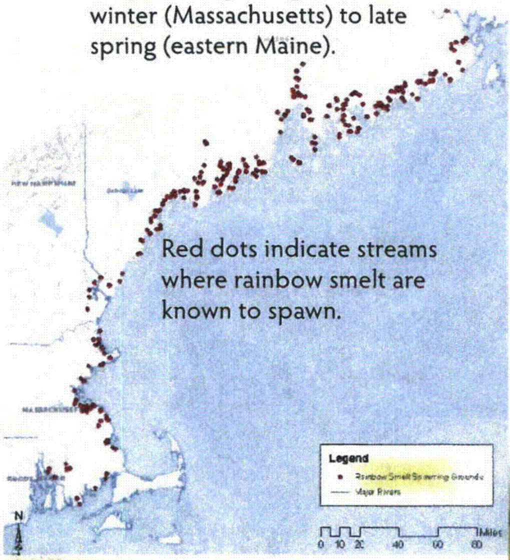
"Second cousin to the grayling and trout, and one of the neatest, most graceful, and delicate of all our food fishes, is that universal favorite, the smelt." Samuels (1904)

Matt Ayer

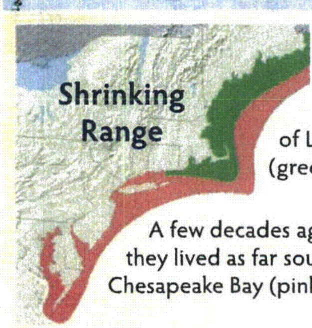
Katherine Mills

Rainbow Smelt at a Glance

- Native to coastal waters of northeastern United States and Canadian Maritimes.
- Eats shrimp, marine worms, amphipods, euphausiids, mysids, and smaller fish.
- Eaten by porpoises, seals, salmon, trout, bluefish, striped bass, Atlantic cod, and birds.
- Slender fish averaging 6 to 8 inches long.
- Can live up to 6 years, but more typically lives 3 or 4 years.
- Lives in estuaries, harbors, and offshore waters during summer, fall, and winter.
- Migrates into rivers and streams to spawn beginning in late winter (Massachusetts) to late spring (eastern Maine).



Red dots indicate streams where rainbow smelt are known to spawn.



At present, rainbow smelt live only north of Long Island Sound (green area).

A few decades ago, they lived as far south as Chesapeake Bay (pink area).

A New England Tradition

Historically, people in New England valued rainbow smelt as an easy-to-catch, abundant source of fresh protein after the long winter. The commercial fishery for rainbow smelt is one of the oldest in New England, and for many years it was among the most valuable. More recently, the catch along the Gulf of Maine coast has dwindled, although parts of eastern Maine still have strong commercial fisheries. Recreational fishing for rainbow smelt continues to be a popular pastime in Massachusetts, New Hampshire, and Maine.

Fish in Peril

Rainbow smelt were so plentiful a hundred years ago that farmers caught them by the barrelful and had enough to eat, use as bait, and even spread on their fields as fertilizer. In many places now, it would be difficult to fill a single barrel with rainbow smelt. The species has largely disappeared from the southern part of its geographic range, and its numbers along the coast of the Gulf of Maine have dropped dramatically. In general, rainbow smelt are least abundant in Massachusetts and increase slightly toward eastern Maine. Reliable data on population size are not available, but Maine fishery data show that rainbow smelt landings have dropped tremendously since the 1800s. While a decrease in fishing effort may contribute to the drop in landings, the overall trend is clear: rainbow smelt are in trouble.

Tom Watson

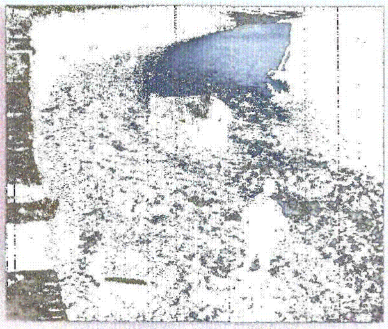
Many Potential Threats

A clear explanation for the rainbow smelt's decline is not yet known, but the species faces three broad types of potential threats:

1. Loss of suitable spawning habitat
2. Unfavorable changes in ocean conditions, such as water temperature or predation
3. Fishing pressure

Science for Solutions

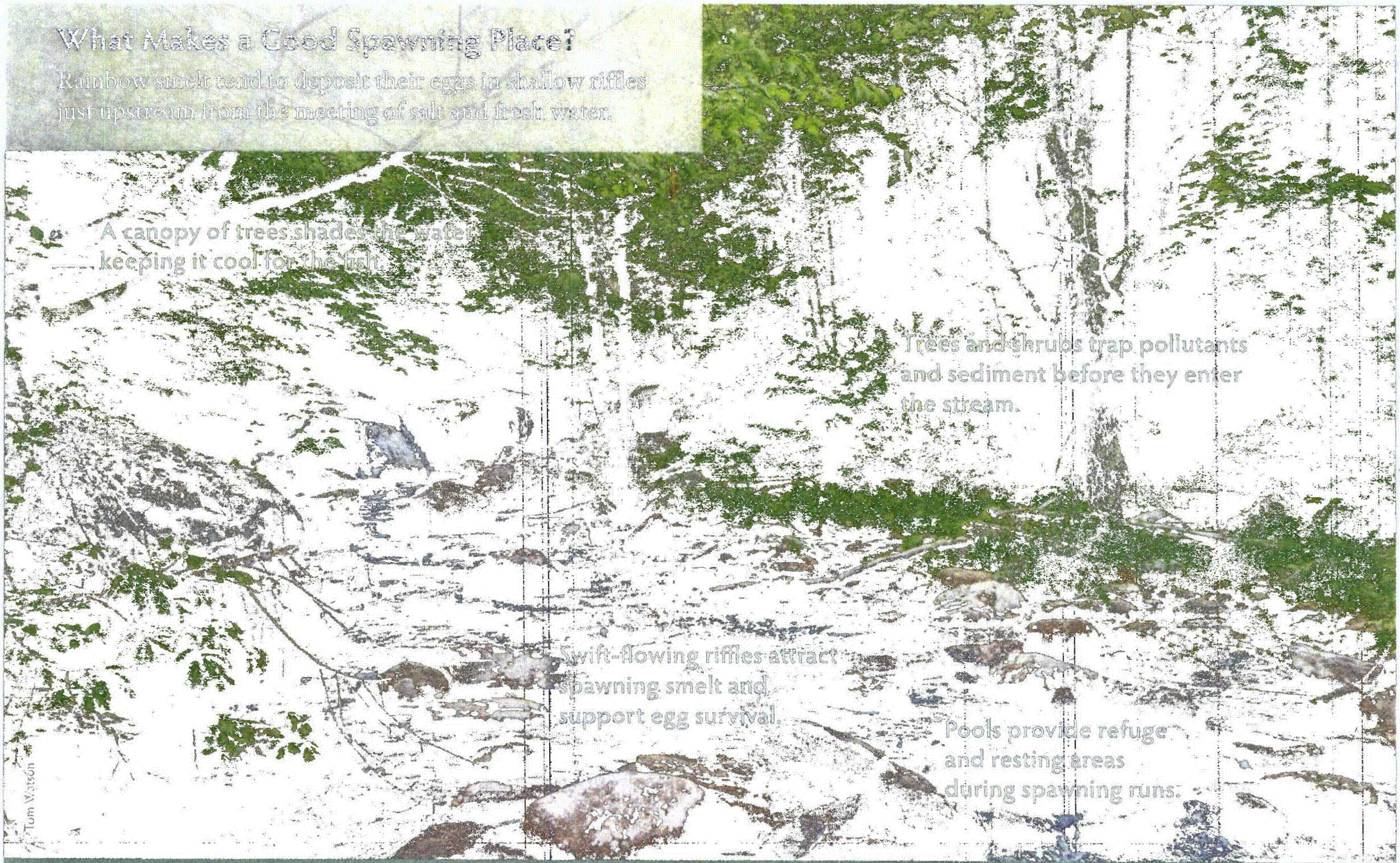
Scientists from the state governments of Massachusetts, Maine, and New Hampshire are collaborating on a study of threats to rainbow smelt, particularly spawning habitat alteration. The states are using the scientific findings to develop a regional solution.



A team of scientists uses a fyke net to catch rainbow smelt in a channelized river.

What Makes a Good Spawning Place?

Rainbow smelt tend to deposit their eggs in shallow riffles just upstream from the meeting of salt and fresh water.

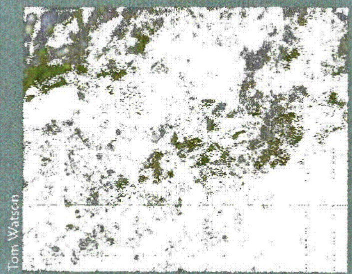


Some Human Activities Harm Spawning Areas

People have degraded many of the rainbow smelt's spawning sites in Massachusetts, New Hampshire, and Maine.

Dams and poorly designed culverts block rainbow smelt from spawning grounds.

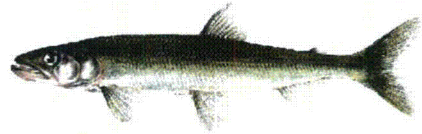
Sediment from construction sites, road maintenance, and other sources smothers eggs.



Fertilizers and faulty septic systems encourage growth of algae on smelt eggs.

Pavement and other impervious surfaces promote runoff of pollutant-laden rainwater.

What Can You Do?



Individual citizens and towns can take important steps to help the rainbow smelt recover. Local efforts are essential and can make a big difference in the survival of the species.

Steve Mishos

1. Use less fertilizer on your property.

Water carries fertilizer into streams, where the nutrients promote growth of algae on smelt eggs.

USDA

2. Fix dams and culverts blocking smelt from spawning areas.

Many dams and culverts prevent rainbow smelt and other fish from swimming upstream and downstream. In collaboration with owners and government agencies, dams can be removed, culverts reconfigured, and culverts replaced with bridges.

USDA

3. Plant shrubs and trees along stream banks and refrain from clearing existing vegetation.

Vegetated buffers help to filter out pollutants, sediment, and excess nutrients before they enter the waterway. Shrubs and trees also shade streams, keeping the water cool for fish.

Brad Chase

4. Maintain natural stream channels and substrate; restore those altered with concrete walls or other structures.

Faster-flowing water in altered streams can lead to scouring or crowding of smelt eggs. Low water velocity and unnatural substrates can reduce egg attachment and incubation success.

Michael Rosenstein

5. Use less road salt and sand near streams.

When salt and sand are washed into streams, they can kill smelt eggs.

Max Wolfe

6. Clean storm drains annually.

Debris and infrequent maintenance can clog storm drains, forcing water to flow over ground. The water carries sediment into streams, which smothers smelt eggs.

Tom Watson

7. Get to know your smelt runs.

Find out where smelt spawn in your town and insist that local officials protect these valuable habitats.

For more information, please visit:
www.nmfs.noaa.gov/pr/species/fish/rainbowsmelt.htm

Editorial Advisory Team: Bradford Chase (MA DMF), Claire Enterline (ME DMR), Katherine Mills (NH DF&G)

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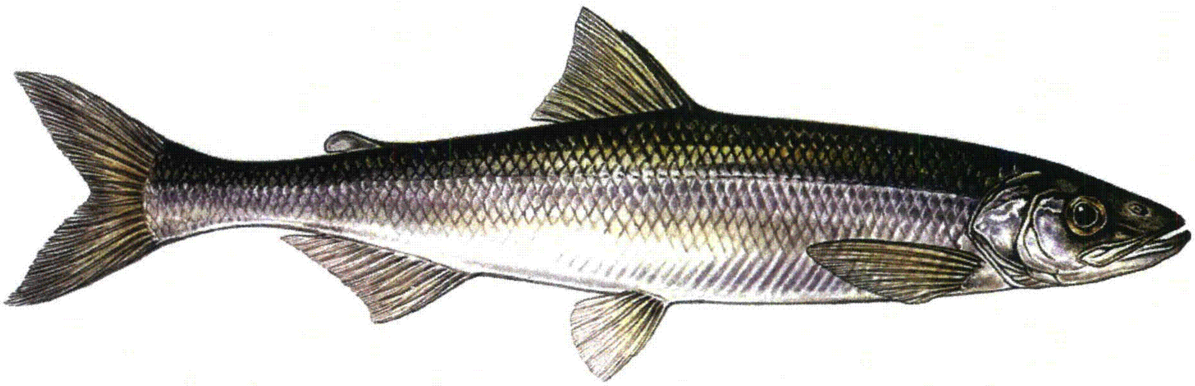
A Regional Conservation Plan

for

Anadromous Rainbow Smelt in the U.S. Gulf of Maine



By

Claire L. Enterline
Maine Department of Marine Resources
172 State House Station, Augusta, ME 04333

Bradford C. Chase
Massachusetts Division of Marine Fisheries
1312 Purchase Street, 3rd Floor, New Bedford, MA 02740

Jessica M. Carloni
New Hampshire Fish and Game Department
225 Main Street, Durham, NH 03824

Katherine E. Mills
University of Maine,
Gulf of Maine Research Institute
350 Commercial Street, Portland, ME 04101

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Dwayne Shaw

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INTRODUCTION

The rainbow smelt *(Osmerus mordax)* is a small anadromous fish that overwinters in estuaries and bays prior to spawning each spring in coastal streams and rivers. Smelt have supported culturally important commercial and recreational fisheries throughout New England since at least the 1800s. However, in recent years, concerns have risen about the population status of rainbow smelt. The species has disappeared from the southern end of its geographic range, which once extended to the Chesapeake Bay and now may extend only as far south as Buzzards Bay, Massachusetts. High numbers of rainbow smelt that once supported commercial fisheries in New England have declined precipitously since the late 1800s to mid-1900s. While recreational fisheries for rainbow smelt continue, declining catches have also been noted by anglers, particularly since the 1980s.

High numbers of rainbow smelt that once supported commercial fisheries in New England have declined precipitously since the late 1800s to mid-1900s.

Based on these observations of range contraction and abundance declines, the National Oceanic and Atmospheric Administration (NOAA) listed rainbow smelt as a federal Species of Concern in 2004; New Hampshire also lists sea-run rainbow smelt as a Species of Special Concern. Although rainbow smelt population declines have been widely documented, the causes are not well understood. In listing the species, factors identified as potential contributors included structural impediments to their spawning migration (such as dams and blocked culverts) and chronic degradation of spawning habitat due to stormwater inputs that include toxic contaminants, nutrients, and sediment.

Following the designation of rainbow smelt as a species of concern, the Maine Department of Marine Resources received a 6-year grant from NOAA's Office of Protected Resources to work in collaboration with the Massachusetts Division of Marine Fisheries and New Hampshire Fish and Game Department to document the status of and develop conservation strategies for rainbow smelt (NA06NMF4720249). This conservation plan represents a summary of key elements of the project, which focused on several objectives:

1) Documenting range contraction and range-wide population declines based on historical data and accounts
2) Evaluating the status of rainbow smelt populations in the Gulf of Maine region
3) Developing a population index to track the strength of spawning runs
4) Assessing a range of potential threats to rainbow smelt populations
5) Proposing management actions to help conserve rainbow smelt throughout the Gulf of Maine region.

This study has significantly advanced our understanding of the biology, status, and threats to rainbow smelt in the Gulf of Maine. A major contribution was the development of standardized procedures for indexing the abundance of spawning rainbow smelt. Four years of fyke net sampling of spawning runs throughout the Gulf of Maine region have provided important baseline information about the status of the species. Observations of truncated age structures within the spawning run, high male to female ratios in some rivers, and lower survival rates and a higher portion of age-1 spawners than historically observed all indicate that Gulf of Maine rainbow smelt populations are currently stressed.

Further evidence of the decline can be derived from a survey of historically active spawning sites throughout the state of Maine, using a study from the 1970s (Flagg 1974) as a valuable baseline for comparison. The recent survey found that 13% of the historically active spawning streams no longer support rainbow smelt spawning, and most of the streams that remain active now support smaller runs than they did historically. The substantial decline in strong spawning runs merits concern and attention.

Many threats to rainbow smelt spawning habitat were identified as part of this study. Obstructions such as dams and improperly designed culverts may physically impede smelt migration to appropriate spawning sites. Further, extremely high or low flows can impede swimming ability or impair the cues smelt rely on to undertake this migration. Once on the spawning grounds, water quality conditions may affect the hatching and survival of smelt eggs. In many rivers studied as part of this project, pH, turbidity, nutrient levels, and dissolved contaminants warranted concern for water quality. Field observations also showed an association between nitrogen levels and periphyton growth at spawning grounds, and laboratory experiments demonstrated that high periphyton growth significantly impaired the survival of smelt embryos.

Many of these threats—particularly flow patterns and water quality—are not driven by factors within the spawning rivers themselves, but rather by activities in the surrounding watersheds. Across a suite of water quality and heavy metal parameters, we found that high levels of development in the watershed were associated with poorer conditions for rainbow smelt, while high proportions of forest in the watershed supported high quality stream conditions. In conjunction, watershed development was negatively associated with the strength of smelt spawning runs, while forested watersheds supported stronger runs in their receiving streams.

Our goal in assessing threats to rainbow smelt was to identify conditions that appear to negatively and positively affect smelt throughout their life cycle so that management actions can effectively target these factors. Based on our assessment of critical threats, management recommendations to protect and restore rainbow smelt populations include:

- Maintain the federal Species of Concern designation for rainbow smelt
- Continue monitoring population trends and biological characteristics in the extant range, and expand efforts towards estimating rainbow smelt population size
- Restore historical or degraded spawning habitat
- Maintain and, where necessary, improve fishery monitoring to ensure that fishing effort is compatible with sustainability of local and regional rainbow smelt populations
- Expand research initiatives to anticipate direct and indirect effects of

climate change and variability on rainbow smelt

- Invest in research to further study environmental requirements, stressors, and drivers in order to effectively manage recovery
- Stock marked larvae to re-establish rainbow smelt runs at restored sites, as needed and as appropriate given considerations of genetic diversity and donor population viability

This Conservation Plan provides: a description of the life history of anadromous rainbow smelt; an account of the historical fishing pressure on the species; a summary of the current population status and monitoring efforts; explanation of the threats to the species at different life stages, including the marine phase; and conservation and management strategies for the region and for each state in the Gulf of Maine. Our intent is that this information will provide important baseline information regarding the status of smelt populations at the present time and that it will offer coastal and fishery managers guidance on appropriate actions and priorities to protect and restore rainbow smelt moving forward.

1 – SPECIES STATUS

Rainbow smelt *(Osmerus mordax)* are small anadromous fish that live in nearshore coastal waters and spawn in the spring in coastal rivers immediately above the head of tide in freshwater (Buckley 1989, Kendall 1926, Murawski et al. 1980). Landlocked populations of smelt also naturally occur in lakes in the Northeast U. S. and Canada and have been introduced to many freshwater systems, including the Great Lakes. Anadromous smelt serve as an important prey species for commercially and culturally valuable species, such as Atlantic cod, Atlantic salmon, trout, Atlantic gray seals, striped bass (Clayton et al. 1978, O'Gorman et al. 1987, Kircheis and Stanley 1981, Kirn 1986, Stewart et al. 1981). Historically, the range of rainbow smelt extended from Chesapeake Bay to Labrador (Buckley 1989, Kendall 1926), but over the last century, the range has contracted and smelt are now only found east of Long Island Sound.

Anadromous smelt serve as an important prey species for commercially and culturally valuable species, such as Atlantic cod, Atlantic salmon, trout, Atlantic gray seals, striped bass.

1.1 – BASIC BIOLOGY

Life History

Smelt are small-bodied and short-lived, seldom exceeding 25 cm in length or five years of age in the Gulf of Maine region (Murawski and Cole 1978, Lawton et al. 1990). By age two, smelt are fully mature and recruited to local recreational fisheries and spawning runs. Life history appears to be influenced by latitude; few age-1 smelt become mature and participate in Canadian smelt runs, however in Massachusetts, New Hampshire, and southern Maine, age-1 individuals are present in the spawning runs (Collette and Klein-MacPhee 2002). Studies in Massachusetts found that the majority of age-1 spawners were male (Murawski and Cole 1978, Lawton et al. 1990). Our current spawning surveys have found that runs in the Gulf of Maine are dominated by age-2 smelt, with few older smelt in Massachusetts, New Hampshire, and southern Maine; however the older ages are better represented in midcoast and eastern Maine. Fecundity estimates of approximately 33,000 eggs for age-2 smelt and 70,000 eggs for age-3 smelt were reported by Clayton (1976).

Habitat Use

Annual movements and habitat use by adult rainbow smelt have been largely assumed based on discrete sampling or patterns in recreational and commercial fishing. Mark and recapture studies have focused on distinct phases of the life cycle, such as movements between spawning areas (Murawski et al. 1980), composition of late and early populations of spawning adults (McKenzie 1964) and winter movements within a river system (Flagg 1983). Larger annual and regional migrations have been synthesized from anecdotal reports by anglers and commercial fishermen as well as from beach seine and spawning surveys.

Rainbow smelt overwinter in estuaries and bays and then spawn in early spring in pool and riffle areas above the head-of-tide in coastal streams and rivers. The spawning habitat characteristics are discussed in detail in sections 2.1 – Threats to Spawning Habitat Conditions, and 2.2 – Threats to Embryonic Development and Survival. Because males have a longer physiological spawning period, they may return to spawning grounds multiple times within the same year (Marcotte and Tremblay 1948). Mark and recapture studies have observed the same male at different spawning sites within a given year, suggesting that males are able to spawn multiple times (Murawski et al. 1980, Rupp 1968). Murawski et al. (1980) hypothesized that spawning in different streams may be facilitated by passive tidal transport, however this has not been directly observed. Females, on the other hand, rarely ascend to the spawning grounds more than once in a season, based on recent mark-recapture surveys (C. Enterline, unpublished data). Because female smelt are broadcast spawners, their spawning is expected to occur in a single event as most or all of their eggs are deposited in a single event.

Spawning females deposit demersal (sinking) adhesive eggs that attach to the substrate and hatch in 7-21 days, depending on temperature. Upon hatching, larvae are immediately transported downstream into the tidal zone, at which point the larvae begin feeding on zooplankton. Larval dispersion is mostly passive in response to river flow and coastal circulation patterns, but there is also an active (swimming) component (Bradbury et al. 2006b). Although horizontal movements of smelt larvae appear passive, they actively migrate vertically in response to tidal flow in order to maintain their position in zooplankton rich water and minimize downstream movement (Laprise and Dodson 1989, Dauvin and Dodson 1990, Sirois and Dodson 2000). This active swimming behavior is overwhelmed by passive transport in local circulation patterns. The importance of local circulation on larvae dispersion is discussed more in the genetic stock structure section below.

Juvenile smelt remain in the estuary, bay, or sheltered coastal area through the summer, and sometimes through the early fall (NHF&G and ME DMR Juvenile Abundance Surveys, 1979-2011, analysis for current study). In Great Bay, NH, juvenile smelt are most abundant in August, while in the Kennebec and Merrymeeting Bay estuary complex in Maine, abundance is more evenly distributed between August, September, and October (Figure 1.1.1). In Maine, catches of juvenile smelt occur from July to October, while in New Hampshire, catches range from June to November.

Habitat use in marine waters is largely unknown but can be inferred through interviews with coastal fishermen and state trawl surveys. Smelt may migrate in search of optimum water temperatures, moving offshore during the summer months to greater depths with cooler water (Buckley 1989). Based on low catches by fishermen in freshwater and larger catches in brackish and saltwater in May, the presumed end of the spawning run, it has been assumed that adults return to estuaries and coastal waters immediately after spawning (Bigelow and Schroeder 1953). However, recent findings indicate that rainbow smelt may remain within estuaries and bays contiguous to their spawning sites for up to two months after spawning (C. Enterline, unpublished data).

Recent trawl surveys have found small schools of smelt as far from the coast as 60 km and in depths up to 77 m (data from the Maine-New Hampshire and

Massachusetts Trawl Surveys). Spring trawl surveys find smelt further from the coast and in deeper water (spring avg. depth = 29.7 m) than during fall trawl surveys (fall avg. depth = 19.9 m) (Figures 1.1.2 and 1.1.3; t-test comparing depth, $p = 0.0338 < 0.05$), however the average spring catch is smaller compared to the fall (spring average catch 2001-2012 = 31, fall average catch 2000-2011 = 129, Wilcoxon non-parametric test of means, $p < 0.0001 < 0.05$), likely because adult smelt are within coastal streams and rivers as part of the spawning event during the spring period. The smelt that are caught further offshore in the spring are smaller, with lengths associated with age-1 fish; these are likely young fish that are not recruited to the spawning run.

As offshore water temperatures drop in the fall, smelt likely move towards the coast, eventually migrating into the upper estuaries where they overwinter (Buckley 1989; Clayton 1976; McKenzie 1964). Anecdotal reports from recreational hook-and-line ice-fishermen describe smelt moving in tidal rivers with the nighttime flood tide and out with the ebb tide, and some moving as far up as the head of tide each night. These foraging movements are the basis for robust recreational fisheries in the fall and winter at many locations in the Gulf of Maine.

Genetic Stock Structure in the Gulf of Maine

Understanding the genetic structure of a species and the driving factors behind that structure is central to well-designed species management. A species may be comprised of one or more genetic stocks, separated by different spawning areas or physical barriers. Managing a species at too large a scale (i.e., assuming there is only one stock when there are multiple) may lead to the loss of genetic structure and the benefits of local adaptation. Managing at too small a scale (i.e., assuming stocks are isolated within individual rivers when in fact there is some mixing), neglects the important role of gene flow and results in loss of genetic variation (Kovach et al., in press).

From 2006-2010, we collected genetic samples at 18 spawning site index stations spanning the Gulf of Maine to understand if unique genetic stocks existed and the extent of gene flow between spawning populations. All information presented in this conservation plan was reported by the University of New Hampshire and in detail by Kovach et al. (in press). The three most genetically divergent populations were found in Cobscook Bay, Maine, Massachusetts Bay, and Buzzards Bay, Massachussetts. Penobscot and Casco bays in Maine also showed some differentiation. Gene flow was high between rivers from downeast coastal Maine, the Kennebec River, ME, and Great Bay, NH to northern Massachusetts; all were dominated by the same genetic signal. Midcoast Maine also seemed to be part of this large stock, but also showed distinct signals from Penobscot Bay and Casco Bay (Figure 1.1.4). These groupings can assist management decisions on stocking efforts, with the goals of maintaining distinct stocks where possible, while still preserving gene flow to maintain and replenish genetic diversity.

Although the study did not find evidence of genetic bottlenecking, genetic variation was significantly reduced in the two most distinct regions: Buzzards Bay (Weweantic River), and Cobscook Bay (East Bay Brook) (Kovach et al., in press). The reduced diversity in the Weweantic River is consistent with its location at the southern extent of the species range, where populations can have reduced gene flow and lower spawning population sizes (Schwartz et al. 2003). The reduced variation in Cobscook Bay is more likely due to isolation by circulation patterns. The reduced diversity and distinctive nature of these smelt runs warrant further population monitoring and possibly updated protection measures.

The divergence patterns observed may be explained partly by coastal circulation patterns (Kovach et al., in press). Because the movement of smelt larvae is largely passive during the early development (Bradbury et al. 2006b), their dispersal is determined first by river flow and secondly by marine circulation. The Gulf of Maine Coastal Current (GMCC) has a counter-clockwise pattern, which is strongest in the summer months when smelt larvae are present in coastal waters. The GMCC consists of two distinct portions. The Eastern Maine Coastal Current (EMCC) flows from the Bay of Fundy southwest along the coast and, in the area of Penobscot Bay, often splits southward and offshore. The remaining portion of the EMCC combines with outflow from Penobscot Bay and continues southwestward towards coastal New Hampshire and Massachusetts, creating the Western Maine Coastal Current (WMCC; Pettigrew et al., 1998, 2005). Backflow eddies are associated with large rivers (like the Penobscot) and to a lesser extent with Casco Bay, and as a result, larvae may be maintained within the nearshore area. Continuing further southwest along the coast, Massachusetts Bay maintains high larval retention as the strength of the WMCC pattern has largely diminished by this point (Incze et al. 2010).

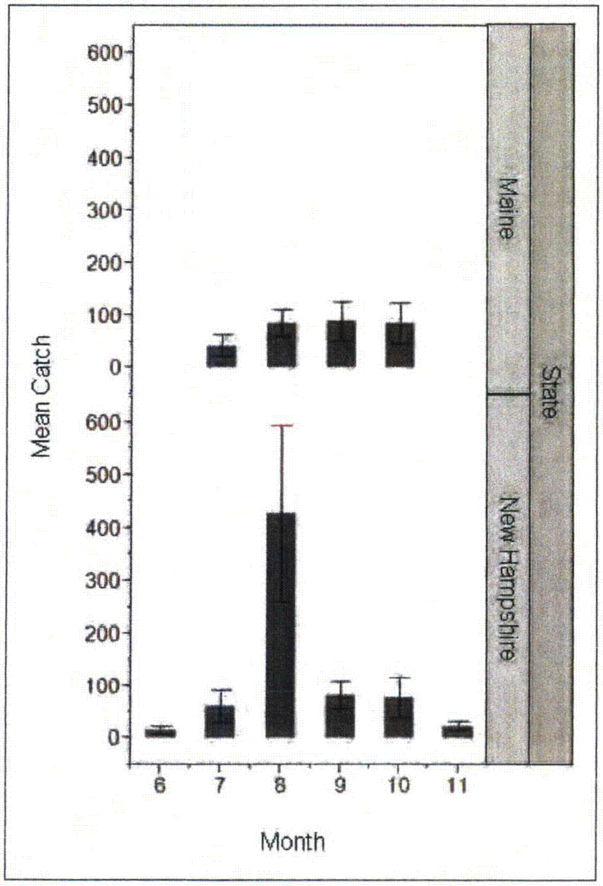


Figure 1.1.1. Mean smelt catch by month in the Maine and New Hampshire Juvenile Abundance Surveys 1979-2011 for all survey sites combined. Error bars represent one standard error from the mean.

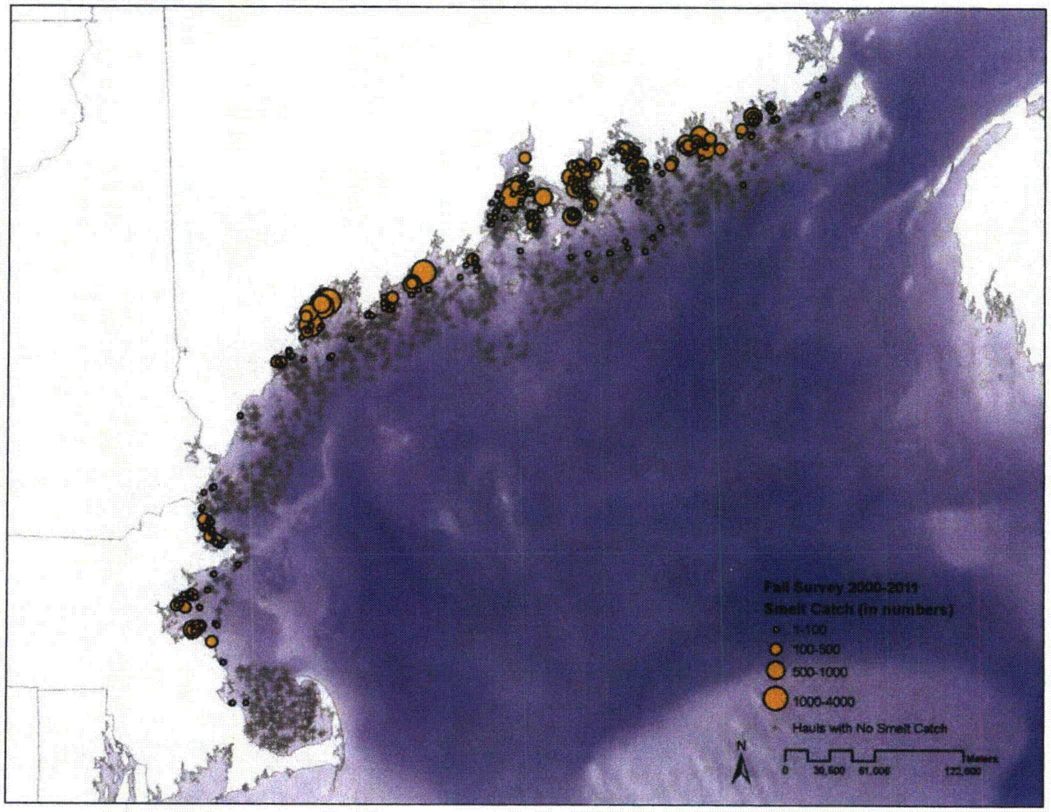


Figure 1.1.2. Smelt catches in the fall state nearshore trawl surveys for Massachusetts, New Hampshire, and Maine 2000-2011.

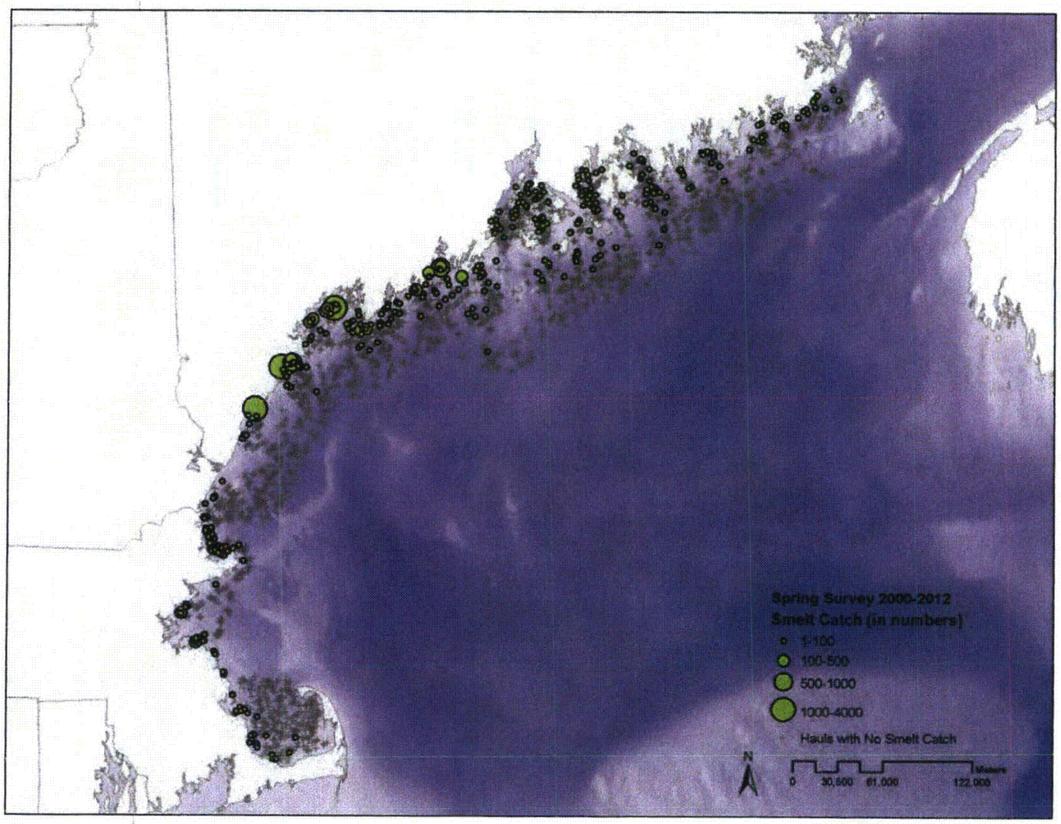


Figure 1.1.3. Smelt catches in the spring state nearshore trawl surveys for Massachusetts (2000-2011), New Hampshire, and Maine (2000-2012).

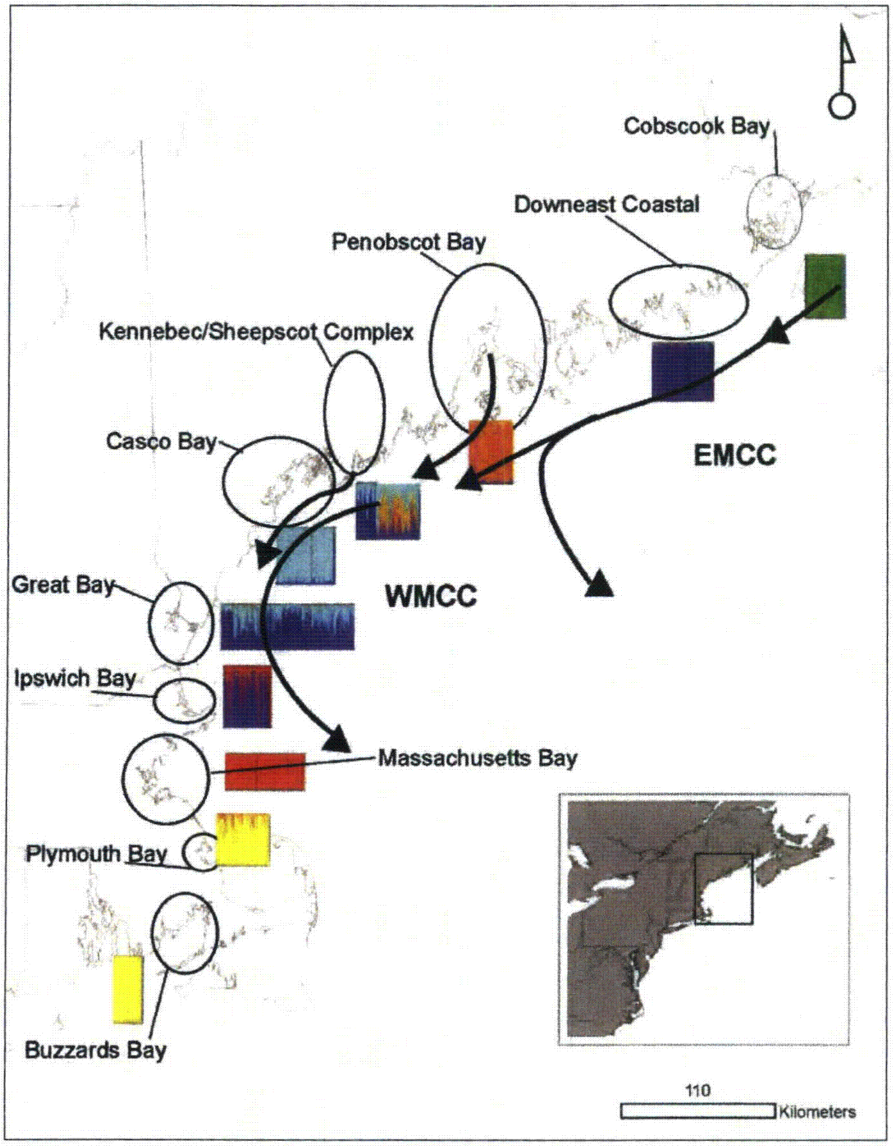


Figure 1.1.4. Genetic differentiation of smelt stocks in the Gulf of Maine from Kovach et al., ("in press"). Divergence may be explained by circulation patterns, where the Gulf of Maine Coastal Current carries larvae from downeast coastal Maine to New Hampshire and northern Massachusetts, while other localized circulation patterns maintain the distinctiveness of Penobscot Bay, Casco Bay, Massachusetts Bay, and Buzzards Bay. The color boxes display the 6 genetic signals – boxes with the same colors indicate the same signal. Length of boxes represents number of samples taken from the region.

1.2 - HISTORICAL SMELT FISHERIES

Smelt fishing is a longstanding tradition in many coastal communities of New England and the Canadian Maritimes. During winter and early spring, smelt schools enter estuaries and embayments and aggregate in preparation for the spring spawning run. During this period of migration, commercial, and recreational fisheries target smelt through the ice and from shore. Some shore fisheries also occur in fall, mainly with hook and line, during foraging movements that precede the spawning migration. Fishing methods for smelt vary by state; including weirs, hook and line, seines, dip nets, bag nets, and gill nets.

This section will describe the historical range of rainbow smelt and the fisheries that targeted them. We focus on the Gulf of Maine, but provide some background on populations throughout the range. We rely heavily on the classic work "The Smelts" by Kendall (1926) and the thorough recent literature review found in Fried and Schultz's (2006) investigation in Connecticut.

By the late 1800s, with the advancement of rail transport, smelt were an important export product shipped on ice from the Canadian Maritimes and Maine to the Boston and New York markets.

The earliest record of smelt harvest in the U. S. was likely by Captain John Smith in 1622; Smith noted the smelts were so plentiful that the Native Americans would harvest the fish by simply scooping them up in baskets (in Kendall 1926). There is little additional information about early New England smelt harvests until the mid-1800s, although extensive subsistence and local commercial harvest occurred before this time, based on occasional references and town records. Early uses of smelt included livestock feed and fertilizer to enrich farm fields. The abundance of smelt in the mid-1800s can be pictured from the account of French settlers along the Buctouche River in New Brunswick harvesting 50 to 60 barrels (36 gallons/barrel) annually to serve as fertilizer for each homestead (Perley 1849 in Kendall 1926). About this time, food markets developed for smelt as human populations grew in coastal cities. By the late 1800s, with the advancement of rail transport, smelt were an important export product shipped on ice from the Canadian Maritimes and Maine to the Boston and New York markets (Kendall 1926).

Mid-Atlantic

Smelt are considered a cold water fish, with a historical center of abundance north of Cape Cod but southerly populations ranging south to the Mid-Atlantic. Early references of smelt range include Virginia, Maryland and Delaware (Goode 1884, Kendall 1926, Bigelow and Schroeder 1953), but we found no information on smelt populations or harvests for these states. Later references on smelt range list New Jersey as the southern limit (Scott and Scott 1988, Collette and Klein-MacPhee 2002). Overall, references south of Delaware Bay are not well documented. The presence of smelt in states south of New Jersey may have been sparse, an indication of occupancy at the edge of the species' range, or alternatively the fisheries may have faded before the onset of recorded commercial harvest data in the early 20th century.

New Jersey

In 1833, smelt were observed to be plentiful in New Jersey with "wagon-loads" of smelt harvested in Newark Bay, yet by 1849, smelt were reported as declining (New York Times 1881 in Fried and Schultz 2006). The Delaware

River had been listed as a southern smelt run, including an early observation in a tributary, the Schulykill River, of cast net fishing for smelt during late winter (Norris 1862). Spring runs of smelt, also called frost fish, were reported in the Delaware, Hackensack, Passaic and Raritan rivers during the late 1860s. By this time, only the Raritan River supported a lucrative commercial fishery, with annual catches nearing 10,000 lbs (NJCF 1872). The New Jersey Commissioners of Fisheries (NJCF) 1872 report also suggested that industrial water pollution in the rivers was severely impacting all anadromous fisheries. The last regular commercial catch in New Jersey was reported in 1921 (Fried and Schultz 2006).

Smelt were considered endangered in New Jersey by 1877 and the state launched an effort in the 1880s to study the reproductive biology of smelt and to stock smelt fry hatched from eggs collected in viable smelt runs to depleted smelt runs (NJCF 1886).

No evidence of stocking success has been located and by 1941 smelt were considered extirpated from New Jersey (Camp 1941 in Fried and Schultz 2006). The New Jersey Fish and Game Department has conducted trawl surveys throughout their coastal waters since the early 1980s, and no smelt have been detected during this time.

New York

Historical references indicate that tributaries near the Hudson River and Long Island once supported prominent recreational and commercial fisheries but that overfishing and poor water quality likely caused declines before the end of the 19th century (Kendall 1926). The smelt trade at the Fulton Market in New York City was reported to average 1,352,000 lbs annually in the 1870s (Scott 1875 in Kendall 1926). By 1887, the smelt fishery was no longer considered commercially viable (New York Times 1881, Mather 1887, Mather 1889; in Fried and Schultz 2006). State fishery agencies in New York became concerned about the declining status of smelt in the late 1800s and embarked on extensive stocking efforts that included placing 127 million eggs in Long Island streams during 1896-1898 (Kendall 1926). The stocking efforts faded when smelt eggs became scarce in the early 20th century (Kendall 1926). Commercial catches declined and became sporadic in the 20th century. Routine commercial harvests exceeding 1,000 lbs annually were last reported in the 1950s (Fried and Schultz 2006).

Since the 1970s, annual surveys in New York have detected rainbow smelt, but catches have become increasingly infrequent and have been rare since the 1990s. The Hudson River Estuary Monitoring Program has conducted ichthyoplankton and juvenile fish surveys throughout the estuary since 1973, and the data show a dramatic decrease in smelt abundance since the mid-1990s, with only trace numbers detected today (ASA A&C 2010). Fish sampling efforts conducted by New York State Department of Environmental Conservation (NY DEC) have produced similar results, with very few adults detected since the 1980s. Today, smelt are considered extirpated or at extremely low numbers in the Hudson River system (C. Hoffman, NY DEC, pers. comm. Sept. 2010).

Connecticut

A synopsis of early fisheries records shows that smelt runs were present in most tidal rivers in coastal Connecticut, and economically important commercial fisheries targeted the seasonal occurrence of smelt (Visel and Savoy 1989, Fried and Schultz 2006). Smelt were targeted primarily with haul seines and gill nets in the Housatonic, Connecticut and Pawcatuck rivers (Visel and Savoy 1989). Hook and line angling was also common in the 19th century at numerous locations; smelt were described as an important export fish to New York City markets. Smelt landings were reported as peaking in Connecticut in the 1880s at 27,000 lbs and steadily declining with minor and intermittent landings since the 1930s (Fried and Schultz 2006). There was a modest increase in landings in the 1960s when several thousand pounds were reported annually. The last years with significant smelt runs in Horseneck Brook of Greenwich, were 1965 and 1966 (Visel and Savoy 1989).

By the 1980s, smelt were recognized as nearly absent from Connecticut's coastal rivers. Similar to regions south of New England, concern centered on the role of point and non-point pollution sources (Visel and Savoy 1989). The decline of smelt in Connecticut prompted dedicated efforts to document their presence in the 2000s. The smelt fishery was formally closed to harvest in 2005, and smelt were listed as a state endangered species in 2008. Fried and Schultz (2006) carried out intensive surveys in five estuaries along the central and eastern Connecticut coast. They documented no evidence of smelt spawning but did catch 9 adults while seining in the upper Mystic River during 2004. State beach seine surveys infrequently encounter smelt, however there have been recent observations of a few adult smelt in 2007 (T. Wildman, CT DEP Inland Fisheries Division, pers. comm. Nov. 2010). The State of Connecticut is currently considering listing smelt as extirpated from the state.

Rhode Island

Smelt landings first appear in Rhode Island records in 1880 with landings of 95,000 lbs, which remains the peak annual harvest for this state (Fried and Schultz 2006). Since that point, landings records steadily declined with minimal landings reported after 1932. Landings rebounded slightly during 1965-1970 when several thousand pounds were reported annually. Since this time, minimal commercial landings have been reported (Fried and Schultz 2006). In response to declining populations, the Rhode Island Division of Fish and Wildlife (RIDFW) began a smelt stocking and monitoring program in 1971 (RIDFW 1971). Over the next seven years, approximately 44 million smelt eggs were transferred from populations in Massachusetts and New Hampshire to four rivers in Rhode Island. Extensive monitoring was conducted at the four recipient rivers, and no evidence was found of successful recruitment following stocking (RIDFW 1978). The monitoring only found evidence of a viable smelt run in the Pawcatuck River where low densities of smelt eggs were observed in 1974. The stocking effort was considered unsuccessful and discontinued in 1977 (RIDFW 1978). In the last decade smelt were briefly listed as endangered in Rhode Island, then delisted and considered extirpated with a chance of a trace populations present. Adult smelt have been captured on rare occasions during coastal pond and bay surveys since the 1990s (A. Libby, RI DFW, pers. comm. Oct 2011).

Massachusetts

Historical Fisheries

Early accounts indicate that smelt populations in Massachusetts supported culturally important sustenance fisheries that evolved into small-scale commercial and recreational fisheries as coastal populations grew. The smelt fisheries prior to 1874 targeted fall and winter feeding aggregations with baited hooks and used dip nets and seine nets during the spring spawning runs (Kendall 1926). The local importance of these fisheries and the potential abundance of the populations is reflected in accounts that describe over nine million smelt taken from the Charles River at Watertown in 1853 (Storer 1858), and over 2,300 fishermen at Hough's Neck in Quincy in one day targeting smelt (Kendall 1926). Overfishing concerns were raised in the 1860s that were attributed to with the use of nets during the spawning run. This concern led the Massachusetts State Legislature to prohibit net fishing for smelt during the spawning run in 1868 (Kendall 1926).

In 1874, a law prohibited the taking of smelt by any method other than hook and line in all state waters with a few exempted rivers – most of these exemptions were revoked by the end of the century. Kendall (1926) relates accounts of rebounding smelt fisheries in the 1870s and praise for the net ban. Catch records are sporadic and largely town or county specific during the latter half of the 19th century. However, there was a general declining trend in this period, and by the 1910s and 1920s there was growing concern about smelt fisheries in Massachusetts and the influence of industrial pollution. A quote the Massachusetts Commissioners on Fisheries and Game in 1917 expressed the concern of the period, "The smelt fishery of Massachusetts is in a depleted condition, and strenuous and radical measures will be required to save this species from extinction" (MCFG 1917).

A quote the Massachusetts Commissioners on Fisheries and Game in 1917 expressed the concern of the period, "The smelt fishery of Massachusetts is in a depleted condition, and strenuous and radical measures will be required to save this species from extinction."

Smelt fisheries are poorly documented in Massachusetts after Kendall's 1926 report. The annual reports of the state fisheries agency depict contrasting trends along a gradient. In southern Massachusetts, there was a sharp decline in commercial importance and the disappearance of smelt in some locations. However, north of Cape Cod and in the greater Boston area, an active and popular fall and winter sportfishery persisted through the 1970s. Fried and Schultz (2006) summarized federal commercial catch records that show three time-series peaks in Massachusetts harvest: 1880 (82,034 lbs), 1919 (39,000 lbs), and 1938 (25,000 lbs). The early landings data were based on the available town and county records and are expected to be incomplete (Kendall 1926). It is likely that no records adequately describe the true extent of smelt harvest at any time in Massachusetts's history. The view provided by the combined historical and anecdotal accounts suggests that smelt supported important seasonal fisheries that attracted large numbers of anglers and that smelt occurrence and abundance greatly exceeded the species' present status.

Recent Trends

Striking changes appear to have occurred in smelt detection and abundance in Massachusetts since Kendall's report (1926). Contemporary studies began with river-specific work in the Jones and Parker rivers in the 1970s (Lawton et al. 1990, Murawski and Cole 1978, and Clayton 1976). These studies were the first to report biological characteristics of the spawning runs and timing of movements in Massachusetts. Concerns over declines in smelt abundance grew after these studies, as sportfisheries' catches declined sharply in the late 1980s. The MA DMF responded to concerns from the sportfishing community with a survey of all smelt spawning habitats on the Gulf of Maine coast within Massachusetts during the 1990s (Chase 2006) and the initiation of fyke net monitoring in 2004 to develop population indices.

Specific mention of Buzzards Bay is warranted because it is presently the southern limit of the documented spawning range. Buzzards Bay lies directly south of Cape Cod, which separates the Virginian marine ecoregion to the south from the Gulf of Maine/Bay of Fundy ecoregion to the north (Spalding et al. 2007). No historical records have been found of spawning runs on Cape Cod, a likely result of its glacial formation and flat gradient. Goode (1884) reported smelt harvest in coastal weir fisheries in Buzzards Bay in 1880. More recently, an anadromous fish survey from 1967 reported 10 rivers in Buzzards Bay with active smelt spawning runs (Reback and DiCarlo 1972). An estuarine survey of the Westport River in Buzzards Bay in 1966-1967 found smelt in seine and trawl surveys and reported a known spawning run and associated fishery in the river (Fiske et al. 1968). Smelt runs in the region have since quietly faded to low levels of detection. Fisheries monitoring during the last 10 years has documented the presence of smelt in only three Buzzards Bay rivers; with a lone viable spawning run in the Weweantic River.

New Hampshire

Historical Fisheries

Significant smelt fisheries of commercial and cultural importance have occurred in the Great Bay estuary of New Hampshire since the 18th century or earlier. Hook and line fishing has mainly occurred in winter through ice on tidal waters. Additionally, bow nets were traditionally fished under the ice, and weirs were deployed during spring spawning runs (Warfel et al. 1943). Historical fisheries in New Hampshire are poorly described relative to Maine and Massachusetts. Kendall (1926) provides very little information on coastal New Hampshire smelt runs, focusing more on landlocked populations. He does provide annual smelt harvest estimates for coastal fisheries as follows: 1888 – 36,000 lbs, 1908 – 2,600 lbs, and 1924 – 3,835 lbs. The reported peak of commercial catch in New Hampshire was between 1940-1945, with an estimated 150,000 lbs harvested per year (Figure 1.2.1; Fried and Schultz 2006). It is expected that the historical records substantially underreported actual harvest from the Great Bay fisheries.

Recent Trends

The state of New Hampshire has monitored smelt fisheries in Great Bay since the 1970s, when concerns were voiced from fishery participants about declining catches. To this end, an angler creel survey was started in 1978 and a smelt egg deposition survey began in 1979. A project was also launched at that time to improve commercial harvest data by mandating bow net and weir net fishermen to record their catches in log books. In 1981, a statewide smelt fishery management plan was written by the New Hampshire Fish and Game Department (NHF&G) to maintain sea-run smelt populations and support commercial and recreational fisheries (NHF&G 1981).

Data collected by the NHF&G indicate declining population trends in recent decades. The angler creel survey data depict a reduction in CPUE and total catch during the 2000s (Sullivan 2010). The smelt egg survey shows egg densities in the 2000s that are an order of magnitude lower than the 1980s (Sullivan 2007); the survey was discontinued in 2008 due to concerns over methodology and very low presence of smelt eggs. The commercial harvest records in New Hampshire have also recorded declines since 1987 (Figure 1.2.1). Commercial dip net and bow net permits remain active, but the fisheries have declined to low levels of catch and effort (J. Carloni, NHF&G, pers. comm., 2011). Despite the apparent decreasing trends, recreational fishing for smelt in Great Bay still remains a popular winter fishery that attracts higher catch and effort than fisheries to the south in Massachusetts.

Maine

Historical Fisheries

Commercial and sustenance smelt fisheries were important to Maine's colonial inhabitants as early as the 18th century, but are poorly documented. Kendall (1926) provides detailed accounts of valuable commercial hook and line and net fisheries from the 1880s to 1920s. The opening of export markets to New York and Boston after the mid-1800s, coupled with growing use of seine and bag nets, led to increases in harvest and the development of a significant commercial fishery. Goode (1884) provides the first reported commercial smelt harvest records for Maine, with landings exceeding a million pounds in the 1880s. In 1894 the smelt fishery was reported to support 1,100 fishermen with shore fishery landings that were the fourth most valuable behind lobster, clams, and sea herring (Whitten 1894). Statewide records are absent before this time, however subsequent catch data show a steep decline after the 1890s (Squires et al. 1976; Figure 1.2.1). The last year the Maine catch exceeded a million pounds was in 1903. As early as 1920, a report by the Maine Commission of Sea and Shore Fisheries described the depleted status of smelt runs and the negative impacts of targeting spring spawning aggregations for commercial harvest (MECSSF 1920). An early management response to this decline was performing egg transfers from both landlocked and sea-run smelt populations to depleted runs (Kendall 1926); these were largely undocumented. While the commercial fishery continued to decline in the 20th century, the recreational fishery that targeted smelt both through the ice and during spawning runs increased in catch and effort starting in the 1940s. The rental ice shack fishery, in particular, grew in economic importance as out-of-state anglers were attracted to Maine's coastal rivers.

Recent Trends

Recognizing the traditional importance of the smelt fishery and continued population declines, the Maine Department of Marine Resources (ME DMR) developed a Smelt Management Plan in 1976 (Squires et al. 1976). The plan outlined present conditions and made recommendations to improve fisheries and spawning habitat. It also attributed the dramatic decline observed in the mid 20th century to increased industrial pollution in Maine's rivers after World War II (Figure 1.2.1). The ME DMR also launched studies at this time to record the presence and distribution of smelt in coastal Maine and investigate causes of the historic decline (Flagg 1974). Flagg's (1974) work on Maine's sea-run smelt documented catches at camp fisheries on the Kennebec River and Merrymeeting Bay, and catalogued spawning runs on 134 coastal streams. As part of the present study, the ME DMR has reinstituted creel surveys and spawning habitat investigations so that current catch records can be compared to the 1970s monitoring. Maine continues to have important recreational fisheries featuring winter ice fishing on tidal rivers and spring dipnet fishing at spawning runs, although annual harvest is at historic lows. A modest commercial harvest continues in downeast Maine, largely centered on the Pleasant River in Columbia Falls, where gill and bag nets are allowed to fish in late winter.

Canadian Provinces

Historical Fisheries

Anadromous smelt populations in Canada have long supported valuable commercial fisheries that greatly exceed the collective harvest from the United States.

Anadromous smelt populations in Canada have long supported valuable commercial fisheries that greatly exceed the collective harvest from the United States. Among provinces, New Brunswick has had the largest fishery, which historically targeted smelt for use as fertilizer and bait (Goode 1884). Growing export markets were driven by the Canadian harvests, which were, and continue to be, the largest commercial harvests in the species' range. Records are sparse before the 20th century, however Kendall (1926) cites accounts of fast developing export markets to Boston and New York in the 1870s that created demand for large harvests – exceeding two million pounds by the 1880s. In 1901, the shipment records of one export company in New Brunswick approached eight million pounds. The highest aggregate landings reported for Canada was just over nine million pounds in 1914 (Kendall 1926). A report from the U. S. Bureau of Fisheries in 1920 noted that while the Maine smelt fishery had declined in the early 1900s, the New Brunswick fisheries had undergone "remarkable" growth to support the market demands in the U.S. (USDOC 1920). The Miramichi River in New Brunswick was long a center of the province's smelt fishery. Shipments of smelt to U. S. markets from the Miramichi River region exceeded 4.3 million lbs for the winter fishery in 1924 (Kendall 1926), making the fishery one of the most valuable industries in the Province at that time.

Recent Trends

New Brunswick and Nova Scotia continue to support important commercial fisheries. There is less evidence of population declines in these provinces than in the U. S. portion of the range. The capitalization of a Great Lakes fishery for smelt in the 1960s and 1970s resulted in high landings that suppressed prices and may have reduced effort in the New Brunswick fishery (McKenzie 1964, DFO 2011). In spite of depressed prices, the eastern New Brunswick smelt fishery remained stable between 1988 and1998, with total reported landings between 1.5 and 2.5 million lbs, a sum that may under represent actual landings (DFO 2011).

The smelt fisheries of the St. Lawrence River have shown a decline comparable to U. S. fisheries. Reduced commercial and recreational fisheries and spawning habitat abandonment in the St. Lawrence River tributaries triggered survey and restoration efforts in the 2000s (Trencia et al. 2005). The fisheries remain culturally important today while operating at historically low harvest levels with ongoing restoration efforts by Quebec's Ministry of Natural Resources (Verreault et al. 2012).

Summary

Dramatic changes have occurred in both Gulf of Maine smelt fisheries and the distribution of smelt on the East Coast since the start of the 20th century. Culturally and economically important smelt fisheries have disappeared or faded to historic lows. The trend is evident of wide-scale abandonment of the historic southern extent of the range, where commercial smelt fisheries were viable before the 20th century. Currently, the southern extent of the species range is likely in the Buzzards Bay, Massachusetts region, with higher population levels observed in more northern rivers.

Popular recreational fisheries remain in Maine and New Hampshire, although these fisheries also appear to be harvesting at historically low levels. The traditional Massachusetts ice shack fisheries have been reduced to very low levels of participation and catch, and they are faced with warmer winters that bring insufficient ice to support shacks. The causes of this steep decline in smelt fisheries on the U. S. East Coast have not been defined, but have been discussed for over a century. Industrial pollution at spawning rivers, structural barriers, and overfishing have received the most attention as causal factors. Watershed alterations, natural predation and climate change are potential factors that have been implicated more recently.

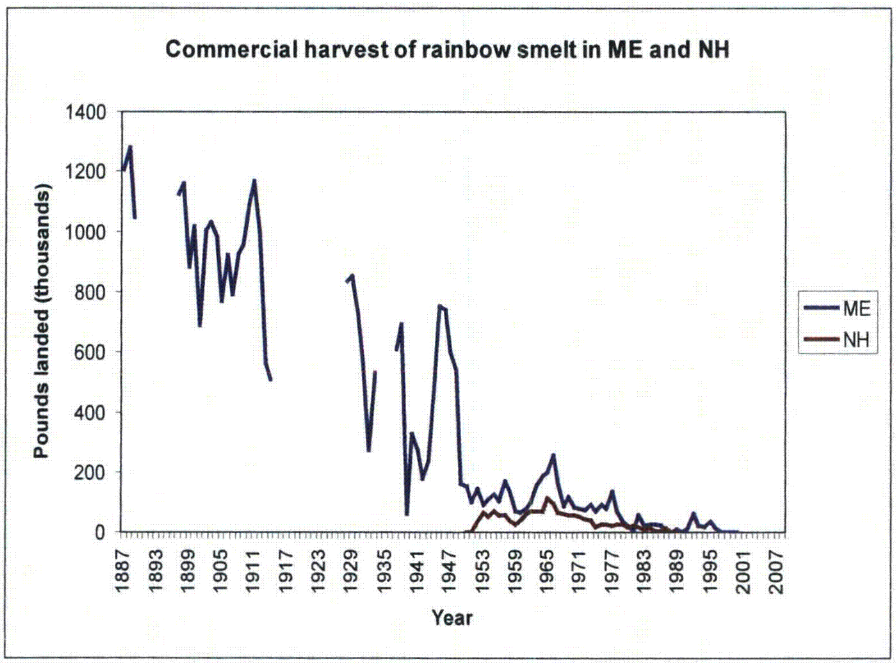


Figure 1.2.1. Commercial smelt landings for Maine (1887-2009) and New Hampshire (1950-2009). Data sources: U.S. Commissioners Report, U.S. Bureau of Fisheries, State of Maine landings data (as summarized by Squiers et al. 1976), and NMFS website.

1.3 – POPULATION STATUS IN THE GULF OF MAINE

Concerns have grown over the health of anadromous rainbow smelt populations throughout much of their range. This concern has prompted interest in assessing smelt populations and developing restoration strategies. Limited information is available from both fisheries-dependent and independent sources on the present status of populations in New England. The Species of Concern (SOC) project reviewed existing smelt population data in New England to consider the potential for developing indices of abundance, and initiated field projects during 2008-2011 to establish new data series to provide information on the status of smelt runs.

Previous Smelt Population Studies

Studies conducted in the late 1950's described several life history characteristics that we also observed in the present study, such as declining average length as the spawning run progresses and few smelt over the age of three.

The earliest smelt population studies occurred in northern portions of their range, likely in response to the commercial importance of smelt fisheries in these regions. Kendall (1926) focused on smelt fisheries but did provide smelt length data gathered from various sources during the 1850s to 1920s. Not much information can be gleaned from these sparse data, except to say the maximum size of smelt from that time period of about 26-28 cm (total length) is quite similar to the maximum size found in the present study (27 cm). Warfel et al. (1943) reported smelt age data for Great Bay, NH; this study provided some of the first age data for the area and perhaps the first documentation of age-1 smelt participating in the spawning run. Summary statistics for Warfel et al. (1943) and the following studies are presented in Table 1.3.1.

McKenzie (1958 and 1964) followed the Great Bay study with a detailed study of the life history of smelt and their fisheries in the Miramichi River of New Brunswick during 1949-1953. McKenzie (1964) demonstrated several life history characteristics that have been confirmed in the present study, such as: declining average length of smelt as the run progresses, a more balanced sex ratio in the winter fishery than during the spawning run and few smelt older than age-4. The age composition in the Miramichi River during 1949-1953 had consistently higher representation of age-3 (22-49% annually) and age-4 (2-8% annually) than seen in the present study and had older fish present each year, although at low proportions (age-5 and age-6 at <0.5% and <0.1%, respectively). Murawski and Cole (1978) calculated an annual survival rate (S) of 0.35 for the overall proportions in McKenzie's age composition data, a value found to be the highest among reported survival data for anadromous rainbow smelt (Chase et al. 2012).

The ME DMR devoted considerable time to the assessment of smelt fisheries in the 1970s and 1980s (Squiers et al. 1976, Flagg 1983). The majority of the effort was fishery-dependent assessments of the winter smelt fishery. The size composition data from these winter fishery studies may not be directly comparable to spawning run size composition. However, summary data on sampling proportion by age and mean length at age are included in Table 1.3.1 because the data document the size composition of smelt populations at the time and the relatively larger contribution of older smelt in the catch.

Murawski and Cole (1978) provided size, age and mortality data from the Parker River, Massachusetts spawning run and winter fishery during 1974-1975. This study sampled both the winter sport fishery catch and spring spawning run with a fyke net, providing a valuable comparison to the Parker River data in the present study. Five age classes were represented in the fyke catches, with a majority at age-2. Murawski and Cole (1978) also provided one of the few estimates of smelt population mortality and survival rates. They reported mean values of the annual survival rate (S) of 0.28 and the instantaneous total mortality (Z) of 1.27 for both sexes using three analysis methods for the spawning runs. They considered the estimated overall annual mortality rate of 72% of the adult population to be high and that increases in fishing pressure could limit reproductive success in the Parker River.

Lawton et al. (1990) investigated biological aspects of the Jones River (MA) smelt spawning run during 1979-1981. The study used a lift net at the upstream limit of smelt spawning habitat to collect mature smelt. All biological data collected by the lift net may not be directly comparable to the present study, wherein a fyke net was deployed downstream of the lowermost spawning habitat. However, the study did produce an age/length key based on length-stratified age subsamples that should be representative of the spawning run demographics and comparable to the fyke net age/length data. Five age classes were found in the Jones River with an age-2 majority for most years and very few age-5 smelt. For the three spawning seasons sampled, age-2 and age-3 smelt comprised 83-99% of the spawning smelt. Lawton et al. (1990) also estimated the Jones River spawning population by extrapolating smelt egg densities to total spawning habitat area. The spawning stock abundance model calculated the spawning run of 1981 to exceed four million adult smelt. They also reported evidence of a strong 1978 year class with relative contributions of this cohort evident in the subsequent three spawning runs.

The smelt runs of the St. Lawrence River have supported culturally and economically important fisheries in Québec for decades. Declining smelt fisheries landings attracted the interest of the Québec Ministry of Natural Resources to conduct biological monitoring in the 1990s. Pouliot (2002) reported on size and age sampling of the spawning run in a St. Lawrence River tributary, the Fouquette River, during 1991-1996. A standardized dipnet sampling method was used at night at the spawning habitat. The results provide the first detailed population demographics and mortality estimates for smelt in the St. Lawrence River watershed. The Fouquette River smelt runs during the 1990s contained four or five cohorts in most years. Estimates of the annual rate of total mortality were 74% for females and 73% for males.

Current Fisheries Dependent Monitoring

New Hampshire Creel Survey

NHF&G has conducted winter creel surveys since 1978. The survey occurs from ice in to ice out, generally between the months of December and March. Four locations are sampled: the Lamprey, Oyster/Bellamy and Squamscott rivers as well as Great Bay. From 1983-1986 no survey was conducted due to lack of funding, and in 2002 and 2006 fishing, and subsequently surveys, were not possible due to lack of ice cover.

Biologists interview all anglers (or a sub-sample when large groups of anglers are present) for catch and effort information during a two hour survey period per day, visiting locations on a rotating basis. The information collected is expanded to provide estimates of catch, effort and catch per unit effort (CPUE) by month and location. Biological information from the smelt catch, including length, sex and scales for ageing, are taken from 150 fish weekly.

The average CPUE for 1987-2011 is 4.48 fish/hour over the entire sample period. High CPUEs have not been observed in the last ten year period (2000-2011, max CPUE = 5.6), compared to the previous twenty year period (1980-1989 max CPUE = 10.3; 1990-1999 max CPUE = 10.6; Figure 1.3.1). In most recent years, the CPUE has been below the series average (4.48) until 2011 when it increased to 5 fish/angler hour. There has not been a peak in CPUE over 6 fish/angler hour since 1995. The CPUE shows large inter-annual variability, and seems to follow a 5-10 cyclical pattern (Figure 1.3.1).

Maine Creel Survey

Adopting sampling methods currently used by NHF&G (Sullivan 2009) and methods used in a 1979-1982 study conducted by the ME DMR (Flagg 1983), ME DMR again began conducting creel surveys in 2009 in the Kennebec River and Merrymeeting Bay area. As part of this survey, ME DMR staff visited participating camps two or three times per week on a rotating basis to collect biological information about the recreational catch. Staff collected biological information from a subset of each angler's catch (up to 100 fish per angler), including length, sex, scale samples for ageing and fin clip samples for genetic sampling. The number of anglers, fishing hours, and the number of fishing lines used was also recorded.

CPUE was calculated as the total number of smelt caught per line-hour of fishing, as opposed to NHF&G calculation of CPUE as smelt caught per angler hour – ME DMR currently calculates CPUE using line-hour to remain consistent with surveys conducted by ME DMR 1979-1982. The recent survey found a slightly lower CPUE (0.48), compared to the 1979-1982 study CPUE (0.64), however inter-annual variability was significantly larger than the comparison between the two study periods (Figure 1.3.2, Flagg 1983). While annual fluctuations in CPUE occurred in both surveys, the recent survey had the lowest CPUE recorded (0.17) during the two time series.

Catch Card boxes were also posted at each camp for fishermen to voluntarily report information about their total smelt catch and any bycatch; responses varied widely between sites and between years. There were 122 responses in 2009, 6 in 2010, and 37 in 2011 for all camps combined. It is our hope that with continued interaction with anglers and camp owners that the number of responses will increase. Despite the low number of responses in 2010, the Catch Cards still reflected the catch patterns found in creel survey data.

Current Fisheries Independent Monitoring

State Inshore Trawl Surveys

The three state fisheries agencies perform inshore small-mesh trawl surveys twice a year, in the spring (MA DMF in May, NH/ME in late May, early June) and fall (MA DMF in September, NH/ME in October, early November). The MA DMF has been performing surveys since 1978, while the ME DMR began sampling the New Hampshire and Maine waters in fall 2000. These surveys provide information about marine habitat use and migration patterns of rainbow smelt, as discussed in section 1.1 – Basic Biology. However, this survey is designed to monitor groundfish abundance, and has limited application for pelagic species like rainbow smelt. The data are helpful in determining the presence or absence of smelt in certain regions and depths, and can give a picture of inter-annual age cohort strength from size data, but are not powerful in showing trends in rainbow smelt abundance. However, trends in catches in both state surveys seem to have a 5-10 year cyclical pattern similar to the creel surveys and juvenile abundance surveys (Figure 1.3.3), although the causal factor behind these cycles is unknown.

Maine and New Hampshire Juvenile Abundance Surveys

In 1979, ME DMR established the Juvenile Alosine Survey for the Kennebec/Androscoggin estuary to monitor the abundance of juvenile alosines at 14 permanent sampling sites, sampled June through November. Four sites are on the upper Kennebec River, three on the Androscoggin River, four on Merrymeeting Bay, one each on the Cathance, Abadagasset, and Eastern rivers. These sites are in the tidal freshwater portion of the estuary. Since 1994, ME DMR added six additional sites in the lower salinity-stratified portion of the Kennebec River. The seine is made of 6.35 mm stretch mesh nylon, measures 17 m long and 1.8 m deep with a 1.8 m x 1.8 m bag at its center. The net samples an area of approximately 220 m^2.

Of all the river sections, the lower Kennebec catches considerably more juvenile smelt than all upstream sections; the average catch over the time period for the lower Kennebec was 92 smelt/haul/year, while all others were under 10 smelt/haul/year, and catches are sporadic. Though the highest average annual catch occurred in 2005 (316 smelt/haul) in the lower Kennebec, juvenile smelt abundance in this river segment has been low since 2007, with three of the four lowest average annual catches occurring in the past four years. Trends in abundance also seem to follow a 5-10 cyclical pattern similar to the other surveys (Figure 1.3.4).

The NHF&G has conducted an annual Juvenile Abundance Survey since 1997. It is designed as a fixed station survey, as opposed to a stratified random survey, because strong tidal currents, rocky shorelines, and various anthropogenic structures limit the amount of suitable beach seining locations. A total of 15 fixed locations are sampled monthly from June to November. The stations are located within the Great Bay and Hampton-Seabrook estuaries. Seine hauls are conducted by boat using a 30.5 m long by 1.8 m high bag seine with 6.4 mm mesh deployed 10 – 15 m from the shore. Over the sampling period, the Piscataqua River has seen the highest CPUE (177 smelt/haul/year), however the highest annual average catch occurred in Great Bay in 2001 (225 smelt per haul). The lowest average catch over the entire sampling period was in the Hampton Beach/Seabrook area (11 smelt/haul/year). While these abundance data also seem to follow a cyclical pattern, there has been a decline in the juvenile rainbow smelt being captured in recent years – excluding the first year of sampling, the four lowest average annual catches have occurred within the past 6 years (Figure 1.3.5).

New Hampshire Egg Deposition Monitoring

New Hampshire Fish and Game Department conducted egg deposition sampling from 1978-2007 using methodologies described by Rupp (1965). A ring of known area (20.3 cm^2) was tossed on natural substrate, and the number of eggs within the ring was counted. Egg counts were conducted weekly, from mid-March to mid-April, in the Oyster, Bellamy, Lamprey, Squamscott and Winnicut rivers. The mean number of eggs per square centimeter was used as an index of spawning stock abundance. Validation of the index was attempted by regressing the index with catch per unit effort (CPUE) of the creel survey but showed very poor correlation. The egg deposition sampling was discontinued in 2008 because comparisons between this dataset and other indices of smelt abundance (creel and juvenile surveys) did not correlate well, while trends in the other surveys did correlate well with each other.

Maine Spawning Stream Use Monitoring

In 2005 and 2007-2009, biologists with the ME DMR worked with the Maine Marine Patrol to document coastal rivers and streams currently being used by rainbow smelt for spawning. The survey collected information about the spawning habitat (substrate, possible obstructions), and the strength of the run as characterized by the density of egg mats or number of spawning adults present. We compared the current use and strength of runs to information collected by ME DMR in the early 1970s (Flagg 1974) and to information compiled in 1984 by the U. S. Fish and Wildlife Service (USFWS 2012).

Of the 279 streams surveyed , the majority either supported smaller runs than they did historically or no longer support spawning, while only a small percentage (19%) seem to currently support strong runs (Table 1.3.2, Figure 1.3.6). Spawning decline was concentrated in southern Maine, lower Casco Bay, the Kennebec River, and the east side of Frenchman's Bay. Spawning runs remain strong in northern Casco Bay, the Medomak, St. Georges, and Penobscot Rivers, and around Pleasant Bay and Cobscook Bay.

Regional Fyke Net Sampling

Earlier research on anadromous smelt populations in the Gulf of Maine has primarily consisted of short-term efforts that monitor smelt size and age structure during spawning runs. These efforts have not produced long-term population indices of abundance for smelt, and presently, no indices exist in New England. The smelt SOC project targeted the spring spawning runs as a source of information on population status. The objective was to produce fishery-independent indices of abundance, with the understanding that only mature smelt participate in the spawning runs. The approach was to record biological data from spawning runs; to conduct analyses on size and age composition, catch-per-unit-effort, and mortality; and to make comparisons as possible among rivers and to previous studies.

<u>Establishing Gulf of Maine Spawning Site Indices</u>

<u>Methods</u>. As part of this project, fyke net stations were selected at coastal rivers in Maine, New Hampshire, and Massachusetts for monitoring during 2008-2011 (Figure 1.3.7, Table 2.1.1). The stations were chosen for suitability to maintain a fyke net in a known smelt run and to represent a range of run sizes and watershed conditions. The fyke net was set at mid-channel in the intertidal zone below the downstream limit of smelt egg deposition. The fyke net opening faced downstream, and nets were hauled after overnight sets. This approach was adopted to intercept the spawning movements of smelt that occur

at night during the flood tide. Fyke net catches were assumed to be representative of the size and sex composition of the spawning run. With each haul, smelt were counted, sexed, measured (total length) and released. Scales were sampled weekly at some stations for ageing.

After pilot deployments in 2007-2008 to identify suitable stations, eight fyke net stations were monitored in Massachusetts, three stations in New Hampshire and six in Maine (Figure 1.3.7). The sampling period in Massachusetts targeted 11 weeks from the first week of March to the third week of May to cover the known smelt spawning period. The sampling duration in New Hampshire and Maine varied due to a later ice-out and spawning season that occurs later with increasing latitude.

<u>2008-2011 Results</u>

Smelt were captured at most fyke stations during the spring spawning runs of 2008-2011. The annual catches ranged from few individual smelt in some rivers to several thousand in the larger smelt runs. The following sections and graphics describe major findings in the fyke net catch data that portray population trends across the species' distribution on the Gulf of Maine coast.

Because smelt migrate from marine to freshwater habitats to spawn during the spring freshet, they are affected by a range of environmental factors most related to temperature and precipitation.

<u>Seasonality.</u> Because smelt migrate from marine to freshwater habitats to spawn during the spring freshet, they are affected by a range of environmental factors most related to temperature and precipitation. Understanding how an unpredictable environment can influence the timing, location and strength of a smelt run is valuable for managing smelt populations. Accordingly, characteristics of the onset, peak, and overall duration of a smelt run can provide measures of population health. In this study, the onset and ending of the spawning run were based on the average date of first and last capture, respectively. Spawning run peak was determined based on the average date of maximum catch. In several cases, the onset and the ending of the spawning run were inconclusive and had to be estimated using best professional judgment. Run duration was determined based on the average yearly duration of the run from 2008-2011.

Inter-system variability was noted in the timing of the spawning run (Figure 1.3.8). Within most systems in Massachusetts and New Hampshire, the spawning run had begun by mid-March. Within several Maine systems, however, the spawning run was delayed and did not start until late-April. Similar patterns were observed in the peak and ending, with Massachusetts and New Hampshire systems having earlier peaks and earlier ending dates than those in Maine. Differences in run timing among states are presumably attributable to regional differences in climate, with cooler, more northerly systems displaying a delayed spawning run.

Run duration also varied with location. The longest run durations were observed for the Fore and Jones rivers, Massachusetts, and Tannery Brook, Maine. In these systems, average run duration appeared to exceed 70 days. Conversely, the shortest runs were observed to occur in the North, Weweantic, and Saugus rivers, Massachusetts, where average run duration did not exceed 40 days. The causes for the differences in run duration are unknown, particularly because previous studies have demonstrated shorter run durations in northern latitudes, with runs in individual tributaries often lasting less than two weeks in New Brunswick (McKenzie 1964) and Québec (Pouliot 2002). In the case of the U. S. Gulf of Maine surveys, population abundance and year class strength may be influential, however the causal factors are not currently understood.

Catch Per Unit Effort (CPUE). The number of fish captured per a given amount of sampling, known as catch per unit effort (CPUE), is a measure used by fishery scientists to assess the relative abundance of a fish population, under the assumption that higher catches for a given amount of sampling effort (e.g., time, gear, habitat area, samplers) represents greater abundance. For the fyke net survey, the number of smelt caught per haul was used as a measure of CPUE. Yearly measures of CPUE were based on the geometric mean of weekly average CPUE.

The results of this study demonstrated that CPUE varied widely among rivers and years. For the entire region, the two highest overall CPUE were found in Maine (Deer Meadow Brook = 58.07, Schoppee Brook = 37.83), while the two lowest were found in Massachusetts (Westport River = 1.01, North River = 1.37). There was an overall trend of higher CPUE in Maine compared to New Hampshire and Massachusetts – out of the 17 index sites, four out of the top five highest CPUE were found in Maine (Table 1.3.3).

Considering abundance by state, in Massachusetts, the Fore River had the highest overall CPUE (20.42), while the Westport River had the lowest (1.01). In New Hampshire, the highest overall value was found at the Oyster River (5.62), while the lowest was at the Winnicut River (1.64). In Maine, the highest was found at Deer Meadow Brook (58.07), and the lowest at Long Creek (11.39, Table 1.3.3).

Yearly CPUE peaked in five of eight Massachusetts rivers in 2008, suggesting that in these systems, the largest smelt runs were observed at the beginning of the study (Table 1.3.3, Figure A.1.1). In New Hampshire, the highest annual CPUE for all rivers was seen in 2011 (Table 1.3.3, Figure A.1.2). In southern and midcoast Maine (Long Creek, Mast Landing, and Deer Meadow Brook), the highest annual CPUE was seen in 2008 or 2009, while in eastern Maine (Tannery, Schoppee, and East Bay brooks), the highest annual geometric mean values were seen in 2010 (Table 1.3.3, Figure A.1.3). It should be noted that when CPUE is calculated as simply the number of smelt per haul, the highest CPUE for East Bay Brook occurred in 2008 (Figure A.1.3).

At this time, high levels of variability in CPUE and the limited duration of the study prohibit a statistical analysis of trends in relative abundance. However, the CPUE data from 2008-2011 for some stations should be valuable as a reference point for future comparisons.

Length and Age Composition. Length and age information yields important insights into the health of a fish population. As a general rule, the presence of a variety of age classes is indicative of a healthy population. Further, populations containing older and larger individuals, which have a relatively high reproductive potential, are considered healthier than those containing only younger, smaller individuals. Smelt are fast growing fish that mature at small size and become fully recruited to the spawning stock at age-2 in the study area. We measured total length of captured smelt to the nearest millimeter (mm). Smelt ages were determined from scale samples.

The age class composition of the runs varied between sites, but displayed geographical patterns. We found that runs in the southern portion of the Gulf of Maine (represented by the Fore River, Massachusetts, and Mast Landing, Maine) displayed two dominant age modes: one comprised mainly of age-1 smelt and second mode comprised of mainly age-2 smelt (Figure 1.3.9 and 1.3.10). Age-1 smelt were common in Massachusetts and, in some years, were the dominant age class; yet this age class was present at much lower frequencies in spawning runs in the northern range of the study area (Table 1.3.4, Figures 1.3.9-1.3.14). In the mid-portion of the region (represented by Deer Meadow and Tannery brooks, Maine), age-1 fish were encountered infrequently – the runs instead were dominated by age-2 fish, and the frequency of age-3 individuals was much higher than seen in more southern runs. Older ages (4-5) were also seen in these runs at higher rates than at all other runs, and these were the only sites to have age-6 fish represented in the runs (Table 1.3.4, Figures 1.3.11 and 1.3.12). In the northeastern portion of the Gulf of Maine (represented by Schoppee and East Bay brooks), runs were composed primarily of age-2 fish, with few to no age-1 fish observed. Age-3 fish were observed, but at a lower frequency than the mid-portion of the region. The occurrence of older ages (4-5) was higher than the southern runs, but not as high as the mid-portion (Table 1.3.4, Figures 1.3.13 and 1.3.14). The fact that fish at age-4 or older were unusual in Massachusetts, but relatively common in Maine samples, suggests higher levels of mortality in southerly systems.

Length at age also varied between sites, but again showed a geographic pattern. Because large sample sizes of age-2 males were present in each run, it is informative to compare the average lengths between sites using this category. The largest length at age was observed in the southern portion of the region (Fore River avg. age-2 male = 184 mm, Mast Landing = 178 mm, Table 1.3.4), indicating a faster growth rate at lower latitudes. Though the Oyster River geographically lies between these sites, age-2 males were comparatively smaller than the other southern sites (162 mm). This smaller age-at-length compared to surrounding sites may be evidence of a stressed population in the Oyster River, although further evidence would be needed to substantiate this idea. Comparisons between previous studies show that length-at-age is observed to decline moving northward (Table 1.3.1). We observed a similar trend, however the smallest length-at-age was observed in the mid-portion of the region (Deer Meadow Brook avg. age-2 male = 157 mm, Tannery Brook = 142 mm, Table 1.3.4). Sites at the most northeastern portion of the Gulf of Maine had larger age-2 males than in this mid-portion, but smaller than the southern sites (Schoppee Brook = 163 mm, East Bay Brook = 166 mm, Table 1.3.4). This pattern in age-at-length, as well as the pattern in run compositions discussed above, is coincident with the genetic stock structure of rainbow smelt reported by Kovach et al. (in press) and discussed in section 1.1 – Basic Biology, which found that the fish from Tannery Brook had a genetically differentiated signal that was also seen in fish from Deer Meadow Brook, but not in any other sites.

Because it was not possible to develop age-at-length keys for all sites due to low sample numbers at some sites, median length (calculated from all fish at a site) and length distributions are useful in understanding region-wide trends. Median lengths were lowest for males in the Massachusetts sites, and for females in the New Hampshire sites, and were generally higher for Maine sites (Table 1.3.5, Figure 1.3.15). The driving factor behind these patterns seems to be the age composition of each of these runs rather than the length at age – runs in the southern portion of region are composed of a large proportion of age-1 fish, while runs in the mid- and northeastern portion have a higher proportion of age 3+ fish (Table 1.3.4). While not all fish were aged, modes corresponding to specific ages can help in affirming this idea. Length frequency figures for all sites with enough samples to produce relevant figures are included in the Appendix (Figures A.1.4 – A.1.14).

Sex Ratio. Although spawning runs of most anadromous fishes are male biased, those displaying a substantially higher proportion of males may be indicative of a stressed population. Because the limiting factor for population growth is often the abundance of females, populations dominated by males may be less robust than those containing a higher proportion of females. In this study, sex ratio was determined based on the ratio of the aggregate 2008-2011 catch of males to the catch of females.

The results of the fyke net survey demonstrated that each system contained a smelt population that was male biased. Overall, this survey observed an average sex ratio of 4:1. Of the systems sampled, the most heavily male biased were the Parker River, MA, and the Squamscott and Oyster rivers, NH, which all displayed a male to female ratio of greater than 8:1. The lowest male to female ratios were found in three systems in Maine: Tannery Brook, Schoppee Brook, and the East Bay River. In each of these systems, the sex ratio was less than 2:1. We acknowledge that these sex ratios are biased themselves due to the behavior of male smelt spending more time on the spawning grounds than females (Murawski et al. 1980).

Mortality. Limited work has been done on population metrics for anadromous rainbow smelt throughout their range, but a few studies have calculated population mortality and survival rates based on age structure (Murawski and Cole 1978, Pouliot 2002). Survival and mortality analyses have potential biases that may limit their accuracy. Few age cohorts are available for the assessment: the age-1 cohort is excluded from mortality estimates because they are partially recruited to the spawning run, and age-4 smelt are presently uncommon. Secondly, the sampling method cannot distinguish the occurrence of repeat spawning movements of individual smelt; this behavior could bias measurements of mortality and survival. Under the assumption that these biases were consistent among studies, we calculated mortality and survival estimates for sites that had sufficient age data for 2008-2011 and compared them to previous studies.

Within the study area, survival rates (S) and instantaneous total mortality (Z) were calculated using the Chapman and Robson equation (Chapman and Robson 1960) at five stations in Maine and one each in Massachusetts and New Hampshire. However, the presence of some small sample sizes, few years of observations and the above discussed biases limit the reporting of these data to a relative comparison across the region and to past studies. Tannery Brook, Maine, had the highest average survival for 2008-2011 at $S = 0.33$, followed by $S = 0.26$ for 2009-2011 at Deer Meadow Brook in Maine. For sites that had at least three years of data, the Fore River, Massachusetts, had the lowest average survival at $S = 0.17$. The range of these spawning population survival estimates places the higher values in the present study among the highest reported by previous studies in the U.S. (Murawski and Cole 1978, Lawton et al. 1990) and

Canadian Provinces (McKenzie 1964, Pouliot 2002), and the sites at the lower range are the lowest survival values reported for anadromous rainbow smelt.

Study Area Summary

Massachusetts. Of the eight fyke net stations monitored in Massachusetts, six caught enough smelt to allow summary comments on run demographics, but only the Fore River had a sufficient sample size to generate age composition data each year. The age and length data in Massachusetts suggest the presence of a truncated age distribution, a sign of stressed populations due to high mortality and potentially poor recruitment. Male smelt in Massachusetts have similar median lengths compared to male smelt in New Hampshire and Maine. However, female smelt in Massachusetts had higher median length than the other states; a statistic driven by larger age-2 to age-4 females. Massachusetts stations are dominated by length modes that indicate age-1 and age-2 smelt, with very low presence of smelt older than age-4. The proportion of age-1 smelt in Parker River and Jones River spawning runs markedly exceeds that found in previous studies. Changes in the contribution of age-1 smelt to the spawning run between previous studies and the present study, and the higher proportion of these small smelt in Massachusetts compared to New Hampshire and Maine raises interesting questions on the significance of these apparent differences. Smelt at the southern stations may experience faster growth in their first year and are reaching a body size that supports maturity sooner than northern runs.

The age and length data in Massachusetts suggest the presence of a truncated age distribution, a sign of stressed populations due to high mortality and potentially poor recruitment.

New Hampshire. The presence of mature smelt was documented in fyke catches in the Bellamy, Salmon Falls, Lamprey, Squamscott, Winnicut and Oyster rivers during 2008, and the standardized fyke net sampling protocol was followed in the Squamscott and Winnicut rivers from 2008-2011, and in the Oyster River from 2010-2011. Sufficient age samples were collected at the Oyster and Squamscott rivers in 2011 to prepare length frequency and age-length graphs. Two length modes are apparent in both rivers composed of age-1 and age-2 smelt. However, more overlap is seen in these modes than is found in Massachusetts smelt age-length data. Few smelt reached age-4 in New Hampshire rivers. For each available age key, age-4 comprised less than 2% of the annual age sample. Growth rates appear to be slower within New Hampshire runs, as age-3 smelt occur at smaller lengths than seen in Massachusetts and no age-2 smelt larger than 19 cm have been sampled.

Maine. All six Maine fyke net stations produced sample sizes large enough to summarize information on smelt run status. Median smelt length for the Maine stations was slightly larger than at the other states because these runs had a lower proportion of age-1 smelt, but higher proportion of age 3+ smelt; however, average length at age was smaller, indicating a slower growth rate compared to sites further south. The Maine smelt runs also averaged higher CPUE rates and showed more balanced age distributions and sex ratios than seen in southern runs. These patterns were most evident in catch data from the easternmost Maine stations. All these observations indicate relatively healthier smelt runs in Maine than in Massachusetts and New Hampshire. The age composition of smelt in Maine's spawning runs contributes to less separation between length modes and an extended age-2+ mode. These features could reflect interesting potential differences in growth rates, maturation, and survival in Maine than at the southern runs.

Conclusions About Regional Fyke Net Sampling

A common goal in fisheries management is to base decisions on a long-term stock assessment that generates defensible biological benchmarks on the health of the fish stock. The present study does not achieve this goal, but it starts the process of providing information on spawning run CPUE, temporal characteristics, and size and age composition of rainbow smelt in three states.

The sampling period from 2008-2011 is too brief for conclusions on population trends. However, such baseline information is vital for all fish stock assessments. The task of assessing the status of rainbow smelt in the Gulf of

Table 1.3.1. Mean length at age and proportion at age of anadromous rainbow smelt sampled during spawning runs in earlier studies in the study area and Canadian Maritime Provinces. All length data were converted to total length.

Mean Length at Age

Location	Region	Citation	Year	Sex	N	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6
Miramichi River	NB	McKenzie (1958)	1949-53	M	NA		157	178	196	211	
Miramichi River	NB	"	"	F	NA		162	186	212	238	
Fouquette River	Quebec	Pouliot (2002)	1991-96	M	NA		133	166	198	215	227
Fouquette River	Quebec	"	"	F	NA		135	173	213	237	245
Great Bay	NH	Warfel et al. (1943)	1942	both	287	86	145	171	220	264	
Penobscott River	ME	Squiers et al (1976)	1974-75	both	260		165	196	226	264	
Kennebec River	ME	Flagg (1984)	1980-82	M	1012		174	202	221	229	
Kennebec River	ME	"		F	680		180	215	239	249	
Parker River	MA	Murawski	1974-75	M	2097	141	188	208	236	242	
Parker River	MA	and Cole (1978)	"	F	584	140	197	219	245	249	
Jones River	MA	Lawton et al. (1990)	1979-81	M	31394	132	184	208	221	242	
Jones River	MA	"	"	F	5009	130	190	222	244	254	

Proportion (%) at Age

Location	Region	Citation	Year	Sex	N	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6
Miramichi River	NB	McKenzie (1964)	1949-53	both	NA		66.2	29.3	4.1	0.4	
Great Bay	NH	Warfel et al. (1943)	1942	both	287	3.5	65.9	29.6	1.0	0	
Kennebec River	ME	Flagg (1984)	1979-82	both	1700		59.9	33.0	5.5	0.5	
Penobscott River	ME	Squiers et al (1976)	1974	both	133		42.1	39.1	17.3	1.5	
Penobscott River	ME	"	1975	both	127		17.3	67.7	14.2	0.8	
Parker River	MA	Murawski	1974	M	343	38.0	42.5	15.9	3.2	0.4	
Parker River	MA	and Cole (1978)	1974	F	50	15.7	50.5	20.8	10.8	2.2	
Parker River	MA	"	1975	M	113	9.9	81.2	7.9	0.8	0.2	
Parker River	MA	"	1975	F	40	3.9	76.6	16.4	2.4	0.7	
Jones River	MA	Lawton et al. (1990)	1979	M	364	15.0	64.6	19.7	0.7	<0.1	
Jones River	MA	"	1979	F	235	15.1	66.7	16.7	1.0	0.5	
Jones River	MA	"	1980	M	428	0.2	88.4	11.1	0.3	0	
Jones River	MA	"	1980	F	353	0	86.0	12.8	1.2	0	
Jones River	MA	"	1981	M	250	2.9	55.7	37.9	3.5	0	
Jones River	MA	"	1981	F	160	0.4	36.0	48.7	14	0.9	

Notes

1. Lawton et al. (1990) and Murawski and Cole (1978) age composition is based on age key proportions assigned to total length sample.
2. Murawski and Cole (1978) mean length combines 1975 winter creel survey with 1974 and 1975 spawning run data.
3. McKenzie (1958 and 1964) length data are converted to TL from SL. Age-6 smelt were caught in most years at low frequency (<0.1%).
4. Pouliet (2002) fork length data were converted to total length using the conversion, TL = (FL-0.5584)/0.9142, from Chase et al. (2006).
5. Flagg (1983) and Squiers et al (1976) size and age data are both from winter smelt ice fishery, but included for comparative value.

Maine is further complicated by the case of having distinct stock structure for some rivers, instead of a coast-wide stock complex. Finally, the assessment of anadromous fish is confounded by their migration between marine and freshwater habitats, where different factors influence their growth and survival. Despite these challenges, the fyke net data from the present study show a gradient of conditions with signs of stressed populations in southern Gulf of Maine and less evidence of stress moving north along the Maine coast, as evidenced by younger age distributions, smaller age-at-length, and lower CPUE rates.

Table 1.3.2. Current state of smelt spawning runs in Maine with respect to their historical status.

Status	Number	Percent
Not historically listed, and currently do not support spawning	42	15%
Historical runs that do not currently support spawning	35	13%
Currently support smaller runs than historically	95	34%
Currently support strong runs	53	19%
Historical runs that were not visited, current status is unknown	54	19%

Table 1.3.3. Catch per unit effort (CPUE) of rainbow smelt at fyke net spawning survey index sites, by annual CPUE and overall CPUE for the entire sampling period, 2008-2011.

		Annual CPUE				Overall
River	State	2008	2009	2010	2011	CPUE
Weweantic R.	MA	2.81	1.27	1.47	1.57	1.78
Westport R.	MA	1.00	1.00	1.00	1.02	1.01
Jones R.	MA	9.13	5.58	7.56	5.13	6.85
Fore R.	MA	33.55	10.41	22.00	15.70	20.42
Saugus R.	MA	6.30	1.19	1.07	2.49	2.76
North R.	MA	1.39	1.12	1.08	1.90	1.37
Crane R.	MA	3.03	1.97	2.12	3.39	2.63
Parker R.	MA	7.63	2.56	1.66	2.47	3.58
Squamscott R.	NH	3.45	1.44	1.08	6.26	3.06
Winnicut R.	NH	1.60	1.34	1.36	2.25	1.64
Oyster R.	NH	-	-	5.45	5.79	5.62
Long Cr.	ME	-	18.69	5.56	9.93	11.39
Mast Landing	ME	52.00	29.84	8.81	13.80	26.11
Deer Meadow Bk.	ME	11.11	100.82	24.86	95.46	58.07
Tannery Bk.	ME	15.28	28.26	41.87	14.03	24.86
Schoppee Bk.	ME	-	-	38.42	37.25	37.83
East Bay R.	ME	15.48	4.42	21.66	11.86	13.35

Proportion (%) at Age

Location	Region	Year	Sex	Length N	Age N	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6
East Bay Brook	ME	2008	both	899	63		92.2	6.7		1.1	
East Bay Brook	ME	2009	both	236	68	0.8	62.3	33.9	3.0		
East Bay Brook	ME	2010	both	1387	261	2.0	80.7	13.7	3.6		
East Bay Brook	ME	2011	both	1211	268		72.0	26.7	1.2	0.1	
Schoppee Brook	ME	2010	both	2034	281	0.9	90.2	3.5	5.4		
Schoppee Brook	ME	2011	both	1831	245	2.2	90.7	7.1			
Tannery Brook	ME	2008	both	2001	74		60.0	34.2	5.8		
Tannery Brook	ME	2009	both	1778	72	3.9	78.6	7.9	6.4	3.2	
Tannery Brook	ME	2010	both	1892	344	2.5	49.6	45.4	1.4	1.0	0.1
Tannery Brook	ME	2011	both	908	172	6.9	36.6	48.0	8.5		
Deer Meadow	ME	2008	both	179	85	5.0	77.1	17.9			
Deer Meadow	ME	2009	both	2016	135	0	90.2	5.7	3.4	0.7	
Deer Meadow	ME	2010	both	1366	320	2.8	26.0	64.7	5.0	1.5	
Deer Meadow	ME	2011	both	1946	108	1.5	83.6	6.9	6.7	0.9	
Mast Landing	ME	2008	both	1620	90	15.2	58.6	24.2	2.0		
Mast Landing	ME	2009	both	1106	128	0.6	85.6	13.9	2.9		
Mast Landing	ME	2010	both	355	268	75.5	8.7	13.8	1.7	0.3	
Mast Landing	ME	2011	both	1833	275	44.5	53.5	0.8	1.2		
Oyster River	NH	2010	both	421	185	65.8	29.0	4.5	0.7		
Oyster River	NH	2011	both	401	231	11.2	75.1	13.5	<0.1		
Fore River	MA	2008	both	1958	380	51.9	41.4	6.2	0.4	0.1	
Fore River	MA	2009	both	846	660	15.5	52.5	31.4	0.6		
Fore River	MA	2010	both	1441	493	89.6	7.9	2.4	0.1	<0.1	
Fore River	MA	2011	both	1241	486	48.3	48.7	2.6	0.4	<0.1	

Mean Length at Age

Location	Region	Year	Sex	N	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6
East Bay Brook	ME	2008-11	M	322	145	166	197	215	241	
East Bay Brook	ME	2008-11	F	338	155	173	212	238	241	
Schoppee Brook	ME	2010-11	M	225	146	163	195	204		
Schoppee Brook	ME	2010-11	F	299	152	169	206	234		
Tannery Brook	ME	2008-11	M	339	135	142	166	183	190	
Tannery Brook	ME	2008-11	F	322	137	146	178	198	211	215
Deer Meadow	ME	2008-11	M	397	138	157	185	209	220	226
Deer Meadow	ME	2008-11	F	250	125	160	194	222	208	
Mast Landing	ME	2008-11	M	447	132	178	192	211		
Mast Landing	ME	2008-11	F	312	137	190	209	232	256	
Oyster River	NH	2008-11	M	344	117	162	179	209		
Oyster River	NH	2008-11	F	60	114	167	180			
Fore River	MA	2008-11	M	1113	141	184	202	215		
Fore River	MA	2008-11	F	507	142	194	217	249	251	266

Table 1.3.4. Mean length at age and proportion at age of anadromous rainbow smelt sampled at fyke net stations for 2008-2011 for the present study. Age keys were applied to length samples for proportion at age.

MALE

State	River	Code	Years	N	Mean	SE	Median	Min	Max
MA	Weweantic	WW	4	188	151	2.01	145	104	238
MA	Jones	JR	4	1249	156	0.93	143	106	254
MA	Fore	FR	4	4396	166	0.43	157	108	241
MA	Saugus	SG	4	401	162	1.30	153	113	240
MA	North	NR	4	79	150	2.18	149	118	217
MA	Crane	CN	4	262	161	1.44	156	121	221
MA	Parker	PR	4	1217	167	0.88	156	86	255
NH	Squamscott	SQ	2	340	154	1.85	159	86	227
NH	Oyster	OY	2	344	149	1.74	156	88	225
ME	Long Creek	LC	4	1191	169	0.41	168	110	228
ME	Mast Landing	ML	4	3099	163	0.40	169	105	227
ME	Deer Meadow	DM	4	4367	166	0.33	163	83	241
ME	Tannery Brook	TB	4	4214	152	0.27	152	104	223
ME	Schoppee	SB	2	2303	164	0.24	163	125	222
ME	East Bay	EB	4	2368	172	0.31	169	136	250
Total				26018					

FEMALE

State	River	Code	Sex Ratio	N	Mean	SE	Median	Min	Max
MA	Weweantic	WW	3.4	55	149	4.29	139	107	225
MA	Jones	JR	2.5	492	160	1.69	144	100	258
MA	Fore	FR	4.0	1090	168	1.06	154	111	270
MA	Saugus	SG	7.7	52	172	5.01	157	129	248
MA	North	NR	3.4	23	154	4.71	153	113	214
MA	Crane	CN	2.8	94	169	3.31	162	114	257
MA	Parker	PR	9.5	128	194	3.18	204	112	272
NH	Squamscott	SQ	3.7	93	135	3.86	118	86	239
NH	Oyster	OY	5.7	60	151	4.80	166	88	224
ME	Long Creek	LC	3.3	360	178	0.99	176	118	251
ME	Mast Landing	ML	2.7	1136	177	0.86	180	93	263
ME	Deer Meadow	DM	3.6	1209	165	0.71	159	83	258
ME	Tannery Brook	TB	1.8	2366	157	0.46	154	108	236
ME	Schoppee	SB	1.5	1564	174	0.53	170	129	256
ME	East Bay	EB	1.7	1389	183	0.59	176	122	263
Total				10111					

Table 1.3.5. Rainbow smelt length data from catches at fyke net stations, 2008-2011. A few stations were excluded because of low sample sizes or potentially biased samples from few hauls. Smelt of unknown sex were excluded from this table. Sex ratio is the ratio of males to females.

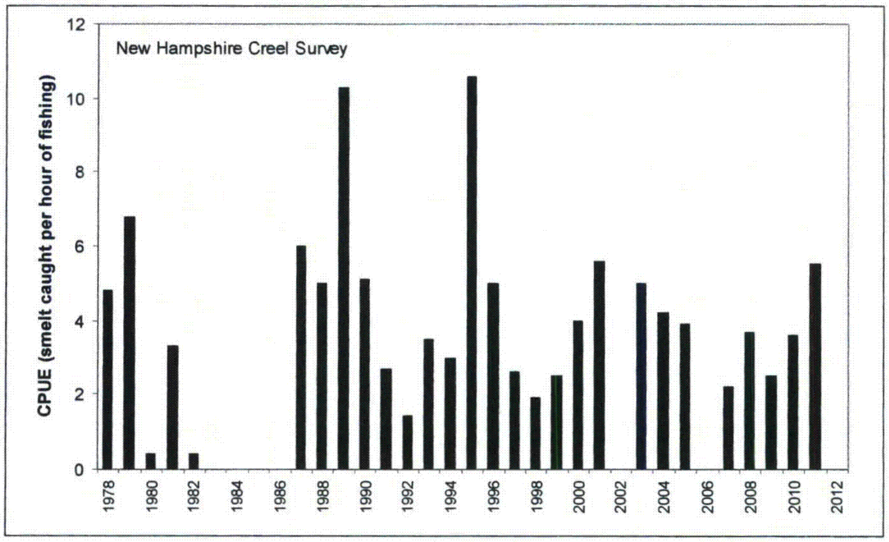


Figure 1.3.1. New Hampshire Fish and Game Creel Survey catch per unit effort (CPUE) calculated as number of fish caught per hour of fishing 1978-2011.

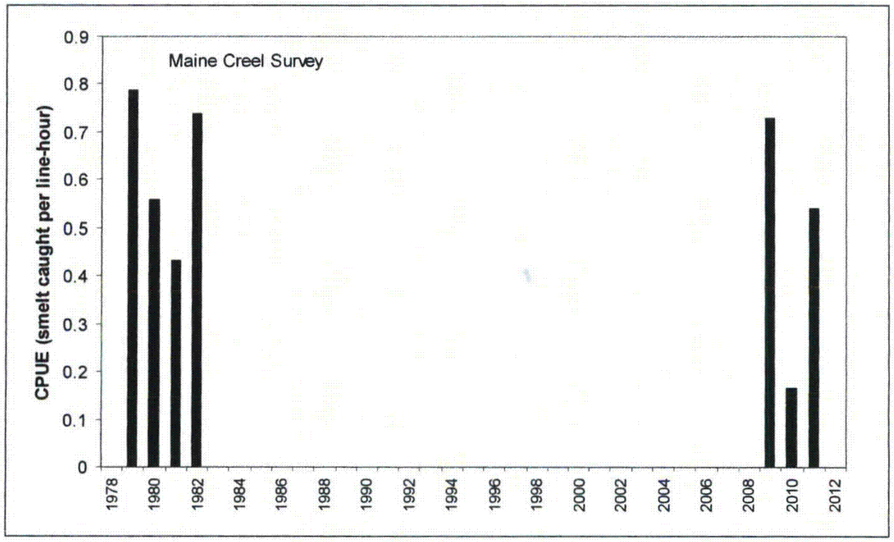


Figure 1.3.2. Catch per unit effort (CPUE) as smelt caught per line-hour of fishing observed during the rainbow smelt winter creel survey in Maine during 1979-1982 and 2009-2011.

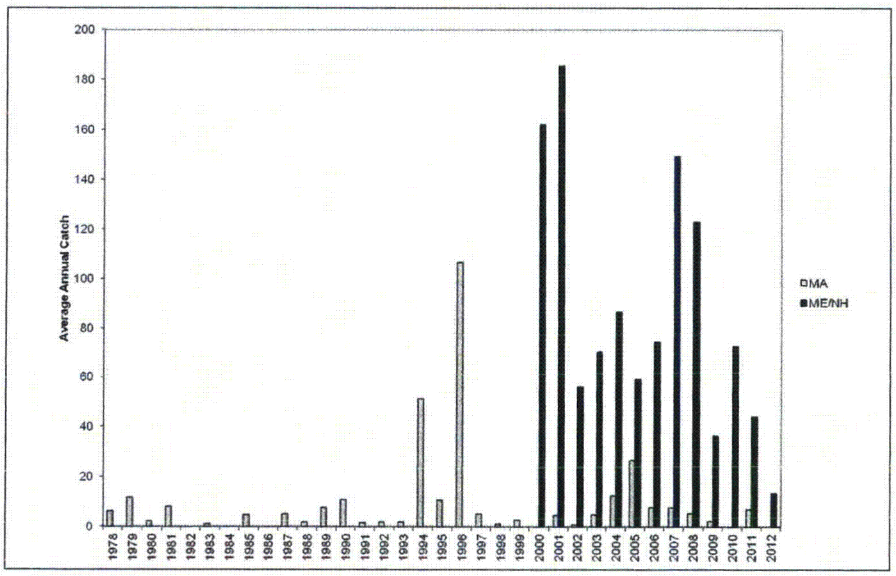


Figure 1.3.3. Inshore Trawl Survey average annual smelt catches (in numbers of fish) from MA DMF state survey (1978-2011) and ME DMR/NHF&G combined state survey (2000-2012).

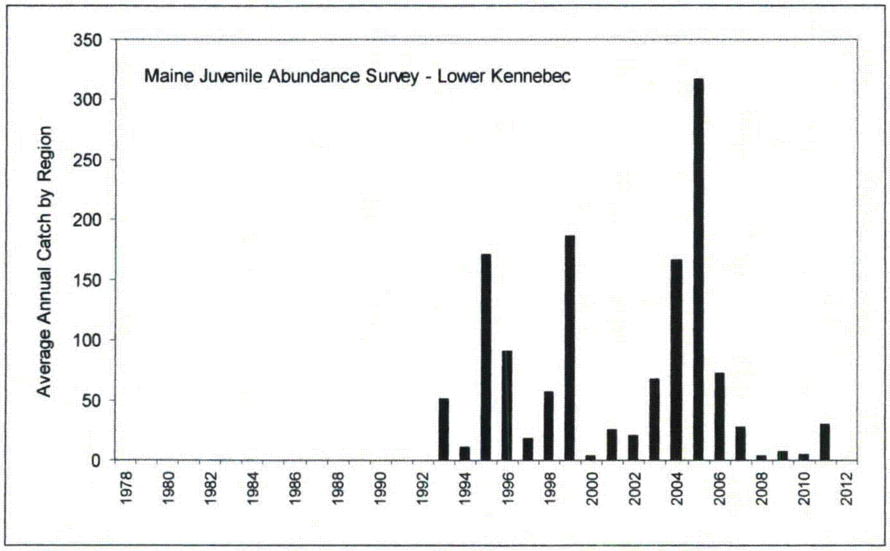


Figure 1.3.4. Average annual catch of rainbow smelt YOY in ME DMR Juvenile Abundance Survey in the lower Kennebec River. Other sites are excluded due to low catches.

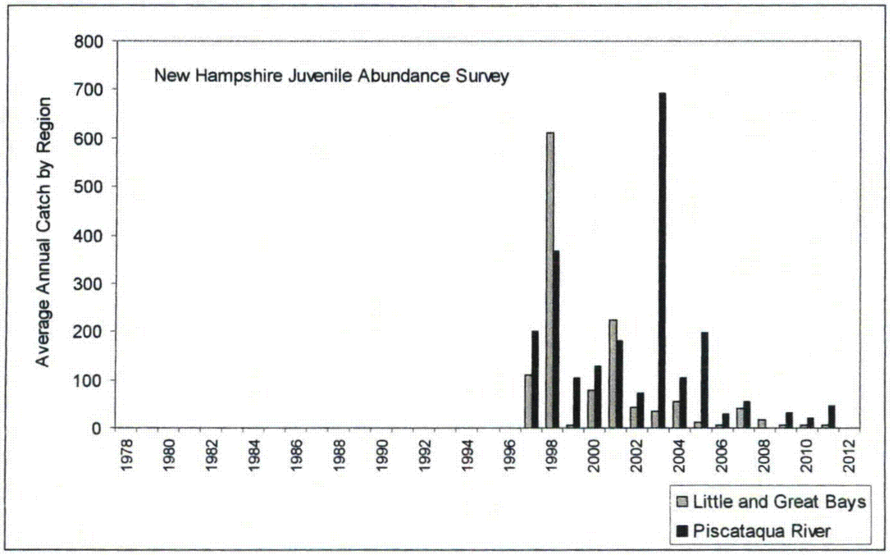


Figure 1.3.5. Average annual catch of rainbow smelt YOY in NHF&G Juvenile Abundance Survey. The 11 locations within the Piscataqua River and Little/Great Bay were grouped into two cohorts to show annual trends. The Hampton/Seabrook area was excluded due to low catches.

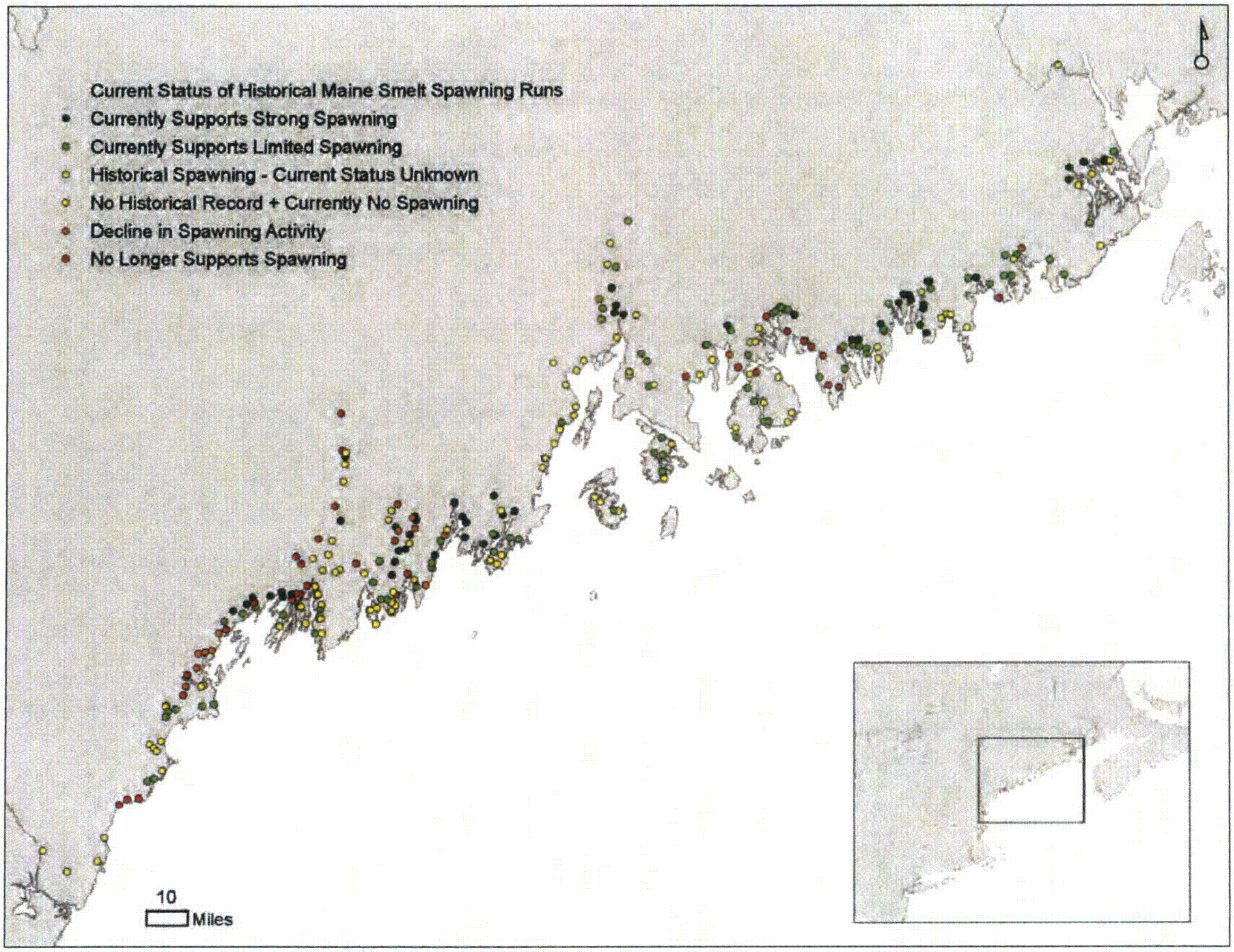


Figure 1.3.6. Current status of smelt spawning runs in Maine and historical sites where the current status remains unknown.

Figure 1.3.7. Fyke net monitoring stations in Massachusetts, New Hampshire, and Maine 2008-2011.

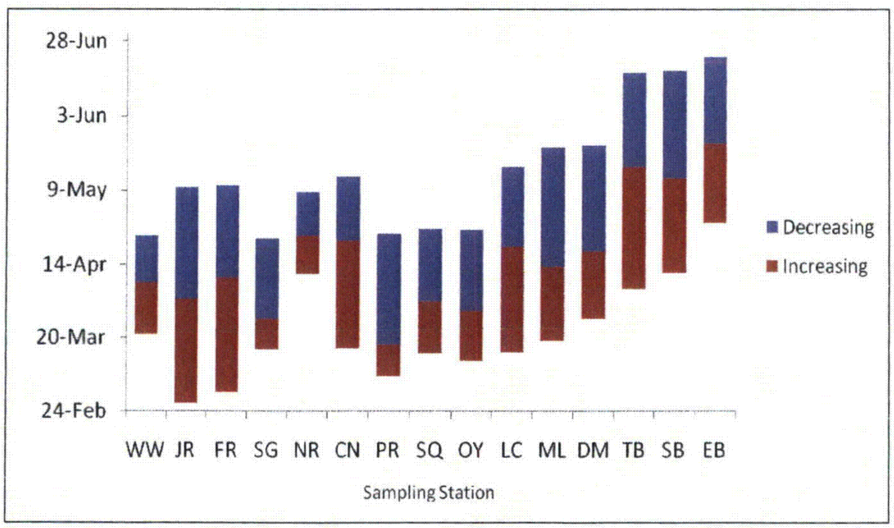


Figure 1.3.8. Smelt runs progress in a bell-curve shape over the season, where the beginning of the run sees few smelt, and the number steadily increases to a peak in the run (red portion of the bars in the figure), after which point the run steadily declines (blue portion of the bars). These patterns are shown here, along with the average beginning and end date of each run 2008-2011. Stations are arranged from south to north starting at the x-axis origin.

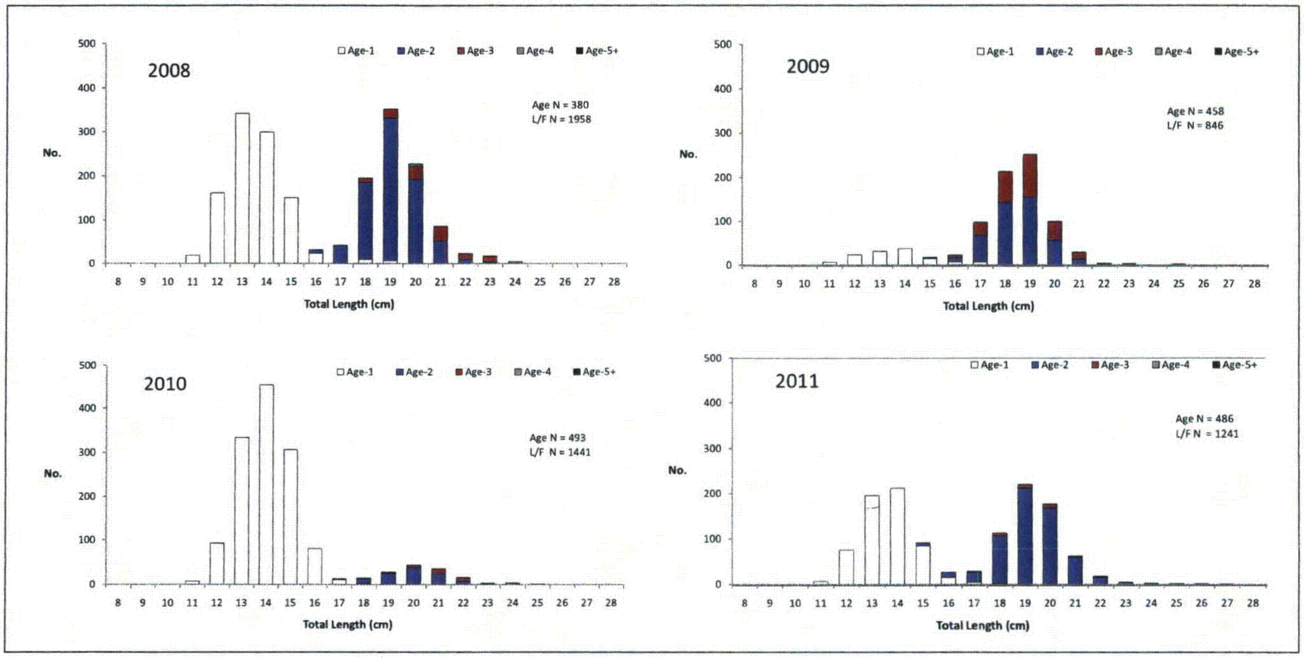


Figure 1.3.9. Age composition of Fore River, MA, fyke net catch in 2008-2011. Both genders were combined with number of age samples reported as "Age N" and length frequency sample size reported as "L/F N".

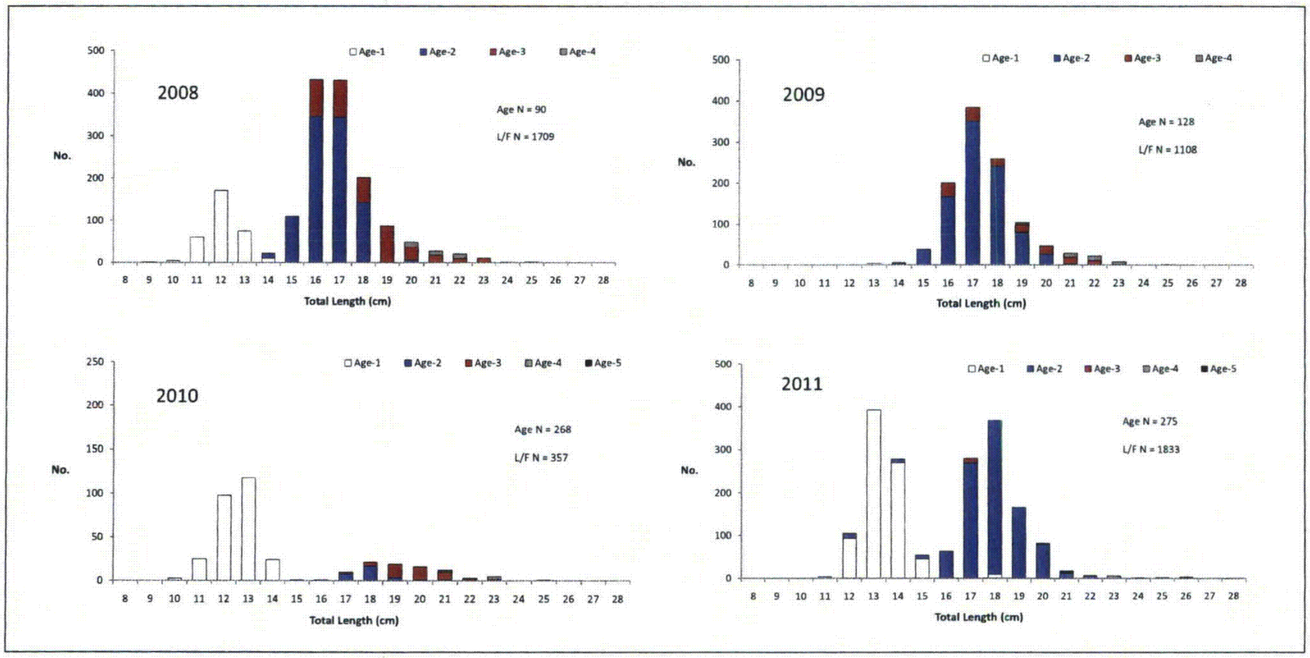


Figure 1.3.10. Age composition of Mast Landing, ME, fyke net catch in 2008-2011. Both genders were combined with number of age samples reported as "Age N" and length frequency sample size reported as "L/F N".

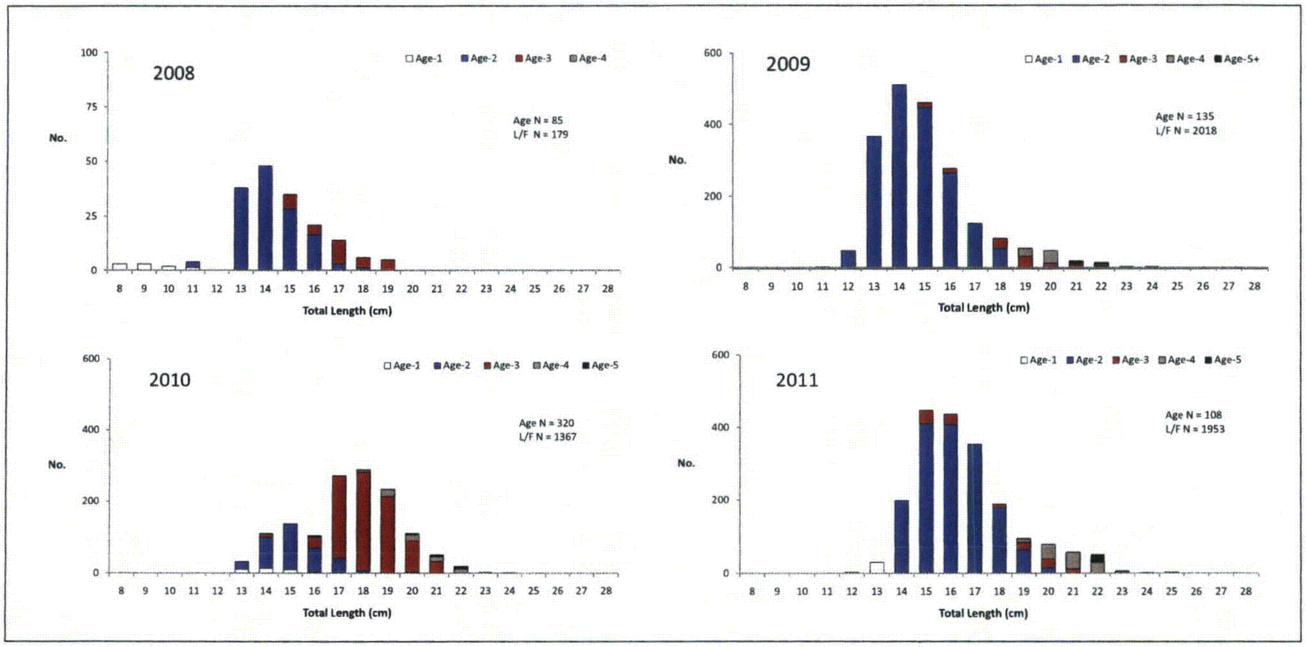


Figure 1.3.11. Age composition of Deer Meadow Brook, ME, fyke net catch in 2008-2011. Both genders were combined with number of age samples reported as "Age N" and length frequency sample size reported as "L/F N".

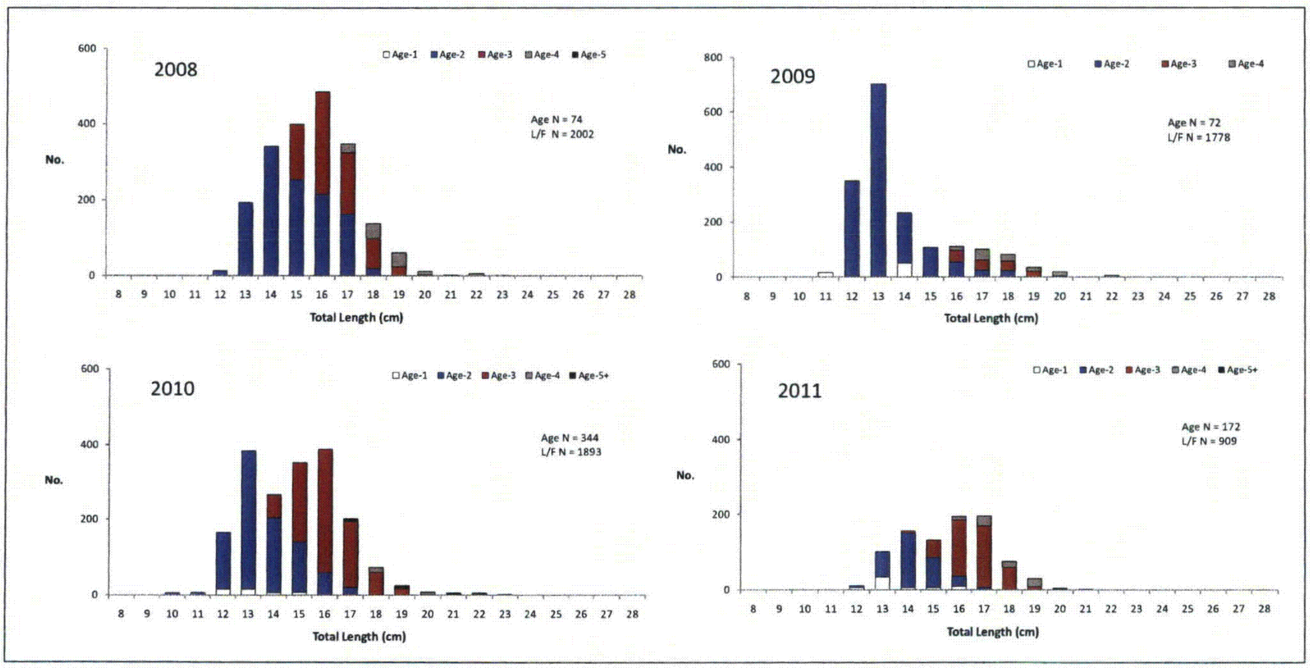


Figure 1.3.12. Age composition of Tannery Brook, ME, fyke net catch in 2008-2011. Both genders were combined with number of age samples reported as "Age N" and length frequency sample size reported as "L/F N".

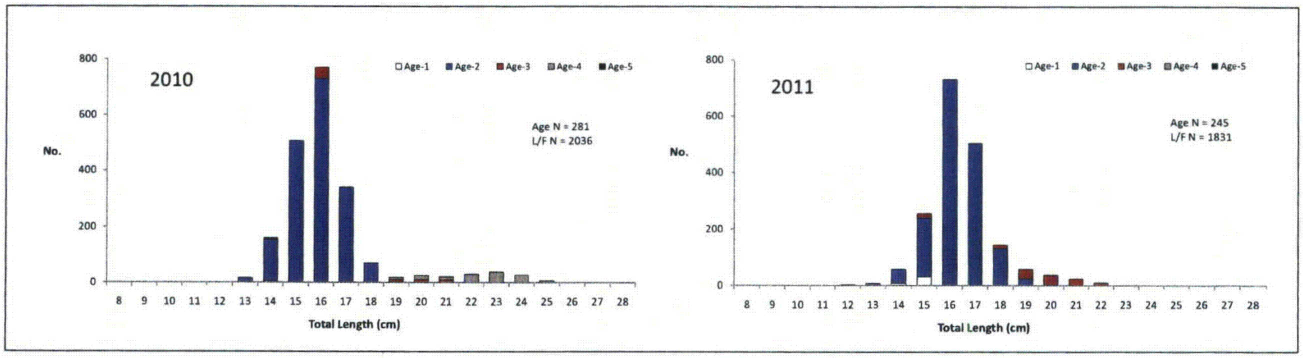


Figure 1.3.13. Age composition of Schoppee Brook, ME, fyke net catch in 2010-2011. Both genders were combined with number of age samples reported as "Age N" and length frequency sample size reported as "L/F N".

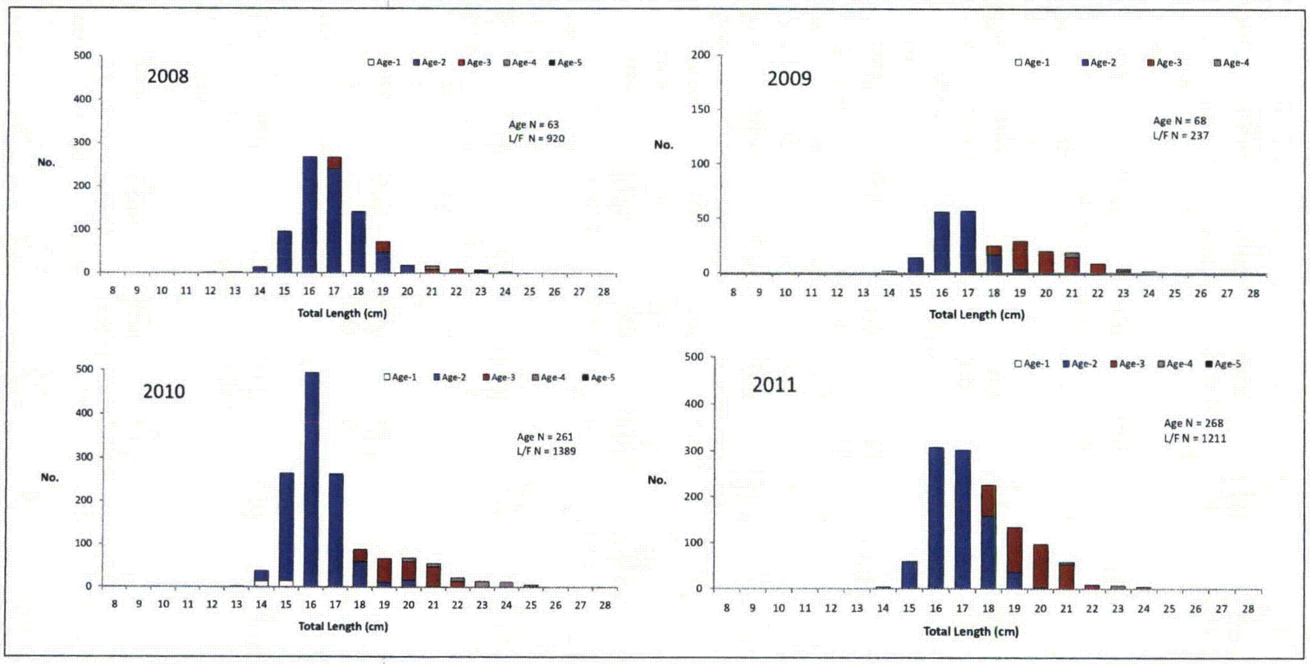
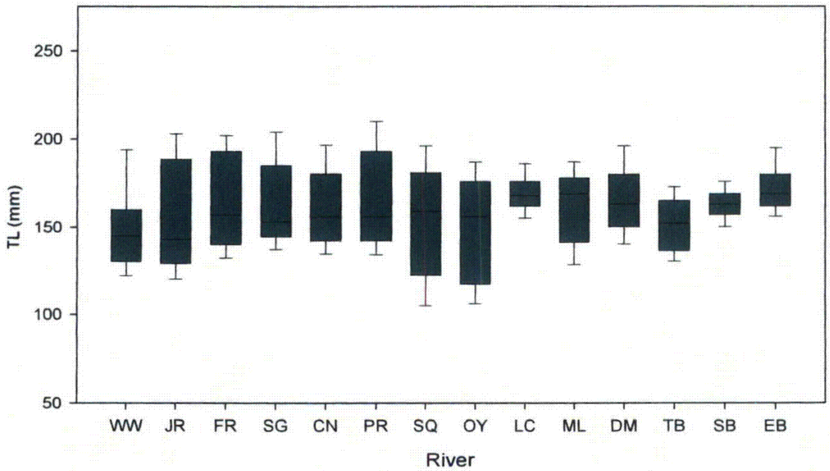


Figure 1.3.14. Age composition of East Bay Brook, ME, fyke net catch in 2008-2011. Both genders were combined with number of age samples reported as "Age N" and length frequency sample size reported as "L/F N".

MALE



FEMALE

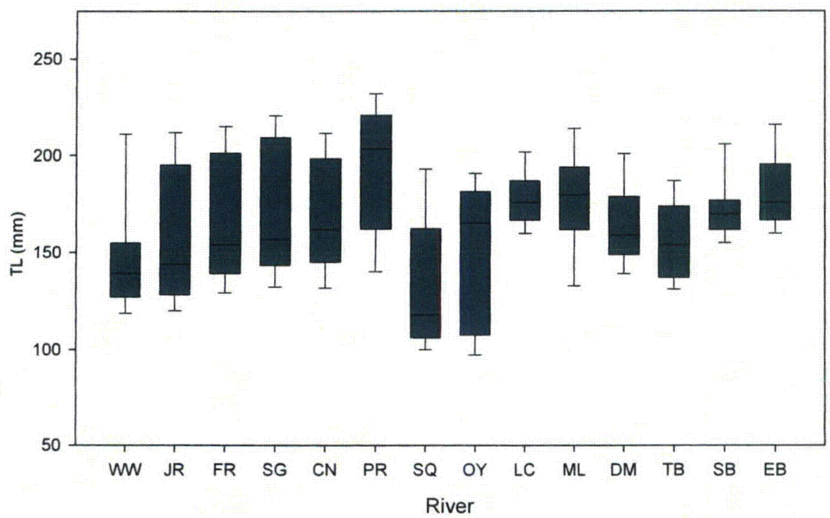


Figure 1.3.15. Median total length of smelt caught at 14 fyke net stations in the study area, 2008-2011. The top of the box plots is the 75th percentile and the bottom is the 25th percentile. The line in the box is the median and the error bars mark the 10th and 90th percentiles. The stations are arranged on the x-axis from the southernmost MA station to the northernmost ME station. Station medians for females and males were found to be significantly different with Kruskal-Wallis test, KW = 1324.94, df = 13, p <0.001; and KW = 2000.77, df = 13, p <0.001, respectively.

2 – THREATS TO RAINBOW SMELT POPULATIONS IN THE GULF OF MAINE

Rainbow smelt encounter a variety of potential threats during their freshwater and marine life stages. Dams, overfishing, and pollution have typically been considered the most important factors affecting diadromous fish, including rainbow smelt (Saunders et al. 2006, Limburg and Waldman 2009). While these factors may have played major roles in the declines of rainbow smelt, other factors may also be responsible for recent declines. Changes in trophic interactions, community shifts, watershed land use, and climate-driven environmental conditions may all need to be considered when evaluating factors that affect rainbow smelt populations.

Dams, overfishing, and pollution have typically been considered the most important factors affecting diadromous fish, including rainbow smelt.

2.1 – THREATS TO SPAWNING HABITAT CONDITIONS AND SPAWNING SUCCESS

Spawning Site Characteristics

Across their distribution range, smelt spawning runs are variable in regard to habitat use, spawning substrate, spawning period, and water temperature range (Bigelow and Schroeder 1953, Hurlbert 1974, Kendall 1926, Pettigrew 1997, Rupp 1959). Investigations of Massachusetts smelt runs have found that spawning begins between late February and mid-March when water temperatures reach 4-6 °C and concludes in May (Chase 1990, 2006; Chase and Childs 2001; Crestin 1973; Lawton et al. 1990). In New Hampshire, spring runs begin in early to mid-March when the water temperatures reach 3-6 °C and conclude in May (NHF&G, current study). In Maine, the timing of the run varies geographically, beginning in late March in waters west of the Kennebec River, in mid-April in waters between the Kennebec River and the Penobscot River, in late April to early May in the Penobscot River and advancing to mid-May in most waters in downeast Maine. Water temperature at the beginning of runs varies from 1.5-9 °C, and most runs in Maine last four to five weeks (ME DMR, current study). There is also some evidence that rainbow smelt may spawn in the main stem of large rivers in Maine earlier than runs begin in smaller streams close to these rivers. In rivers such as the Kennebec, Penobscot, Union, and Pleasant, spawning may occur under the ice or directly following ice-out in mid-March to early April (ME DMR, current study).

The best documentation of the physical characteristics of smelt spawning habitats in the Gulf of Maine is provided by a detailed assessment of Massachusetts rivers that was conducted between 1988 and 1995 (Chase 2006). This study identified both stream attributes and water chemistry conditions that were suitable for smelt spawning. Chase (2006) documented and mapped smelt spawning habitat at 45 locations in 30 rivers on the Gulf of Maine coast of Massachusetts. Rainbow smelt egg deposition was documented to take place over stream sections ranging from 16 m to 1,111 m in length, with an average of 261 m. In most cases, the downstream limit of egg deposition occurred near the interface of salt and fresh water, while the upstream limits were typically delimited by physical impediments that prevented further passage. When passage allowed, smelt would continue spawning in freshwater riffles beyond tidal influence. The average patch size of substrate where smelt eggs were observed was 2,336 m^2, with a range of 16 m^2 to 13,989 m^2.

Smelt were found to spawn in shallow riffles where water velocity increased in stream channels. Within the streams where smelt eggs were found, channel width averaged 6.8 m. Depth transects conducted in 16 of these streams found that the average depth of spawning riffles was 0.28 m, and the range of average depths was 0.1 - 0.5 m under baseflow conditions. However, smelt eggs were found in depths up to 1.5 m in three surveyed rivers. The average water velocity at the riffle transects was 0.39 m/s, with a range of 0.1 to 0.9 m/s. These measurements and observations of associated egg deposition led Chase (2006) to hypothesize that 0.5 – 0.8 m/s was an optimal range for adult attraction and egg survival.

Observations in smelt spawning rivers in Massachusetts led Chase (2006) to conclude that the ideal channel configuration for spawning habitat may begin with a deep channel estuary where the salt wedge rises to meet a moderate gradient riffle at the tidal interface and follows into the freshwater zone with ample vegetative buffer and canopy and an extended pool-riffle complex that spreads out egg deposition and provides resting pools. However, this scenario was not common in Massachusetts spawning rivers, and likely is not in many other rivers and streams in the Gulf of Maine. Many of the spawning streams and rivers were altered by: (1) a range of passage obstructions (undersized culverts, dams, etc.) that limited or completely blocked the smelts' ability to reach their spawning grounds, (2) channelization and flow alterations that changed water velocity and substrate conditions, and (3) removal of riparian vegetation, leading to increased amounts of polluted runoff flowing directly into the stream, as well as reduced canopy cover leading to increased water temperature. These three categories represent major threats to spawning habitat and to smelt spawning success, and they are described further in the following sections. In many cases, these threats are present simultaneously in more developed watersheds, compounding the threats to successful smelt spawning.

Obstructions

Dams

Industrial development depended on rivers for power, and over 500 dams remain on rivers in Maine, New Hampshire, and Massachusetts that may have a large impact on diadromous species (Martin and Aspe 2011). Dams block access to spawning habitats for many anadromous species, but their effect on rainbow smelt is particularly acute. The small body size of rainbow smelt makes them unable to jump to heights necessary to migrate through fish ladders, which pass other diadromous fish over dams. In Maine, at least 13 out of 275 (5%) historical and current spawning sites are either reduced in area or the spawning habitat is blocked by coastal dams (Abbott, USFWS, pers. comm., 2012). In New Hampshire, although smelt spawning occurs in most of the coastal rivers, head-of-tide dams exist on all of these rivers (with the exception of the Winnicut River), reducing habitat and forcing smelt to spawn within areas subject to tidal influence. Although the exact number has not been documented, the same situation exists in Massachusetts, where head-of-tide dams limit spawning habitat.

Road crossings

The majority of smelt spawning streams in the Gulf of Maine are small coastal streams that are not dammed. More frequently, barriers are road-stream crossings. Undersized, improperly installed, or poorly maintained culverts at road-stream crossings can severely impair smelt migration. This can occur when culverts have become perched, where the downstream side stream height is well below the culvert height, or when culverts are undersized to such an extent that they create velocity barriers or reduce freshwater flow to levels that impede environmental cues for smelt. Reducing stream habitat fragmentation is critical for increasing access to smelt spawning habitat. In Maine, there is an ongoing effort to ground-survey all stream barriers. At the time of this report, 35% of the state has been surveyed. Of the 88 smelt historical or current spawning sites falling within this surveyed portion, 34 (39%) sites have potential barriers to passage. Extending the scope to the entire state, 127 historical or current spawning sites out of a total of 275 are crossed by roads at least once, and multiple times in many cases. While some of these crossings may have adequate passage, it is estimated that two-thirds of these crossings are undersized and may present passage problems for smelt (A. Abbott, USFWS, pers. comm.., 2012). The frequency of the problem is magnified in Massachusetts where only 1 of 45 mapped smelt spawning habitats were unaltered by road crossings or impediments (Chase 2006).

Channelization and Flow Disruptions

Discharge and Velocity

In Massachusetts, New Hampshire, and Maine, most smelt runs occur in small coastal rivers or streams with low seasonal baseflows where spring stream discharge is sufficiently high to attract adults and support egg incubation. In the Northeast United States, early spring flows are typically enhanced by snow melt and precipitation, but discharge may decline progressively later in the season. In a survey of 45 spawning rivers in Massachusetts, aside from the Merrimack River, only nine had average spring discharges over 1 m^3/s (35 cubic feet per second (cfs)), and only four exceeded a spring average of 10 m^3/s (353 cfs) (Chase 2006).

During the current study, when USGS gauge stations were present, we recorded river discharge weekly at our smelt spawning sampling sites. None of the survey stations in Maine were located on rivers with gauge stations; however, measurements were available for two New Hampshire sites and four Massachusetts sites (Table 2.1.1). Over a two year period (2008-2009), we found an average discharge of 1.83 m^3/s (65 cfs) across all sites, with most values (75%) under 1.99 m^3/s (70 cfs) (Table 2.1.2). Discharge varied significantly between the sites, and was directly correlated to watershed size (Spearman's rank correlation = 0.78).

Although high discharge is not a threat to smelt spawning, if it results in sharp increases in velocity it impairs smelts' ability to reach their spawning grounds. In watersheds with large amounts of impervious surface and not managed for stormwater, infiltration of runoff is reduced and the smoother impervious surfaces allow water to run off the surface and into streams faster. The combined result is a rapid increase in both volume and velocity (Cooper 1996, Klein 1979). Substantial variability in velocity may be found within a coastal stream depending on specific location (e.g. pool versus riffle), and timing (precipitation events and tidal stage will affect daily velocities). However, as part of the current study we found that velocities at all spawning index sites fell within a fairly narrow range (0.32 m/s – 0.58 m/s) when measurements were taken within riffles when no tidal influence was present (Table 2.1.2). Velocity exceeded 0.79 m/s only 10% of the time, and generally the catch per unit effort of spawning adult smelt was lower during those high velocity events.

Conversely, low discharge may also threaten successful spawning. Sufficient freshwater flows are necessary for other anadromous species to cue their migrations and enable them to successfully locate their spawning site (Yako et al. 2002). Low discharge associated with urbanization may also lead to insufficient water mixing, resulting in higher water temperatures, lower dissolved oxygen, increased sedimentation, and increased concentrations of pollutants and contaminants (Klein 1979). Reductions in baseflow can be caused by water withdrawals and impounding as well as increases in impervious surface (Klein 1979, Simmons and Reynolds 1982). In many cases, withdrawals during the spring months may be expected to remove a small proportion of available spring flows. However, concerns are growing in urban areas where human population growth has increased water demands. Furthermore, a gradual but measured loss in snow pack over the last century has led to a reduction of spring baseflow in coastal streams, a situation that could compound concerns over water withdrawals.

Substrate and Channel Stability

Natural stream and river channels that are vegetated and dynamic can absorb the impacts of flooding by accommodating changes in discharge and water levels. However, in urbanized areas with extensive impervious surface or where streams have been channelized by fixed walls, the runoff from large rain events flows directly into streams, leading to increases in the frequency and severity of flooding. In turn, these events can cause channel erosion and alteration of the stream bed (Klein 1979). The timing of flood events can cause positive responses to smelt spawning substrata by scouring sediment and periphyton before spawning occurs or negative responses by scouring away large egg sets (Chase 2006). Booth and Reinelt (1993) report that pool and riffle habitat may be altered and channel stability may be degraded when impervious surface exceeds 10-15% of the watershed area These impacts can be mitigated by restoring riparian buffers along stream and river banks.

Watershed characteristics

Watershed activities can have a substantial influence on many of the conditions identified above as potentially affecting rainbow smelt spawning habitat. Land cover in a watershed affects habitat conditions and biological communities in receiving waters in a variety of ways (Burcher et al. 2007, Allan 2004). Urbanization and agricultural activities can contribute to erratic flow levels, warmer water temperatures, channel alterations, sedimentation, chemical and bacterial pollution, and nutrient loading (Wang et al. 2001a, Allan 2004). In addition, barriers to spawning passage are more likely to exist due to road networks in more urbanized watersheds than in less developed areas. These watershed-associated factors can all influence the suitability of streams for rainbow smelt spawning.

Associations between watershed characteristics and spawning site use have been observed for other anadromous species. Limburg and Schmidt (1990) noted that spawning activity of anadromous fishes (mostly alewife) in tributaries to the Hudson estuary was inversely related to the proportion of urban land use in the surrounding watershed. In the Pacific Northwest, Pess et al. (2002) found that median densities of spawning coho salmon were 1.5-3.5 times higher in forest-dominated areas than in urban or agricultural areas. These examples indicate that there may be linkages between spawning success and watershed characteristics. While the causal factors have not been identified, urbanization may influence in-stream habitat by increasing water velocities associated with flood events, changing substrate, removing canopy cover and thus increasing water temperature, and other habitat changes.

Our analysis found that weak spawning runs existed in rivers surrounded by urbanized watersheds, while rivers draining forested watersheds supported stronger smelt spawning populations.

In this study, we evaluated correlations between rainbow smelt catch per unit effort at the spawning index sites and land use in the adjacent watersheds at two spatial scales: (1) the full drainage basin and (2) the 210 meter buffer immediately adjacent to the stream. Watersheds within which rainbow smelt spawning runs were sampled represented a wide variety of conditions (Table 2.1.1). A principal components and cluster analysis suggests that the smelt spawning watersheds can be classified into three distinct types: (1) urbanized, (2) forested, and (3) wetlands/agricultural (Figure 2.1.1). Correlations between the aggregate mean CPUE of spawning rainbow smelt over 2008-2011 (standardized based on net coverage of the stream width) indicate that weak spawning runs exist in rivers surrounded by urbanized watersheds, while rivers draining forested watersheds support strong smelt spawning populations. Interestingly, the negative association between development and CPUE was substantially stronger at the scale of the full drainage basin than when only the riparian buffer zone was considered (Table 2.1.3). This appears to be because many rivers within urbanized watersheds have extensive riparian wetlands in their buffer zones. The presence of these wetlands at the 210-m scale weakens the influence of urbanization on smelt spawning. Other land cover types and the number of downstream crossings, at either the scale of the watershed or riparian buffer zone, were not significantly correlated to the strength of rainbow smelt spawning populations.

River	Fyke Net Location: Latitude	Longitude	Town	State	Hydrologic Information: Channel Width (m)	Average Discharge (m^3/s)	Average Velocity (m/s)	Watershed Information: Watershed (HUC 10)	Drainage Area (km^2)	Land Cover (1°/2°)
Westport River	41.6209	-71.0598	Westport	MA	11.3	-	-	Buzzards Bay	26.5	Forest / Agriculture
Weweantic River	41.7662	-70.7461	Wareham	MA	35.7	-	-	Buzzards Bay	148.2	Forest / Agriculture
Jones River	41.9960	-70.7233	Kingston	MA	27.3	1.92	0.492	South Coastal Basin	69.3	Forest / Wetland
Fore River	42.2225	-70.9732	Braintree	MA	13.7	1.92	0.623	Boston Harbor	74.7	Development / Forest
Saugus River	42.4680	-71.0077	Saugus	MA	55.4	-	-	Boston Harbor	55.8	Development / Forest
North River	42.5221	-70.9116	Salem	MA	9.1	0.49	0.454	North Coastal Basin	12.6	Development / Forest
Crane River	42.5566	-70.9364	Danvers	MA	8.2	0.17	0.497	North Coastal Basin	14.0	Development / Forest
Parker River	42.7505	-70.9282	Newbury	MA	54.8	-	0.516	Plum Island Sound	66.0	Forest / Wetland
Squamscott River	42.9824	-70.9461	Exeter	NH	101.0	5.65	0.384	Exeter River	276.9	Forest / Wetland
Winnicut River	43.0389	-70.8455	Greenland	NH	36.6	1.05	0.3	Great Bay	45.5	Forest / Wetland
Oyster River	43.1310	-70.1310	Durham	NH	32.9	-	-	Great Bay	59.9	Forest / Development
Long Creek	43.6332	-70.3133	S. Portland	ME	24.3	-	0.64	Fore River	17.5	Development / Forest
Mast Landing	43.8587	-70.0842	Freeport	ME	15.2	-	0.468	Casco Bay Basin	20.7	Forest / Wetland
Deer Meadow Brook	44.0369	-69.5874	Newcastle	ME	24.9	-	0.489	Sheepscot River	27.6	Forest / Wetland
Tannery Brook	44.5706	-68.7888	Bucksport	ME	67.7	-	0.402	Penobscot River and Bay	13.2	Forest / Agriculture
Schoppee Brook	44.6627	-67.5533	Jonesboro	ME	16.0	-	0.583	Roques Bluffs Frontal Drainages	9.3	Forest / Wetland
East Bay Brook	44.9547	-67.1041	Perry	ME	21.9	-	0.217	Cobscook Bay	3.0	Forest / Wetland

Table 2.1.1. Rainbow smelt spawning habitat station locations for water quality monitoring. Drainage areas are GIS calculations set from the location of fyke net placement.

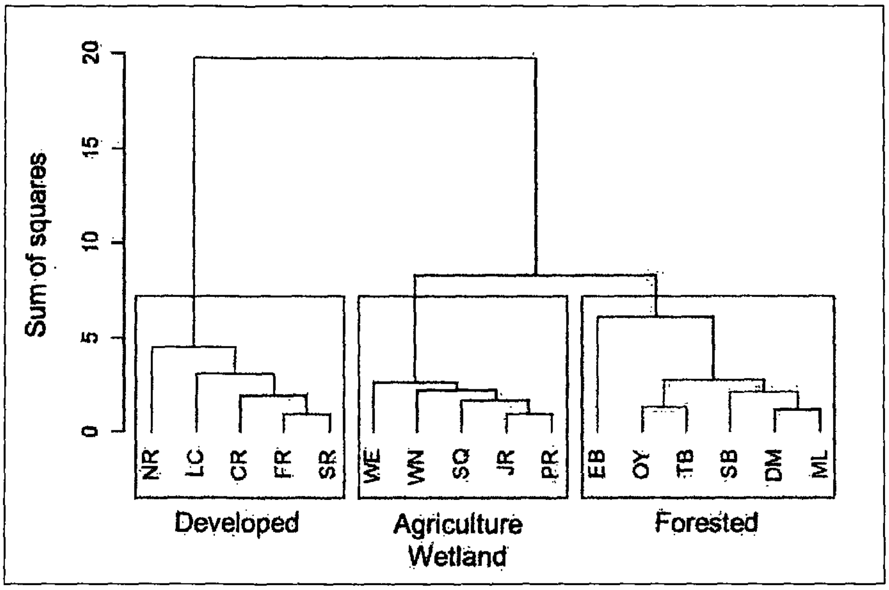
	Discharge (m^3/s)	Velocity (m/s)
Minimum Value	0.04	0.050
Lower Quantile (25%)	0.35	0.323
Mean	1.83	0.478
Upper Quantile (75%)	1.99	0.579
Maximum Value	12.81	1.483

Table 2.1.2. Discharge and velocity measurements from spawning survey index sites. Discharge measurements taken from USGS gauge stations upstream of spawning sites and velocity measurements taken by state biologists at the spawning sites (discharge n = 6, velocity n = 13) in active riffle areas.

Land Cover	Correlation with smelt spawning CPUE: Watershed Level	Stream Buffer Zone (210m)
% developed	-0.62	-0.48
% developed open space (parks, golf courses)	-0.47	-0.32
% forest	0.60	0.60
% wetland	-0.29	-0.28
% agriculture	-0.06	0
number of downstream crossings	-0.46	-0.46

Table 2.1.3. Spearman's rank correlation between rainbow smelt spawning CPUE and land cover at two spatial scales. Correlation coefficients in bold type indicate significance at the p = 0.5 level.

Figure 2.1.1. Cluster analysis (Ward's method) of study watersheds based on dominant land uses (as indicated by the proportion of developed, developed open, forest, agriculture, and wetland areas) and watershed characteristics (i.e., population density, stream crossings, and proportion of impervious surface). Station codes: NR = North River, LC = Long Creek, CR = Crane River, FR = Fore River, SR = Saugus River, WE = Weweantic River, WN = Winnicut River, SQ = Squamscott River, JR = Jones River, PR = Parker River, EB = East Bay Brook, OY = Oyster River, TB = Tannery Brook, SB = Schoppee Brook, DM = Deer Meadow Brook, ML = Mast Landing.



2.2 - THREATS TO EMBRYONIC DEVELOPMENT AND SURVIVAL

Smelt deposit demersal (sinking), adhesive eggs at fast-flowing riffles, where they attach to the substrate or aquatic vegetation. The duration of egg incubation is related to water temperature (McKenzie 1964), and in the Gulf of Maine, eggs hatch 7-21 days after fertilization (Chase et al. 2008, McKenzie 1964). The success of this reproductive strategy depends on access from marine waters, low predation, and suitable water and habitat quality for successful recruitment. In many watersheds, the tidal interface is the physical location favored for the development of commerce and community centers. This change in landscape can lead to hydrologic alterations, particularly in urban areas, leaving streams vulnerable to point and non-point source pollutants; nutrient enrichment; and reduced streamflow, shading and riparian buffer.

Changes in spawning habitat may be a major factor in the decline of smelt populations. However, up to this point, the degree to which water quality impairment may be impacting smelt populations in the Gulf of Maine has not been described. With this concern in mind, we developed monitoring programs to assess baseline water and habitat conditions at smelt spawning habitat index sites spanning the entire Gulf of Maine and explored possible impacts on spawning success resulting from changing habitat conditions. This information is applied to support recommendations for conserving and restoring smelt populations and habitats.

Four indicators were measured to assess water quality at smelt spawning index sites: basic water chemistry, nutrient concentrations, periphyton growth and heavy metal concentrations. The sampling was guided by a Quality Assurance Program Plan (QAPP) for monitoring water and habitat quality at smelt spawning habitats in coastal rivers on the Gulf of Maine coast (Chase 2010). The QAPP integrates smelt life history with existing state and federal water quality criteria, with the objective of developing a standardized process to classify the suitability of smelt spawning habitat. Beyond characterizing smelt habitat, it is our hope these data will contribute to water quality and habitat restoration efforts at coastal rivers in New England.

Summary statistics were generated for water quality data by site and then compared to thresholds assembled from existing water quality criteria (Table 2.2.1). The U.S. Environmental Protection Agency (EPA) developed criteria for turbidity, total nitrogen (TN) and total phosphorus (TP) based on the 25th percentile of the distribution of observed values in an ecoregion (US EPA 2000). The 25th percentile is the value of a given parameter where 25% of all observations are below and 75% are above. The 25th percentile was adopted by EPA as the threshold between degraded conditions and minimally impacted locations. Additionally, the Massachusetts Department of Environmental Protection (MassDEP) established Surface Water Quality Standards (SWQS) for temperature, pH and dissolved oxygen (DO) as part of their Clean Water Act waterbody assessment process (MassDEP 2007). These thresholds were selected to protect designated categories of aquatic life, including fish habitat. Stations were classified as Suitable (minimally impacted) or Impaired for each parameter. Water quality data were also evaluated to explore the potential of establishing new thresholds specifically derived from smelt spawning habitat measurements.

Water Chemistry

Basic water chemistry parameters were measured during smelt spawning runs at 19 index station stations: the 16 fyke survey sites and 3 additional spawning sites of interest in Massachusetts (Figure 1.3.7 and Table 2.1.1) following the QAPP protocol. Yellow Springs Incorporated (YSI) water chemistry sondes were used to measure water temperature (°C), DO (mg/L and % saturation), specific conductivity (mS/cm), pH and turbidity (NTU, Nephelometric Turbidity Units) in freshwater at the spawning grounds. At most stations, discrete water chemistry measurements were recorded three times per week. The seasonality of water chemistry monitoring was not synchronized for all stations due to the later onset of the spawning season at the northern end of the study area. For this reason, detailed comparisons of some parameters, such as temperature, should be made cautiously.

Water Temperature

Water temperature has an important influence on smelt metabolism, the onset of smelt spawning and the duration of egg incubation. Median water temperatures during the spawning period were fairly consistent across the study area, with a range of 8.8 – 12.9 °C (Table 2.2.2, Figure A.2.1). No measurements exceeded the water temperature criterion of 28.3 °C adopted from MassDEP SWQS to protect aquatic life. The relatively high temperature threshold has little relevance for smelt that spawn in the cool water of the spring freshet; however, the temperature data have value for documenting baseline conditions and may have future application for monitoring reference values, such as station medians or 75th percentiles.

Specific Conductivity

Specific conductivity is proportional to the concentration of major ions in solution corrected to the international standard of 25 °C. High conductance in freshwater can indicate high watershed contributions of natural alkaline compounds or ionic contributions from pollution sources. For this reason, conductivity has been discussed as a potential proxy for pollution sources, urbanization, and eutrophication. Median specific conductivity during the spawning period ranged from 0.031 – 0.997 uS/cm (Table 2.2.2, Figure A.2.2). The four highest medians occurred at urban sites near the Boston metropolitan area.

Dissolved Oxygen

Adequate dissolved oxygen (DO) concentrations are necessary for embryonic survival and normal development. The QAPP provides a DO criterion of ≥ 6.0 mg/L to protect aquatic life. Median DO concentrations during the spawning period ranged from 9.5 – 12.5 mg/L (Table 2.2.2, Figure A.2.3), and median DO saturation levels ranged from 91.0 – 107.8% (Table 2.2.2, Figure A.2.4). All individual DO measurements were well above the DO threshold. Similar to water temperature, the DO threshold may have limited relevance because of the high concentrations of DO found in turbulent riffles during the spring freshet. The distribution of DO saturation data does show increasing supersaturation in urban Massachusetts and a declining DO saturation moving north in the study area. Supersaturation of oxygen can indicate eutrophic conditions, where due to the photosynthetic cycle of the algal communities, supersaturation is observed during the daylight hours, but anoxic conditions are present during darkness (Carlton and Wetzel 1987).

pH

Increased acidification of water bodies in New England is a widely recognized threat to fish populations, as low water pH can increase the impact of aluminum toxicity and disrupt fish respiration. Geffen (1990) conducted laboratory experiments to examine the influence of pH on smelt embryo survival; trials found that survival was most influenced by the duration of low pH exposure and embryo developmental stage. For example, high mortality occurred to early stage smelt eggs (4-6 days post-fertilization) at 5.5 pH when exposure ranged from 6-11 days. Fuda et al. (2007) conducted similar experiments and found survival was not affected until pH was ≤ 5.0. The QAPP adopted the water pH criterion of ≥ 6.5 to ≤ 8.3 from MassDEP (2007) to protect aquatic life. Most stations had pH measurements in a range that was not a concern for rainbow smelt. Median pH during the spawning period ranged from 5.92 – 7.67 (Table 2.2.2, Figure A.2.5). Of the 19 rivers sampled, seven were classified as Impaired (>10% of individual measurements below pH 6.5). Among the stations classified as Impaired, only four had routine measurements below 6.0 pH: the three southernmost Massachusetts stations and Schoppee Brook in Maine.

Turbidity

Turbidity in water is the result of suspended inorganic and organic matter; it can be caused by natural fluctuations in sediment transport or by changes in productivity. The QAPP adopted the turbidity criterion of ≤ 1.7 (NTU) from the EPA Northeast Coastal Zone ecoregion (US EPA 2000). Most rivers had median turbidity values >1.7 NTU, and all were classified as Impaired for having at least 10% of measurements > 1.7 NTU (Table 2.2.2, Figure A.2.6). Several stations in New Hampshire and southern Maine had median values well above the threshold. However, this elevated turbidity may result from the natural suspension of sediments, either due to soil type or the naturally high turbidity in the spring associated with snow melt and higher runoff. Adopting the study's 25th percentile of 1.9 NTU would still result in all stations being classified as Impaired. The turbidity data will be further evaluated to determine if a more appropriate turbidity threshold can be established by removing precipitation effects through an analysis of baseflow data.

Data Analysis

Median values of water temperature, DO, specific conductivity, pH and turbidity were compared among sampling stations (Kruskal-Wallis, $p < 0.001$), and a multiple comparison test was used to determine which stations were significantly different from others (Siegal and Castellan, 1988; R code, kruskalmc; $p = 0.05$; Figures A.2.1 – A.2.6). Significant differences were found for all parameters; trends between parameters were common among rivers and regions. Conductivity was especially variable among sites and may be related to watershed characteristics; in the most urban sites (Crane and North rivers, Massachusetts) conductivity was significantly higher than most other sites, whereas at the forested sites (Deer Meadow and East Bay Brooks, Maine), conductivity was significantly lower than most other sites. The relation of these variables to spawning smelt populations is discussed in the Watershed Characteristics Section.

Nutrient Concentrations

Nitrogen and phosphorus are vital nutrients for plants but can cause excessive growth and degrade the health of aquatic life at high concentrations. The influence of nutrient pollution on water and habitat quality in rivers and lakes is a growing concern in the United States (Mitchell et al. 2003). The health or trophic state of aquatic habitat is influenced most by light, carbon sources, nutrients, hydrology and food web structure (Dodds 2007). Among these influences in developed watersheds, nutrient enrichment is most dependent on human activity and may be most amenable to remediation efforts. Total nitrogen and total phosphorus were recorded weekly at index stations in the freshwater portion of the streams on the spawning grounds from 2008-2011. Field sampling procedures are documented in the QAPP (Chase 2010), and the laboratory analysis followed EPA-approved Quality Assurance /Quality Control (QA/QC) protocols.

Nutrient concentrations for smelt spawning habitat were classified using EPA recommended thresholds for freshwater streams and rivers that were developed from the distribution of available water quality data (US EPA 2000). These EPA thresholds for Suitable habitat for the study area are 0.57 mg/L for total nitrogen (TN) and 23.75 ug/L for total phosphorus (TP). The EPA also recommends that states develop their own nutrient water quality criteria for protecting specific designated uses of aquatic habitat under Clean Water Act assessment and remediation processes (US EPA 2000). In this light, the TN and TP data recorded for this study were compared to the EPA nutrient criteria and the data distributions were evaluated for potential smelt habitat-specific thresholds (Table 2.2.3)

Total Nitrogen

Measurements of TN at 20 stations during 2008-2011 showed a trend of higher concentrations in urban areas (Table 2.2.3, Figure A.2.7). The range of median concentrations for all stations was 0.216 - 1.395 mg/L. Only five stations were classified as Suitable for TN (≤ 10% of measurements below 0.57 mg/L; EPA 2000), with four of these stations at the northeastern end of the study area. All others were classified as Impaired. The TN 25th percentile generated from the study sites was 0.340 mg/L, which was 40% lower than the EPA ecoregion threshold.

Total Phosphorus

Measurements of TP displayed a more stable trend across the study area (Table 2.2.3, Figure A.2.8). The range of median concentrations for all stations was 12.18 ug/L to 36.72 ug/L. Only 4 stations were classified as Suitable for TP (≤ 10% of measurements below 23.75 ug/L; EPA 2000). All others were classified as Impaired. The TP 25th percentile generated from the study stations was 17.56 ug/L; 26% lower than the EPA ecoregion threshold.

TN/TP Ratio

While total concentrations of nitrogen and phosphorus are important for plant production, the balance or ratio of TN to TP can also influence growth and species composition. Most TN:TP ratios were in a range expected for freshwater systems in New England (15:1-30:1). Higher ratios indicating high nitrogen and possible phosphorus limitation were found at the most urbanized stations, and low ratios most influenced by high phosphorus were only found at a few stations where watershed development was low.

Data Analysis

Comparisons of median TN, TP and TN:TP ratios among sampling stations found significant differences for all three parameters (Kruskal-Wallis, $p < 0.001$). A multiple comparison test was used to determine which stations were significantly different from others (Siegal and Castellan, 1988; R code, kruskalmc; $p = 0.05$). The box plots in Figures A.2.7 – A.2.8 represent a graphic display of the multiple comparisons. The high TN concentrations at Crane River and North River (> 1.0 mg/L) in Massachusetts were significantly different from all stations except the Saugus River. The four stations with median TN < 0.3 mg/L were significantly lower than most the remaining stations, all but one found in urban areas of Massachusetts and New Hampshire.

Periphyton

Periphyton is the complex of benthic algae, detritus and other microorganisms that attaches to the river bed and is an important indicator of primary production and environmental disturbances in aquatic habitats. Periphyton growth responds to nutrient enrichment and can reach excessive or nuisance growth in eutrophied systems (Biggs 1996). Eutrophication has been identified as a major concern for smelt spawning habitat due to the potential impact of excessive periphyton growth on smelt embryo survival at spawning riffles in Massachusetts (Chase 2006). These concerns have also been raised for smelt runs in tributaries to the St. Lawrence River in less urban regions of Québec (Lapierre et al. 1999). Periphyton monitoring was conducted to provide a biological response variable for nutrient concentrations that may be directly related to successful embryonic survival. Laboratory experiments studying the effect of periphyton growth on smelt embryo survival complimented the field monitoring. The lab results demonstrated that embryo survival was significantly lower on substrata with high periphyton growth/concentrations than on clean surfaces (Wyatt et al. 2010).

Field monitoring measured the growth of periphyton on spawning ground substrate at the index sites during the spawning period to determine how growth may differ between sites. Ceramic tiles were deployed to collect periphyton during the 2008-2009 spawning period at riffle habitat where smelt deposit eggs. Periphyton growth on the tiles was collected biweekly to quantify daily growth and describe algal species composition. Ash-free dry weight (AFDW, $g/m^2/day$) was calculated as a measure of periphyton biomass. Average periphyton growth ranged from 0.006 to 0.120 $g/m^2/day$ at 12 smelt spawning habitat stations (Table 2.2.3). The range of periphyton growth included very low growth at the easternmost Maine stations to high growth at urban centers in Massachusetts.

No algal biomass thresholds are available specifically for smelt spawning habitat. In the absence of published thresholds, the 25th percentile of 0.0143 $g/m^2/day$ was calculated from the AFDW medians observed during this study and compared to all values. All river stations exceeded this threshold and were classified as Impaired for periphyton, except for Deer Meadow Brook, Chandler River and East Bay Brook, Maine. The periphyton data suffer from high variability and low sample sizes at some sites. However, there appears to be potential value in using the 50th percentile (0.0533 $g/m^2/day$) as a threshold for moderately impacted rivers. At the stations with medians above the 50th percentile (Figure 2.2.1), the periphyton could be characterized as excessive growth that could impede egg incubation and appears to be associated with higher TN and urbanization. However, more work is needed to understand the range of periphyton growth at different spawning streams, how this varies annually in response to environmental conditions, and the point at which periphyton growth impairs embryo survival.

Heavy Metal Concentrations

Heavy metals such as cadmium, chromium, copper, iron, lead, manganese, mercury, silver and zinc can be absorbed by both fish embryos and larvae and lead to developmental abnormalities and reduced survival (Finn 2007, Jezierska et al. 2009, Wegwu and Akaninwor 2006). Short-term, high-intensity contamination mostly occurs in the spring months during snowmelt periods, when mild water acidification that is associated with snow melt leads to free metal ions being leached from sediments (Jezierska et al. 2009). Long term exposure to lower concentrations of heavy metals may be of equal concern. The toxic effects of aluminum on salmonid embryos are seen when pH is below 6.5; at this level, pH can inhibit the swelling of the egg shell, reducing the amount of space for the embryo to develop and move, and leading to stunted growth or physical abnormalities (Finn 2007). Cadmium, lead and copper at low levels can exacerbate these effects at any pH (Jezierska et al. 2009). Above critical thresholds, mercury, lead, cadmium, chromium, iron, and zinc have all been shown to reduce the number of embryos successfully hatching (Wegwu and Akaninwor 2006), as well as to disturb skeletal growth, impair hemoglobin (red blood cell) formation, cause osmoregulatory failure, and limit overall growth because the organism's energy is spent ridding the body of the toxic contaminants (Finn 2007; Jezierska et al. 2009).

We sampled heavy metal concentrations and other minerals (calcium and magnesium) at all index sites during baseflow conditions over the course of the spawning period in 2010 and 2011 to describe the range of concentrations to which smelt embryos are chronically exposed. Although not part of this study, corollary laboratory experiments should be performed to ascertain which metals and what concentrations reduce survival and impair normal development in smelt embryos and larvae.

Of the heavy metals, silver, cadmium, and mercury concentrations were below detection levels for all sites during all sampling periods (detection levels 0.002 mg/l, 0.5 ug/l, 0.5 ug/l, respectively). Chromium was detected only once during the sampling period, in the Oyster River, New Hampshire (0.003 mg/l; detection level 0.002 mg/l). Although these metals were not detected, or detected only once, it should not be assumed that they are not present. They may in fact be present either at concentrations below the detection levels or during runoff or precipitation events neither of which our sampling captured. All other metal concentrations were detected at most sites, and the range of values followed a log distribution. As log distributions are typical of metal concentrations in many regions, the values we measured likely represent much of the range of metal concentrations present in the region during the smelt spawning season (Table 2.2.4).

A principal components analysis (PCA) was performed using the 2010-2011 average concentrations (log transformed to produce normal distributions) to determine which metal and mineral concentrations trended together, and which seemed to vary on their own. From this analysis, we find that lead (Pb; abbreviations refer to labels in associated figure, and are not the full elemental symbols with ionic sign), copper (Cu), and zinc (Zn) are highly related and trend opposite from aluminum (Al). This pattern indicates that when high values of lead, copper, and zinc were present, aluminum values were low, and vice versa. Being drivers of water hardness, calcium (Ca) and magnesium (Mg) were highly related to hardness and alkalinity, but notably nickel (Ni) was also highly related to these variables (Figure 2.2.2).

The relationship between metal concentrations and watershed characteristics is explored in the following section.

Watershed characteristics

As suggested throughout the preceding sections, watershed land use can affect water quality in receiving streams and rivers in a variety of ways. The development of wetlands, agricultural fields, or forested areas replaces porous soils with impervious surfaces, which increases the velocity of water flowing off the land and the supply of suspended sediments, nutrients, and contaminants to adjacent streams (Brenner and Mondok 1995, Corbett et al. 1997, Strayer et al. 2003, US EPA 2004). In addition, agricultural areas contribute nutrients—both nitrogen and phosphorus—to receiving streams. In aquatic ecosystems, these nutrients can promote algal blooms, deplete oxygen, and degrade fish habitat (Carpenter et al. 1998, Howarth et al. 2000).

Understanding how water quality, nutrient levels, and heavy metal concentrations are related to watershed land use is important for developing management strategies to minimize impacts to rainbow smelt eggs and larvae.

Correlations between watershed land use and water quality parameters, nutrient levels, periphyton growth, and heavy metal concentrations were evaluated using Spearman's rank correlation statistic. Results are presented in Table 2.2.5 at the scale of the full drainage basin and riparian buffer zone. Several key patterns emerge from these correlation results that are relevant to rainbow smelt conservation. First, patterns are very similar at full watershed and riparian buffer scales, indicating that land use in the broader watershed exerts a similar influence on water quality as land use immediately adjacent to the receiving stream. Second, the percent of development and forest in the watershed show the strongest associations with water quality, with the direction of influence occurring in opposition to one another. For example, higher percentages of developed areas are associated with higher stream dissolved (available) nitrogen and heavy metals concentrations; conversely, highly forested watersheds are associated with lower concentrations of nitrogen and metals (Crawford and Lenat 1994). Because periphyton growth is dependent on available nutrients (like dissolved nitrogen), and because heavy metals can negatively affect embryo development and survival, this pattern suggests that protecting forested areas is important for maintaining water quality conditions that are beneficial to rainbow smelt.

Understanding how water quality, nutrient levels, and heavy metal concentrations are related to watershed land use is important for developing management strategies to minimize impacts to rainbow smelt eggs and larvae.

Conclusions

When compared to the established EPA thresholds, the water quality data collected during 2008-2011 show widespread impairment due to elevated TN, TP, and turbidity and more localized impairment from acidification and excessive periphyton growth. More work is needed to evaluate existing criteria and to establish new thresholds that are specific to smelt spawning habitat. For example, the turbidity criterion is likely too low to be relevant for stream riffles during spring; conversely, the water temperature and DO criteria may be too high, as smelt embryos require a lower temperature than the current EPA threshold. The highest median values for TN, conductivity and periphyton were associated with urban sites. Most sites with few identified impairment were at the northern end of the study area.

These results provide a range of water quality conditions that affect successful embryonic survival. From high impairment in urban settings to suitable water quality in rural settings, these sites are examples of both conditions requiring remediation and demonstrating restoration targets. We encourage resource managers to use these baseline conditions to consider potential remediation measures (e.g., riparian buffers, stormwater improvements, point source reductions) to improve impairments and to plan for protecting locations with suitable conditions for supporting smelt spawning success.

Table 2.2.1. Water chemistry criteria related to smelt spawning habitat. The water chemistry parameters were adopted to protect Aquatic Life at Class B Inland Waters (MassDEP 2007), and US EPA reference conditions (25th percentile) for the Northeast Coastal Zone sub-Ecoregion (US EPA 2000). Potential criteria are presented based on 25th and 50th percentiles from 2008-2011 project data. Blank cells indicate either that no criterion exists or the derived percentile has limited relevance for smelt habitat.

	Existing Water Quality Criteria			
	Suitable	Minimally Impacted	Minimally Impacted	Moderately Impacted
Parameters	(MassDEP 2007)	25th Percentile (US EPA 2000)	25th Percentile (2008-2011 data)	50th Percentile (2008-2011 data)
Temperature (°C)	≤ 28.3			
Sp. Conductivity (mS/cm)			≤ 0.131	
pH	≥ 6.5 to ≤ 8.3			
DO (mg/L)	≥ 6.0			
Turbidity (NTU)		≤ 1.7	≤ 1.9	≤ 2.1
TN (mg/L)		≤ 0.570	≤ 0.340	≤ 0.452
TP (ug/L)		≤ 23.75	≤ 17.56	≤ 20.43
Periphyton Biomass (g/m2/d)			≤ 0.0143	≤ 0.0533

			Temp.		Cond.		DO %		DO mg/L		pH		NTU	
State	River	Code	Median	Exceed	Median	Exceed	Median	Exceed	Median	Exceed	Median	Exceed	Median	Exceed
MA	Westport	WP	9.55	0%	0.130		96.1		10.96	0%	5.92	99%	1.4	33%
MA	Weweantic	WW	11.05	0%	0.092		95.9		10.55	0%	6.23	90%	2.2	74%
MA	Jones	JR	9.71	0%	0.200		100.0		11.74	0%	6.39	68%	2.8	90%
MA	Fore	FR	10.26	0%	0.558		105.1		12.06	0%	7.09	2%	2.1	71%
MA	Saugus	SG	8.89	0%	0.663		102.3		11.98	0%	7.28	0%	2.9	91%
MA	North	NR	9.57	0%	0.962		105.0		12.45	0%	7.24	0%	2.0	74%
MA	Crane	CN	9.22	0%	0.997		99.1		11.89	0%	7.18	1%	3.4	99%
MA	Essex	ER	9.83	0%	0.200		105.2		12.32	0%	6.71	28%	1.3	29%
MA	Parker	PR	9.11	0%	0.252		105.1		11.88	0%	7.02	1%	1.8	65%
NH	Squamscott	SQ	11.69	0%	0.152		100.4		10.93	0%	6.93	2%	1.8	57%
NH	Winnicut	WR	11.50	0%	0.315		97.6		11.21	0%	7.43	0%	4.3	88%
NH	Oyster	OY	10.48	0%	0.195		101.0		11.31	0%	7.38	0%	4.4	100%
ME	Long Creek	LC	10.36	0%	0.525		97.0		11.07	0%	7.25	0%	6.9	100%
ME	Mast Landing	ML	8.79	0%	0.134		98.1		11.52	0%	7.11	8%	8.8	100%
ME	Deer Meadow	DM	10.99	0%	0.031		98.0		11.14	0%	6.84	18%	2.4	84%
ME	Tannery Brook	TB	12.68	0%	0.157		98.1		10.43	0%	7.67	4%	1.8	55%
ME	Schoppee	SB	9.46	0%	0.089		92.5		10.26	0%	6.27	77%	2.1	82%
ME	Chandler River	CR	12.86	0%			92.8		9.47	0%	6.72	21%	2.0	100%
ME	East Bay	EB	9.80	0%	0.046		95.1		10.76	0%	7.31	7%	2.0	69%
25th Percentile			9.51		0.131		96.6		10.85		6.72		1.9	
50th Percentile			9.83		0.197		98.1		11.21		7.09		2.1	

Table 2.2.2. Basic water chemistry measured at 19 smelt fyke net index stations in the U. S. Gulf of Maine and Buzzards Bay, Massachusetts. Median values were calculated from all available data from 2008-2011. The percentage of samples at each station that exceed the QAPP (Chase 2010) thresholds are presented in shaded cells, indicating an impaired classification for the parameter. No water quality criteria are available for conductivity or DO saturation.

			TP			TN			N:P		AFDW (g/m²/day)	
State	River	Code	N	Median	Exceed	N	Median	Exceed	N	Median	N	Median
MA	Westport	WP	25	19.20	20%	25	0.608	56%	25	33.2	0	
MA	Weweantic	WW	26	37.60	81%	23	0.283	17%	23	7.8	0	
MA	Jones	JR	48	16.70	13%	47	0.569	49%	47	34.1	8	0.0169
MA	Fore	FR	47	21.10	36%	48	0.530	31%	47	23.1	8	0.0154
MA	Saugus	SG	10	26.95	70%	11	0.917	100%	10	36.1	0	
MA	North	NR	47	21.06	28%	49	1.395	100%	47	68.0	6	0.0828
MA	Crane	CN	48	21.89	42%	48	1.265	100%	48	58.9	8	0.1198
MA	Essex	ER	11	12.80	9%	11	0.411	9%	11	31.3	0	
MA	Mill	MR	45	21.80	36%	46	0.644	72%	45	26.0	8	0.0685
MA	Parker	PR	11	17.60	0%	11	0.523	46%	11	31.0	0	
NH	Squamscott	SQ	37	17.44	19%	37	0.420	11%	37	22.7	9	0.0598
NH	Winnicut	WR	37	20.10	32%	36	0.516	36%	36	25.3	9	0.0867
NH	Oyster	OY	15	22.70	40%	15	0.387	20%	15	18.3	0	
ME	Long Creek	LC	30	20.75	27%	29	0.425	28%	29	23.6	4	0.0625
ME	Mast Landing	ML	37	18.81	22%	37	0.258	0%	37	11.9	0	
ME	Deer Meadow	DM	37	17.90	16%	35	0.253	0%	35	16.5	4	0.0068
ME	Tannery Brook	TB	32	23.64	50%	32	0.332	0%	32	13.9	5	0.0468
ME	Schoppee	SB	18	27.00	61%	18	0.479	11%	18	15.5	0	
ME	Chandler River	CR	10	14.95	0%	9	0.342	11%	9	24.6	4	0.0111
ME	East Bay	EB	34	11.15	6%	33	0.216	0%	33	17.7	4	0.0055
25th Percentile				17.56			0.340			17.4		0.0143
50th Percentile				20.43			0.452			24.1		0.0533

Table 2.2.3. Nutrient and periphyton measurements for all index stations in the U. S. Gulf of Maine and Buzzards Bay, Massachusetts. The percentage of samples at each station that exceed the QAPP (Chase 2010) thresholds are presented in shaded cells, indicating an impaired classification for the parameter. No criteria are available for the N:P ratio or periphyton.

Analyte	Unit	2010 Detection Limit	2011 Detection Limit	2010-2011 Mean Value	2010-2011 Low Value	2010-2011 High Value
Aluminum	mg/L	0.005	0.01	0.1347	0.0059	1.0000
Arsenic	ug/L	0.5	0.5	1.30	0.51	4.00
Cadmium	ug/L	0.5	0.5	BDL	BDL	BDL
Calcium	mg/L	0.05	0.05	13.78	0.55	52.00
Chromium	mg/L	0.002	0.002	0.003	0.003	0.003
Alkalinity	mg/L	1	1	29.14	3.26	100.00
Copper	mg/L	0.0005	0.0005	0.0013	0.0005	0.0077
Iron	mg/L	0.05	0.05	0.62	0.16	2.70
Lead	ug/L	0.5	0.5	1.05	0.38	3.10
Magnesium	mg/L	0.05	0.05	4.27	0.27	39.00
Nickel	mg/L	0.0005	0.0005	0.0016	0.0005	0.0050
Silver	mg/L	0.002	0.0005	BDL	BDL	BDL
Zinc	mg/L	0.002	0.002	0.006	0.002	0.021
Total Hardness	mg/L	0.35	0.33	54.6	2.5	430.0
Mercury	ug/L	0.5	Not Sampled in 2011	BDL	BDL	BDL

Table 2.2.4. Analytes measured in water samples taken at baseflow at smelt spawning index sites 2010-2011. Detection limits and mean, low, and high concentrations are shown for each analyte. BDL = below detection limit.

	Full watershed					Stream buffer				
	%dev	%devopen	%forest	%wetland	%ag	%dev	%devopen	%forest	%wetland	%ag
Water quality										
conductivity	**0.95**	**0.9**	**-0.83**	-0.16	-0.12	**0.94**	**0.92**	**-0.79**	-0.01	-0.24
DO conc.	**0.67**	**0.65**	-0.38	-0.18	-0.19	**0.51**	**0.56**	-0.34	-0.05	-0.2
pH	0.36	0.39	-0.25	-0.42	0.01	0.42	0.43	-0.3	-0.33	-0.14
turbidity	0.32	0.47	-0.22	-0.14	-0.04	0.28	**0.51**	-0.12	-0.21	-0.18
TP	0.26	0.34	-0.46	-0.21	0.04	0.36	0.31	-0.48	-0.11	-0.02
TN	**0.87**	**0.77**	**-0.81**	0.1	-0.16	**0.85**	**0.74**	**-0.74**	0.24	-0.19
AFDW	**0.62**	0.49	-0.57	-0.1	0.23	**0.69**	0.55	-0.58	0.04	-0.02
alkalinity	**0.83**	**0.77**	**-0.66**	-0.23	-0.14	**0.8**	**0.76**	**-0.66**	-0.05	-0.25
hardness	**0.83**	**0.78**	**-0.7**	-0.24	-0.11	**0.88**	**0.88**	**-0.68**	-0.16	-0.33
Metals										
Al	**-0.53**	-0.44	0.46	0.2	0.22	-0.39	-0.28	0.56	0.02	0.13
As	**0.54**	0.45	-0.44	0.13	0.22	**0.61**	**0.57**	-0.4	0.15	-0.04
Ca	**0.83**	**0.75**	**-0.68**	-0.3	-0.16	**0.86**	**0.82**	**-0.67**	-0.19	-0.36
Cu	**0.58**	0.45	-0.37	-0.41	0	0.42	0.35	-0.41	-0.25	-0.09
Fe	0.26	0.43	-0.32	0.22	0.42	0.19	0.41	-0.3	0.24	0.34
Mg	**0.86**	**0.84**	**-0.74**	-0.05	-0.06	**0.89**	**0.92**	**-0.67**	-0.01	-0.26
Ni	**0.89**	**0.89**	**-0.74**	-0.21	-0.04	**0.81**	**0.83**	**-0.69**	-0.08	-0.2
Pb	**0.64**	**0.63**	**-0.72**	-0.45	**-0.81**	**0.81**	0.59	**-0.64**	-0.36	**-0.8**
Zn	**0.7**	**0.74**	**-0.87**	-0.29	-0.35	**0.74**	**0.71**	**-0.82**	-0.25	-0.44

Table 2.2.5. Spearman's rank correlation between water quality metrics and land cover at two spatial scales (e.g., full watershed and riparian buffer zone). Correlation coefficients in bold type indicate significance at the p=0.05 level.

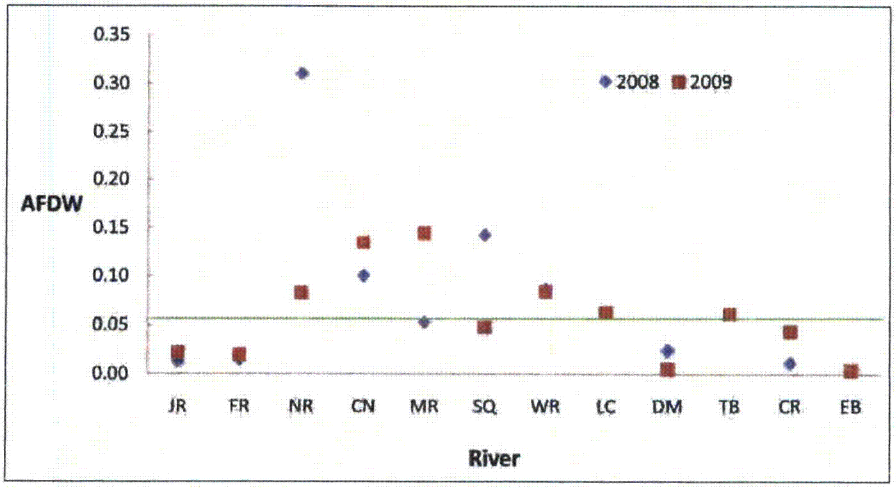


Figure 2.2.1. Annual median periphyton growth (ash-free dry weight, g/m²/day) displayed by sample station with 50th percentile of station median values marked by green line. Refer to Table 2.2.2 for river codes.

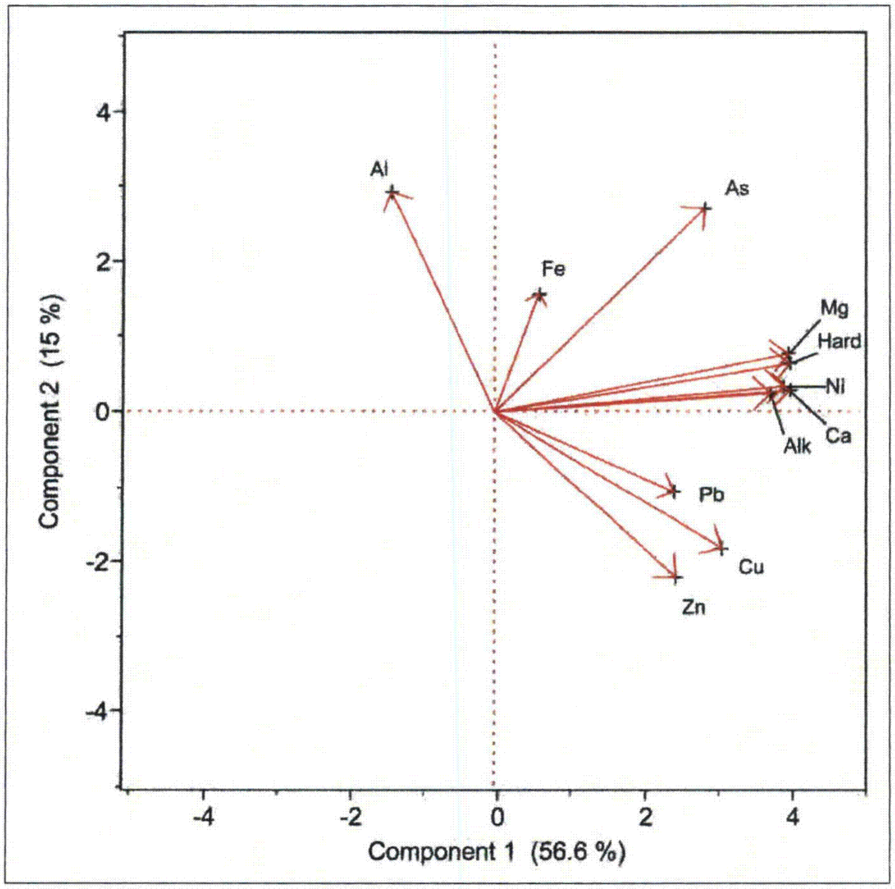


Figure 2.2.2. Principal components analysis (PCA) performed on 2010-2011 average metal and mineral concentrations (log transformed). The first component is driven most by hardness (a variable which represents the total mineral concentration of water, driven by calcium and magnesium), magnesium, calcium, alkalinity, and nickel. The second component is driven most in the positive direction by aluminum and arsenic and less so by iron, and in the negative direction by zinc, copper, and lead.

2.3 – THREATS TO SMELT IN MARINE COASTAL WATERS

Smelt spend at least half the year in marine coastal waters during the summer and fall months. As adults and juveniles they are a schooling fish that attract a wide range of predators. While monitoring this life phase can be more difficult than monitoring discrete spawning runs, it is no less important when considering the species decline. During this period, smelt are susceptible to environmental influences on survival, shifts in natural mortality and to capture in small mesh fisheries targeting other species. These topics are discussed below, using the best available information to discuss how each issue may be affecting smelt populations; however, to fully understand the implications, each requires further study.

Fish Health

Improving understanding of fish health status as well as the abundance, geographic distribution, and vectors of areas of study necessary to support the development and implementation of conservation strategies designed to protect and restore rainbow smelt populations. Pathogens can adversely affect both juveniles and adults in both general and acute ways, including organ failure, energy loss, interruption of hormonal pathways and reproductive weakness (D.

Bouchard, University of Maine, pers. comm., 2011).

We characterized pathogen presence endemic to smelt at fourteen spawning index sites spanning the Gulf of Maine over a two-year period, 2009-2010 (Bouchard 2010). Sampling did not detect bacterial pathogens of regulatory concern but did detect endemic parasites that are well documented for similar anadromous species. Parasitological results were typical of wild fish populations, with various trematodes (e.g., black grub), cestodes, nematodes and protozoa observed at all sites. A microsporidian parasite detected in various tissues of many individuals in this study was not identified as to species, but is consistent with *(Glugea hertwigi)*, which was confirmed at one site: the Fore River, Massachusetts. This parasite has been documented extensively in freshwater smelt can be detrimental to successful spawning because this parasite infests the gonads of smelt (Jimenez et al. 1982, Nsembukya-Katuramu et al. 1981). The observation of large numbers of *(Philometra spp.)*-like nematodes in the gonads of the majority of female fish in the study is also consistent with reports of this parasite as an opportunistic pathogen of spawning female fish in other species (Moravec and de Buron 2009).

Fish from a majority of the sites spanning the entire Gulf of Maine region showed evidence of erythrocytic disease, or degradation of red blood cells, leading to anemic effects.

Virology results revealed a viral agent from adults from Casco Bay, Maine; however, it is difficult to place any significance to this agent at the present time because the virus is not similar to currently catalogued agents (IPNV, IHNV, ISAV, and VHSV have been ruled out by PCR techniques). More analysis on this agent is needed to fully understand the physiological effects it may be having. Fish from a majority of the sites spanning the entire Gulf of Maine region showed evidence of erythrocytic disease, or degradation of red blood cells, leading to anemic effects (Bouchard 2010). This last point may be of specific concern and warrants further investigation to understand the extent of disease and causal factors.

Fishing Mortality

Overfishing in historical fisheries

While historical fisheries for rainbow smelt landed thousands (and in Maine millions) of pounds annually in the 1800s, because the relative size of the entire population was unknown, it is not possible to quantify the effect of these targeted fisheries on smelt populations.

As populations declined in the 20th century, and as regulations limited fishing gear and take in response to this decline, targeted fishing effort has also been reduced. Today, few targeted commercial fisheries exist: a dip and bow net fishery is open to permitted individuals in Great Bay, New Hampshire; and a gill and bag net fishery are allowed during a regulated time period to permitted individuals on five rivers in downeast Maine. Large-scale recreational hook-and-line ice fisheries also exist in Great Bay, New Hampshire, and on many rivers and embayments in Maine (most notably the Kennebec River and Merrymeeting Bay area). While these fisheries are not thought to contribute high mortality for the smelt populations they target, the current extraction rates are unknown. Studies by the ME DMR in the late 1970s estimated that the ice-fishery on the Kennebec River extracted less than 5% of the total smelt population in the river (Flagg 1983). In Maine there is also a large recreational dip net fishery that targets adult smelt on the spawning grounds during the spring runs.

While there is a limit of 2 quarts of smelt per person per day in this spring fishery, the contribution to mortality is unknown.

Incidental catch in small mesh fisheries

Five small mesh fisheries operate in the Gulf of Maine, all capable of encountering rainbow smelt. Because smelt is not a regulated species for federally permitted fisheries, incidental catch (bycatch) is not required to be reported, although it is in some cases. Thus, it is difficult to determine the total amount of smelt bycatch; however, the relative impact on the species can be assessed based on reports from the Northeast Fisheries Science Center Observer (NEFSC) Program, which monitors catch from a representative sample of each fleet (NEFCS 2012). The following analyses represent all Gulf of Maine states.

The Northern shrimp fishery operates in nearshore coastal waters during the winter and early spring months. Since 1992, the fishery has been required to install a finfish excluder device in their nets, the Nordmore grate. Prior to 1992, total bycatch in this fishery comprised almost two-thirds of the catch (Howell and Langan 1992). Subsequent surveys have found that the grate is extremely effective in limiting bycatch; Eayrs et al. (2009) observed reductions to 4-8% of the total catch over a two-year period.

Using NEFSC observer records, the effect of the Nordmore grate on reducing smelt bycatch can specifically be seen. In the period directly preceding the requirement of the excluder device (1989-1992), there were 197 observed trips on vessels targeting Northern shrimp, and smelt were caught on 38 (19%) of these trips. A total of 201 lbs of smelt were caught during these trips combined, for an average of 5.3 lbs per trip. The highest was 46 lbs of smelt bycatch, although 87% of these trips caught less than 10 lbs. In the period directly following the excluder panel requirement (1993-2006), the amount of smelt bycatch on observed trips decreased, although not significantly (Wilcoxon ranked sum test: $p = 0.129 > 0.05$). During this period, smelt were observed on 74 (24%) out of 303 observed trips. A total of 289 lbs of smelt bycatch were caught during these trips, with an average weight per trip of 3.1 lbs. The highest smelt catch was 31 lbs, and 92% of these trips had less than 10 lbs. Recent data (2007-2011) show that smelt bycatch has decreased significantly from the last two time periods (Wilcoxon ranked sum test: $p < 0.0001 < 0.05$). During this most recent period, smelt bycatch was observed on only 22 162 (14%) observed trips, all of which saw less than 10 lbs. The average smelt bycatch for this recent period was 0.5 lbs, with a maximum catch of 2 lbs.

Vessel Trip Reports (VTRs) were implemented in 1996, at which point it became mandatory for vessels to report all catch. From the VTR reports, smelt were only reported in the shrimp fishery post-2006, but reported annually since then. From 2006-2011, smelt were reported in 35 trips out of 14,339 trips (0.2%). Of the trips that did report smelt, the average catch was 5.3 lbs, the highest 100 lbs (one occurrence), and 94% of trips reported less than 10 lbs. Further work is needed to estimate the total amount of smelt taken in the shrimp fishery using both observer and VTR data.

The mackerel, whiting (silver hake), Atlantic herring, and loligo squid fisheries are all also capable of encountering smelt as bycatch. These fisheries operate on multiple scales with various gear types, including pound (trap) nets at fixed locations close to shore, offshore trawling, and bag netting. Smelt bycatch has been reported on VTRs in the Atlantic herring and whiting fisheries, however too few reports have been given from the mackerel fishery to draw any inferences, and no smelt bycatch has been reported from the loligo squid fishery.

In the Atlantic herring fishery, some smelt bycatch was reported in each year 1996-2011, although was reported on fewer than five reports in 1997, 2002, and 2008-2011. For the total period, smelt were reported in 135 trips out of 5463 total Atlantic herring trips (2.4%). The average reported catch was 5.1 lbs, the highest was 100 lbs (one occurrence), and 84% of these trips reported less than 10 lbs.

In the whiting (silver hake) fishery, smelt bycatch was reported for 71 trips out of a total of 20,204 trips (0.3%) for 1996-2011. In seven of these years, fewer than 5 VTRs reported smelt (1999, 2004, 2005, 2008-2011). The average reported catch was 6.4 lbs, the highest was 42 lbs, and 73% of these trips reported less than 10lbs.

If these data are representative of smelt bycatch in these fisheries, it is likely that they are not having a large effect on smelt populations at this time. However, because we do not have a population estimate for smelt, it is not possible to ascertain the mortality rate due to bycatch in these fisheries. Further, the effect of small-mesh fisheries in the past cannot be determined. To fully understand the effect of small-mesh fisheries on smelt populations, more work is necessary to ensure that the observer and VTR programs are accurately capturing the extent of smelt bycatch.

Predator-prey relationships

Prey Availability

Rainbow smelt are voracious feeders on amhipods, euphausiids, mysids, shrimps, marine worms, and any available small fishes (e.g., silverside, mummichog, herring) (Scott and Scott 1988). We do not know of existing broad-scale data to evaluate changes in the prey of rainbow smelt over time, however, the prey base was likely affected by changes in primary production and zooplankton community composition during the 1990s (Greene et al. 2012), and such variability should be expected as a result of oceanographic and climate variability. In addition, the balance between small prey species and larger fishes may shift as a result of ocean acidification (Wootton et al. 2008), which will likely affect calcifying organisms such as zooplankton and shrimp.

Predator Population Shifts

Predators of rainbow smelt include a variety of aquatic birds (e.g., mergansers, cormorants, gulls, terns), fish (e.g., Atlantic cod, Atlantic salmon, striped bass, bluefish), and seals (Collette and Klein-MacPhee 2002). While the abundance of some of these predators has declined since the 1990s, others have increased. For example, striped bass populations have increased dramatically over the past 20 years, although the recovery has not been seen consistently along the coast. Maine striped bass populations have actually declined or remained at low levels compared to other regions (ASMFC 2011). Striped bass predation has been shown to have a significant impact on blueback herring populations in Connecticut River, and has been attributed as one of the factors limiting blueback herring restoration in this river (Davis et al. 2009). Similarly, populations of grey seals in the Gulf of Maine have increased dramatically over the past few decades (NEFSC 2010). Like striped bass, grey seals are capable of ingesting large amounts of forage fish, and are found feeding in nearshore coastal waters in late spring when smelt are present in large schools. Although not as closely documented, cormorant populations have also sharply increased in recent years and are known to prey heavily on smelt. Striped bass, cormorants, and grey seals have received protections as managed species that have increased their populations sharply in short periods of time. Although these are natural predators that smelt have coexisted with while adapting to Gulf of Maine environments, it is possible that the impact of increasing predation on declining smelt populations results in proportionally higher natural mortality than in the past.

Recent shifts in predator range may also increase the exposure of smelt to predators. Friedland et al. (2012) suggested that the survival post-smolt Atlantic salmon may be affected by increasing predator abundance in the Gulf of Maine; increasing predator abundance that is due not necessarily to increasing population size, but to northward shifts in range due to recent changes in climatic and oceanic conditions. Because many of these species prey on a wide range of forage fish, this increasing predator abundance may affect smelt populations as well, although more research would be necessary to assess this relationship.

Community shifts

Dramatic declines of diadromous fish populations have been observed across North America (Limburg and Waldman 2009; Hall et al. 2012). Saunders et al. (2006) proposed that coherent declines within a co-evolved diadromous community could negatively affect individual species. While Saunders et al. (2006) focused on benefits that may have been lost for Atlantic salmon through community-level shifts, several of these could also affect rainbow smelt. In particular, the decline of species such as alewives, blueback herring, and American shad—which are present in rivers and estuaries as juveniles during the same time as rainbow smelt—could have resulted in the loss of a prey buffer for rainbow smelt juveniles, making them more vulnerable to predation.

Climate-driven environmental change

It is anticipated that climate change will influence temperature and precipitation patterns in New England, and some of these effects may already be evident in recent environmental trends. Surface water temperature has been monitored monthly nearly continuously since 1905 (ME DMR 2011). This temperature series shows periods of warming during the 1940s-1950s and again from the 1990s to mid-2000s, with the warmest water on record observed in 2006 (Figure 2.3.1). Because smelt are a cold water species, their geographic distribution shift northward may be influenced by the trend in warmer waters.

In addition to warmer coastal waters, freshwater conditions have changed in recent years as well. During the 1980s and 1990s, the Northeast experienced an increase in heavy precipitation events, and warmer temperatures have reduced ice cover and prompted earlier spring flows (Hodgkins et al. 2003, Frumhoff et al. 2007). On New England streams that are substantially affected by snowmelt, the winter/spring center of volume dates and peak flow dates advanced by 1-2 weeks between 1970 and 2000 (Hodgkins et al. 2003). Water temperature and flow changes may affect spawning migration timing (Juanes et al. 2004, Ellis and Vokoun 2009), development rates, and early life stage survival in rainbow smelt. More research is needed to understand how climate-related environmental changes influence smelt abundance and distribution changes and to anticipate future implications for rainbow smelt.

With concern to species communities and shifts that are due to climate change, evidence suggests that the balance between small prey species and larger fishes may shift as a result of ocean acidification (Wootton et al. 2008). As the amount of atmospheric carbon increases, the amount of dissolved carbon in oceanic water also increases, in turn decreasing the pH of seawater. At lower pH values, the development and survival of calcifying marine organisms like coralline algae and phytoplankton are inhibited. Because these organisms are the base of the marine food chain and the direct diet of many of smelts' prey species, a decline in these organisms may also negatively affect smelts' prey base. This hypothesis has been examined on the Pacific coast, but with no conclusive results, and has only begun to be considered in the Gulf of Maine. More research is needed to fully understand the effect of climate change on species composition changes in this region.

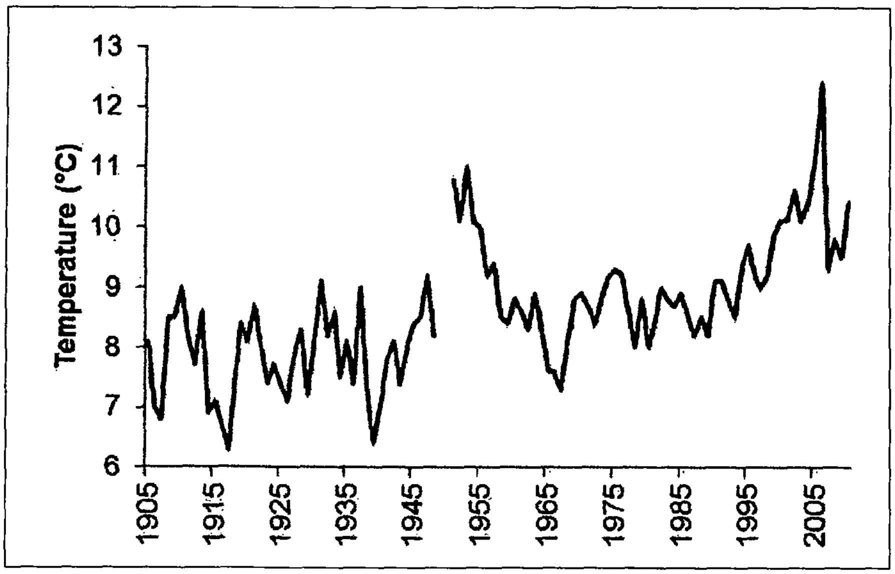


Figure 2.3.1. Mean annual surface water temperature at Boothbay Harbor, Maine, from 1905-2010.

3 – CONSERVATION STRATEGIES

We recommend that rainbow smelt remain federally listed as a Species of Concern. Populations have disappeared from their southern range in a short period of time and are also declining in their present distribution in the Gulf of Maine. The species should continue to be monitored, and factors contributing to its decline should continue to be assessed.

3.1 - REGIONAL CONSERVATION STRATEGIES

We recommend that rainbow smelt remain federally listed as a Species of Concern and that current population monitoring efforts continue in the Gulf of Maine.

Recommendation 1: Continue monitoring programs

Each state within the present distribution of rainbow smelt in the Gulf of Maine currently monitors populations through inshore trawl, juvenile abundance, fyke net, and/or creel surveys.

In states at the extreme southern limit of the range where spawning populations have not been documented within the past ten years, inshore trawl surveys are likely the most effective way to monitor the remnant populations. In the Gulf of Maine states, trawl surveys provide the only source of data on the marine life phase of smelt. It is necessary that these surveys continue to document smelt presence and quantify abundance, and it is recommended that biological information is collected from a sub-sample of catches.

The regionally standardized fyke net survey developed for this study should be continued in the Gulf of Maine. A standardized survey is necessary to provide long-term data that can track inter-annual variability across distinct spawning stocks. This information is critical for detecting whether populations are declining or showing signs of stress, as may be characterized by truncated age distributions, decreases in length at age, and decreases in CPUE over time. The juvenile abundance surveys should also be continued in New Hampshire and Maine as the only surveys targeting this life stage. Further, creel surveys should be maintained at recreational fishing sites to provide a measure of the impact of the fishery as well as information about changes in population size and biological characteristics over time.

Because some pathological concerns were found as part of this project (see section 2.3 – Threats to Smelt in Marine Coastal Waters), Gulf of Maine states should periodically monitor rainbow smelt from multiple spawning stocks for pathology, including parasite occurrence, viral agents, and systemic physiological problems. Further, states should cooperate with Canadian provinces to compare parasite and disease prevalence in the entirety of the species' range.

Recommendation 2: Restore historical or degraded spawning habitat

Spawning habitat degradation and obstructions to access have been identified as two important factors that have reduced successful spawning. Restoring in-stream habitat (e. g. substrate, water volume and velocity, pool and riffle areas), riparian buffer, improving and preserving watershed functions, and restoring access are important management strategies to improve local smelt populations.

Where possible, head-of-tide dams should be removed. Eggs deposited below dams are subject to periods of salinity during high tide and may be exposed to air at low tide if freshwater flows coming over the dam are low. Perched culverts and small water control barriers can also have this effect. When these obstructions are removed, smelt are able to ascend into freshwater, where water chemistry is more stable over time and water level is relatively constant. While undersized culverts (less than 1.2x bank-full width) may not completely block access, they can limit the number of smelt that reach the spawning grounds by creating velocity barriers. Restoration projects to improve road-stream crossings should design replacement culverts that target minimum water depth of 6 inches with average velocities in the culvert of 0.5 m/s or less, and flood velocities below 1.5 m/s (see section 2.1 – Threats to Spawning Habitat Conditions and Adult Spawning).

Restoring in-stream habitat (e. g. substrate, water volume and velocity, pool and riffle areas), riparian buffer, improving and preserving watershed functions, and restoring access are important management strategies to improve local smelt populations.

Additionally, water quality at the spawning grounds must support healthy embryonic development and survival. We found that diminished rainbow smelt spawning runs existed in rivers surrounded by urbanized watersheds, while rivers draining forested watersheds supported strong smelt spawning populations. Comparing watershed conditions to water quality, higher concentrations of nutrients and toxic contaminants were associated with developed areas, while highly forested watersheds were associated with lower concentrations of nutrients and metals. This pattern suggests that protecting forested areas is important for maintaining water quality conditions that are beneficial to rainbow smelt. Furthermore, regional efforts to purchase conservation lands should consider parcels in watersheds that support smelt spawning habitats. When development does occur in watersheds with smelt spawning habitat, the amount of impervious surface should be minimized, and stormwater mitigation techniques should be implemented to curtail the impacts on water quality (e. g. riparian buffers, vegetated stormwater retention pools, underground filtration systems, etc.).

Recommendation 3: Smelt Fishery Management Actions

The results of the present study documented evidence of high population mortality (truncated age distribution) and poor recruitment (low abundance) in smelt populations in the southern portion of the study area. The time series of population data collected among the fishery dependent and independent surveys is too brief to determine the causes of these stressors on smelt populations. However, overfishing was consistently identified as a significant concern in the latter half of the 19th century and the early 20th century in the southern portion of smelt's distribution.

The sustainability of current smelt fisheries, both recreational and commercial, will require management strategies to quantify natural mortality and fishing mortality. We recommend that each state in the study area review current smelt fishery regulations and identify locations where present management may not be sufficient to protect distinct populations that display evidence of stress. We recommend that states estimate fishing mortality from all targeted smelt fisheries and review bag limits on both commercial and recreational fisheries that target smelt.

Recommendation 4: Expand research to estimate population size and assess the potential impacts of ecosystem and climate changes

The surveys carried out as part of this project did not enable us to develop a population estimate for rainbow smelt. However, the standardized fyke net survey established by the study should be continued with additional research in order to assess smelt population status in the region, understand the impact of targeted fishing and incidental bycatch, and to understand the relative contributions of each spawning stock to the regional population. This may be accomplished through a large-scale mark and recapture effort that targets each genetic stock (Kovach et al., in press; section 1.1 – Basic Biology). Tagging studies carried out as part of this project to understand habitat use and within-season repeat spawning behavior documented few inter-annual returns (less than 1%), although approximately 200 smelt per year were tagged (assumed to be less than 10% of the entire run based on estimated fyke net catch efficiencies). Future tagging studies should tag a representatively larger sample of the spawning population to effectively monitor inter-annual repeat spawning and estimate population size. Additionally, improved and validated age structure data are needed to support future estimates of population size. Efforts should be made to maintain sufficient age structure sample sizes in each state.

Further research is needed to understand how changes in prey availability and predator abundance affect smelt populations. Other studies have found connections between increasing predator populations and depressed forage fish populations (see section 2.3 – Threats to Smelt in Marine Coastal Waters). Because these studies looked at predators that also feed on anadromous smelt, the impact on smelt populations should also be examined.

Species that are important prey of rainbow smelt may be particularly affected by changes in the chemistry of marine waters. Increases in the amount of carbon in the atmosphere are associated with increases in the amount of carbon in salt water, which leads to a reduction in oceanic pH that may negatively impact small prey species, such as calcareous plankton (Wooton et al. 2008). This relationship needs to be better quantified to understand the effect of a smaller prey base on smelt populations. Conversely, predator populations that have shifted in their range in response to climate conditions may be preying upon forage fish populations more than in previous times (Friedland et al. 2012). Further studies are necessary to understand how rainbow smelt will be affected by changes to their prey and predators as a consequence of climate change.

Climate change may also impact smelt populations by changing the extent of available spawning areas. Smelt spawn directly above the head of tide, and the upstream extent of the freshwater spawning area is typically either a natural barrier or road crossing. Thus, a rise in sea level that extends the tidal limit to these barriers may greatly reduce the number of spawning sites or the area within sites that is suitable for spawning. Conversely, a rise in sea level could increase habitat by raising tidewater above natural barriers allowing access to new reaches. Future research should model the potential effects for various sea level rise projections.

Expanded research to understand reasons for systemic health issues and reduced survival is needed to effectively guide management actions. While it is helpful to understand overall relationships such as watershed composition and smelt population responses, it is only a starting point. For example, research into dose responses to specific water quality constituents at all life stages would enable managers to develop smelt specific water quality criteria. These criteria may then be used to guide water treatment goals around which non-point or point source controls can be designed. This would be especially important in those already developed watersheds that are impractical to restore to forest. Controlled studies in both laboratory and field settings are critical to improve our understanding of cause and effect, not just correlations, and to develop measureable relationships. Lastly, post-restoration monitoring is necessary to evaluate the success of any prescribed restoration technique.

Expanded research to understand reasons for systemic health issues and reduced survival is needed to effectively guide management actions.

Recommendation 5: Implement stocking of marked larvae, with continued monitoring and genetic considerations

Rainbow smelt are currently extirpated or have severely declined in many coastal rivers and streams that once supported robust spawning populations. Historical fishing pressure at the spawning grounds and degraded habitat and water quality may be causal factors. When improvements are made to water quality and habitat in these streams, restoration practices, such as stocking, may be appropriate to re-establish rainbow smelt runs at these sites.

Successful stocking efforts must include marking and subsequent recapture of hatchery stocked smelt to quantify effectiveness of restoration efforts. Utilizing recent advances in smelt culture techniques, Ayer et al. (2012) developed methods for marking otoliths in larval rainbow smelt with oxytetracycline (OTC) for monitoring returns. Using these methods, the Massachusetts Division of Marine Fisheries began a pilot program to stock OTC-marked smelt larvae in the Crane River, MA, after water quality suitability was confirmed and passage improvements were made to upstream spawning habitat (Chase et al 2008). Over 10 million marked smelt larvae have been stocked into the Crane River since 2007, and spawning adult smelt with OTC-marked otoliths have been recaptured, providing a positive response for the project to continue stocking and monitoring.

New restoration sites for rainbow smelt are being examined in both Massachusetts and Maine. In many situations, the protection and enhancement of existing habitat and water quality at both donor smelt runs and potential stocking sites will be preferential to initiating a stocking effort. Before any stocking begins, these sites will be sampled for baseline population data, and a site suitability assessment will be conducted, which will include water quality monitoring, streambed characterization, and flow measurements. Further, the genetic information presented in this plan (section 1.1 – Basic Biology) must be used in determining the appropriate parent stock. Managing at too fine a scale can lead to reduced allelic diversity and ignores the natural occurrence of gene flow, while managing at too large a scale can reduce genetic diversity and ignore local adaptations. Another important consideration is the status of donor populations to support stocking efforts. Careful planning should be made to remove a minimal proportion of a donor smelt run's productivity for stocking. Finally, long-term post-stocking monitoring should be performed to demonstrate stocking success.

3.2 - STATE MANAGEMENT RECOMMENDATIONS

Massachusetts

Massachusetts has a long history of implementing management measures to ensure sustainable smelt fisheries. Concern over the capability of net fisheries during smelt spawning runs to negatively impact the long-term viability of smelt runs was documented in the 1860s (Kendall 1926). In 1874, the Massachusetts state legislature banned harvest using nets during the spawning period and limited harvest to hook and line for most coastal rivers in Massachusetts. By the start of the 20th century, nearly all smelt runs had this protection, and local smelt fisheries continued mainly as sportfisheries with little change until recent decades.

The only location in Massachusetts that presently allows net fishing for smelt during the spawning run is the Weweantic River in Wareham. This fishery is conducted under authority of M.G.L 67 of 1931 that gives the Town of Wareham the responsibility to manage a smelt fishery from March 1 to March 31. This recreational fishery continues today with a 36 smelt/day bag limit for each permitted fisherman and limits the net size to 5 square feet. This location was monitored as a smelt fyke net station during the present study. The smelt catch at the Weweantic River station had low CPUE for Massachusetts rivers and a size composition dominated by the age-1 mode. MA DMF intends to initiate cooperative efforts with the Town of Wareham to ensure this unique southern smelt run can be sustained.

Following the net bans of the 19th and early 20th centuries, no smelt laws or regulations were made in Massachusetts until 1941 when three provisions were added to M.G.L. Chapter 130 that focused specifically on smelt fisheries. Section 34 of Chapter 130 standardized the spawning run ban for harvest during March 15 to June 16. Section 35 standardized the method of harvest to hook and line only in Massachusetts. Section 36 gave the Division of Marine Fisheries authority to close smelt spawning river beds to entry during the spawning season. Following these three laws, no changes to smelt regulations were made until 2009 when a daily bag limit of 50 smelt per angler was adopted. Unlike Maine and New Hampshire that drafted smelt management plans in the 1970s and 1980s, no such plan has been prepared in Massachusetts.

Declining recreational smelt catches in the 1980s prompted a review of the status of smelt fisheries and spawning runs by the MA DMF. A survey of all coastal drainages on the Gulf of Maine coast of Massachusetts was conducted from 1988-1995, during which 45 smelt spawning locations were documented and mapped in 30 coastal rivers (Chase 2006). The report for this survey included specific habitat and water quality recommendations for each smelt run. Following the survey, effort was directed toward acquiring smelt population data. A grant was received from NOAA's Office of Protected Resources to develop fyke net indices at six smelt runs during 2004-2005 (Chase et al. 2006). This approach and the six fyke net stations were adopted for the present study. These contemporary efforts, when compared to the historical records and fishery accounts from the 1960s and 1970s, present evidence of a sharp decline in Massachusetts smelt populations in the past 2-3 decades. Locations that once supported popular winter ice fisheries for smelt no longer have fisheries, and some known spawning runs have had no recent evidence of spawning activity.

Smelt Stocking Efforts

The transfer of smelt eggs from larger donor smelt runs to smaller runs or rivers with no smelt spawning was a common practice late in the 19th century in Massachusetts, followed by a large dedicated effort during 1910 to 1920 (Kendall 1926). The ease with which smelt eggs could be collected and the appearance of large numbers of excess eggs in some settings contributed to the zeal behind decades of stocking. Unfortunately, documentation of responses to stocking is essentially absent, other than brief narratives in annual agency reports. Short-term increases in smelt spawning run size appear to have occurred in some systems, especially for coastal to inland lake transfers. However, no evidence can be found of long-term benefits of coastal to coastal river transfers. Smelt egg transfers continued periodically through the 1980s with strong sportfishing constituency support. Recent requests to stock smelt eggs led to a MA DMF evaluation that attempted to quantify the number of eggs transferred, egg survival and returning adult smelt (Chase et al. 2008). Returning spawning adults were documented in a pilot river with no smelt run during the first year of possible returns, but low egg survival and expected low recruitment concluded with MA DMF discouraging the use of smelt egg transfers and prioritizing passage, water quality, and habitat quality improvements over stocking as methods for restoring smelt populations. MA DMF presently does not support the use of egg transfers but is conducting a pilot study on the stocking of oxytetracycline marked larvae as a potential substitute for egg stocking in specific cases where population enhancement can be coupled with habitat improvements and monitoring.

Habitat Restoration

The survey of smelt spawning habitat provided recommendations for specific habitat improvement projects (Chase 2006), four of which have since been conducted. Each of these projects has focused on improving spawning substrate. Two of these projects were able to take advantage of planned culvert replacements to add substrate improvements as part of the scope of work, while the other projects specifically targeted grant and mitigation funds to augment spawning substrate. The experience gained from these projects will assist future efforts in the region.

Recommendations

1) Apply the information gained from the present study and recent smelt habitat improvement projects to identify potential restoration sites and design smelt spawning habitat improvements that meet the life history requirements of smelt. Projects that can remove barriers and extend habitat connectivity for smelt and other diadromous fish should be prioritized

2) Continue monitoring smelt fyke net stations from the present study that have been identified as having promise to support long-term indices of abundance (i.e., Weweantic River, Jones River, Fore River and Parker River). Improve and maintain data collection at fyke net stations to support future development of biological population benchmarks

3) Develop water quality criteria that relate to designated uses within the Massachusetts Wetlands Protection Act in order to protect the specific habitats of anadromous fish, including smelt spawning habitat

4) Conduct a smelt habitat survey of the Buzzards Bay region of Massachusetts that was not mapped during the previous Gulf of Maine survey in Massachusetts

5) Develop a state smelt conservation plan similar those completed for Maine (1976) and New Hampshire (1981)

New Hampshire

The recreational smelt fishery in New Hampshire has been monitored and regulated for decades, and current fishing pressure is not believed to pose a major threat to the smelt population in the state. Ensuring that fishing pressure is compatible with a sustainable smelt population requires continuing monitoring efforts that are already underway, including creel surveys, spring spawning run surveys, and biological sampling during the ice fishery and young-of-the-year seine surveys. Current monitoring of the fishery does not capture recreational fishing for smelt that occurs in the fall prior to the onset of ice. There is also a limited hook and line commercial fishery for smelt in New Hampshire with local markets that is not well recorded. Developing surveys that obtain data from these portions of the fishery would be helpful for appropriately characterizing fishing related mortality. Currently, the daily limit for recreational smelt fishing is 10 liquid quarts, which is approximately equivalent to half of a 5 gallon bucket. Given that smelt is a species of concern, this limit would be re-evaluated if in the future fishing pressure is believed to pose a major threat to the population. Neighboring states of Maine and Massachusetts, which have larger smelt runs, have a daily limit of 2 quarts and 50 fish, respectively.

Population monitoring

The most current statewide fisheries management plan for rainbow smelt was written in 1981, but it predominately focuses on lake smelt populations. The objectives for smelt management were to maintain or increase the population of smelt and to provide for commercial and recreational fisheries. Management measures implemented following development of the plan included closure of the fishery to net or weir fishermen from March 1 to December 15, a 10 quart daily possession limit, and implementation of a smelt egg transfer program that occurred intermittently until 1991.

To evaluate the effectiveness of the management measures and detect trends in smelt abundance, an annual creel survey of the recreational ice fishery was implemented, and a smelt egg deposition index was developed. Data have been collected for the smelt egg index from 1979-2006. The intent of the index was to provide a fisheries independent relative measurement of spawning stock abundance. Validation of the index was attempted in 1993 by regressing it with catch per unit effort of the winter fishery, but results showed very poor correlation between the two. The Department also compared data from the creel survey with the abundance of young of the year (YOY) rainbow smelt collected via a seine survey that was initiated in 1997. This comparison resulted in a much stronger correlation with age-2 smelt CPUE from the creel survey. The Department discontinued egg deposition surveys in 2006 as a result of poor data correlation with other surveys, but will continue to monitor rainbow smelt through juvenile abundance surveys, creel surveys, as well as spawning surveys at the fyke net index stations that were implemented for this project.

Habitat Restoration

Improving water quality in the Great Bay Estuary is expected to benefit smelt using New Hampshire waters. An increase in the concentration of dissolved nutrients and substantial increases in nutrient loading have been detected in the estuary in recent years. These observations prompted the New Hampshire Department of Environmental Services (NH DES) and the U. S. Environmental Protection Agency to develop nutrient criteria for the estuary. Applying these criteria will result in water quality being classified as impaired in the entire estuary, including all of its tributaries. These noted nutrient increases have the potential to spur periphyton growth, which may reduce the viability and hatching of smelt eggs, as discussed in section 2.2 – Threats to Embryonic Survival and Development. The current nutrient criteria assessment is motivating local action to reduce nutrient loading, which should result in improved water quality and reduced periphyton during the smelt spawning season.

Habitat assessment and restoration are key conservation strategies that will be pursued in New Hampshire to enhance spawning conditions for smelt. While main stem spawning habitats are well known in the major tributaries to Great Bay, a comprehensive assessment of other potential spawning locations in smaller tributaries would be beneficial. Habitat improvement projects that would benefit smelt include mitigating siltation and removing head-of-tide dams to increase the amount of freshwater area available for spawning. Currently most spawning in New Hampshire occurs in intertidal areas. Intertidal bars have developed in some tributaries following recent flood events; smelt eggs are deposited on these rocky bars and are then exposed to air at low tide. Grading of these bars to minimize their intertidal exposure would reduce egg mortality.

In addition, head-of-tide dams currently block smelt migration on most of the major tributary rivers to Great Bay. One of these obstructions has recently been removed; the dam in place for 55 years on the Winnicut River in Greenland, NH, was recently demolished, restoring spawning habitat for smelt. Following the dam's construction in 1957, there was a steady decline of a once well-known large smelt run. Other head-of-tide dams in the Great Bay Estuary are under consideration for removal. The potential benefits to smelt will be a key factor in deliberations about the future options for these dams.

Finally, siltation in some rivers has reduced smelt spawning habitat. Dam removal should increase stream flows and help remove accumulated sediments, and actions to reduce nutrient inputs will also reduce sediment inputs to the Great Bay Estuary and its tributaries. These actions should improve smelt spawning habitat conditions in the tributaries.

Recommendations:

1) Continue monitoring efforts in place including: winter creel survey, juvenile abundance seine survey, spring spawning run fyke net sampling
2) Improve water quality and support NH DES in developing nutrient criteria for Great Bay Estuary
3) Identify habitat restoration projects to enhance smelt spawning conditions.
4) Continue to support dam removal projects to connect smelt to historical spawning habitats
5) Conduct a smelt spawning habitat assessment of coastal areas in New Hampshire.

Maine

Through this project, we have found that while rainbow smelt populations are contracting rapidly in range, there are still strong populations in Maine. However, our surveys have also shown that smelt populations in the state are not as strong as previous Department studies have found. Comparing the number and strength of spawning runs currently to that of the late 1970's, we have found that many runs have declined, while others are extirpated (see section 1.3 – Population Status). Data collected during our fyke net survey and creel surveys has also shown that length at age has declined compared to historical records in upper Casco Bay and Kennebec River populations. Because smelt continue to support an economically important and sizable recreational fishery in Maine, as well as a locally economically important commercial fishery in Washington County, it is imperative to pursue management measures that will sustain and restore this species.

Continue monitoring smelt populations at multiple life stages

The state surveys that are currently in place target four important life history stages for rainbow smelt. The annual fyke net survey, which began in 2008, monitors the adult spawning runs at six index sites spanning the Maine coast. From this survey, we collect information about the inter-annual variability of the spawning stock, the strength of age classes, and mortality rates. The genetic information combined with movement and habitat studies show that while adult smelt may not home to the same stream each year, they do show fidelity to larger bay and estuary areas. Thus, by monitoring adult smelt during the spawning season, we can observe changes in a specific stock over time. The other surveys do not have this ability. While the inshore trawl survey can track relative population abundance over time, it likely catches mixed genetic stocks and annual CPUEs may be skewed by stock variability.

The creel survey that targeted the Kennebec River and Merrymeeting Bay beginning in 2009 was expanded with the help of the Downeast Salmon Federation in 2010 to survey anglers on the Pleasant and Narraguagus rivers. Flagg (1984) estimated an extraction rate of less than 5% on the Kennebec River in the late 1970s. However, the population during that time period was likely larger than at present (see section 1.3 – Population Status in the Gulf of Maine); the fishery may have a more significant effect when population levels are low. Given the cultural and economic value of these fisheries, the creel survey should be expanded to target aggregations of fishing camps in other locations (e.g., Great Salt Bay on the Damariscotta River), and efforts should be made to repeat the mark-recapture survey performed by Flagg (1984) to determine a current extraction rate.

The juvenile abundance survey is extremely important in understanding the reproductive success and early life stage survival in the Kennebec River and Merrymeeting Bay. Because we also monitor adult populations in this river system through creel surveys, it may be possible to compare data from the two surveys to quantitatively link adult winter catches to late summer juvenile abundance as NHF&G has been able to do. Additionally, by further understanding how juvenile abundance varies between river segments, we may be able to identify important juvenile habitat.

Improving connectivity and access to spawning grounds

Local smelt runs may be affected by a combination of factors, including habitat degradation, access problems, and current fishing practices.

In many locations where smelt runs have historically declined or disappeared on the Maine coast, the decline is due to the inability of smelt to reach the spawning grounds. Road crossings on small coastal streams are often provided by undersized or hanging culverts or by small historic water control dams that no longer have purpose. Undersized culverts present problems when velocities increase during rain events because the water is constricted to a width smaller than the natural streambed. Because smelt are not strong swimmers, high water velocities can impede their ability to swim through the culvert, and thus to reach their spawning grounds. Hanging culverts (those where the downstream water level is lower than the culvert height) and dams that are downstream of the spawning grounds completely block access. Unlike other anadromous fishes (e.g., alewife and salmon) that can ascend fish ladders or jump vertical obstructions, smelt are unable to pass vertical obstructions over six inches.

State agencies in Maine, including ME DMR, are currently working to catalogue such obstructions and prioritize which should be removed or redesigned to allow for anadromous fish passage. As part of this effort, a web-based tool will be publicly available so that municipalities and land trust organizations can identify road crossings in their area where improvements could re-establish smelt habitat access. In many cases, removing these barriers can have immediate effects in opening smelt spawning passage into a stream when strong runs exist nearby. If this is not the case, stock enhancement may be considered in the absence of other habitat degradation. The ME DMR will continue to work with other state agencies, municipalities, and non-governmental organizations to identify barriers to historical smelt habitat and restore access.

Assessing causes for local decline

Some smelt populations in Maine have declined or become extirpated, while others remain strong. In some cases, local declines can be attributed to historical overfishing; however, habitat degradation, access problems, and current fishing practices may also be impacting smelt populations in the state.

Effective stormwater management techniques can reduce the impact of development on water quality in urbanized watersheds in the state. As an example, the Maine Department of Environmental Protection has worked with the South Portland Water District and businesses within the Long Creek watershed to build stormwater retention areas that reduce the amount of nutrients and contaminants flowing directly into the stream. While the stream quality still shows the effects of development, impairment is reduced and the stream is able to support a limited smelt spawning run. Because this regional smelt project has found that development within a watershed can impact water quality to the point where smelt embryonic health and survival are impaired, watershed management efforts that reduce runoff into receiving streams are recommended in urbanized or developing watersheds.

Current fishing regulations regarding anadromous rainbow smelt limit take by season and location. Recreational fishing is allowed July 1 through March 14; there is no catch limit, but the gear is restricted to hook and line or dip net. During the spawning season (March 15 through June 30), take is limited to two quarts per person per day, and it is predominantly a dip net fishery. While the state Marine Patrol does actively enforce this regulation regarding gear and catch limitations, the number of violations that go without reprimand is unknown. Further, it is currently unknown what impact the recreational fishery may have on smelt populations. With the creel survey of the ice fishery beginning again in 2009, the ME DMR now has the opportunity to assess the extraction rate of the winter fishery and determine if a limit on take is necessary. However, at this point there is no survey of the spring dip net fishery; the effect of fishing mortality during the spawning season and the subsequent loss of possible embryos is unknown. Future work should include an effort to quantify fishing mortality due to both the recreational winter and spring fishery. In locations where there is evidence of stressed smelt runs, management action should be considered to limit mortality during spawning runs.

Commercial fishing for smelt is allowed in only six tidal rivers in the state, all in Washington County: the East Machias, Pleasant, and Narraguagus rivers from January 1 through April 10, without any limit on quantity; and the Indian, Harrington, and Chandler rivers with no limit on quantity or time period. Anyone fishing commercially for smelt must possess a Pelagic License from the ME DMR. With possession of this license, the fisherman is required to submit landings data to the ME DMR. The ME DMR is working with Downeast Salmon Federation to survey the biological composition of the catches to determine if the fishery may be impacting life history or age structure. This collaboration is necessary to monitor the fishery, and should continue in the future. If over time there is evidence of smelt population decline in this region or evidence that the commercial fishery may be contributing to a high mortality, management actions should address the fishing effort possibly by limiting take or further gear restrictions.

Marked larval stocking at monitored sites

As part of this project, the ME DMR revisited historical spawning runs to document their current status and found that many sites no longer support spawning or support only limited runs (see section 1.3 – Population Status in the Gulf of Maine). When the decline at these sites can be attributed to historical fishing pressure that no longer exists or to habitat degradation or passage constraints that have been addressed, larval stocking may be an option to reintroduce smelt.

Adapting methods by Ayer et al. (2012), the ME DMR began a project to restore rainbow smelt populations to North Haven, Maine, an island in the center of Penobscot Bay that supported robust smelt populations up until the 1950s. After visits by ME DMR to identify the most appropriate stream for the project, the North Haven Community School completed pre-monitoring and found no water quality impairments that would affect smelt embryo survival. In spring 2012, the ME DMR and school worked together to mark larvae with oxytetracycline (OTC) for release at the stream. The school and ME DMR will continue to monitor adult returns in subsequent years to determine the success of the project. Following this model, the ME DMR hopes to continue to re-establish smelt populations at sites where restoration projects have improved habitat quality or connectivity. However, habitat restoration must always precede any stocking efforts.

Recommendations

With continued population monitoring and threat assessment in collaboration with fisheries managers, university scientists, recreational and commercial fishermen, and interested citizens, rainbow smelt populations could be maintained or possibly expanded.

With continued population monitoring and threat assessment in collaboration with fisheries managers, university scientists, recreational and commercial fishermen, and interested citizens, the rainbow smelt populations in Maine could be maintained or possibly expanded. To this end, the ME DMR has begun to implement restoration efforts, including a stocking project in North Haven and assessment of culvert replacements that would provide access to historical habitat. Future work in the state of Maine to protect this species of concern should include:

1) Continuing monitoring of smelt populations through fyke net sampling, creel surveys, the inshore trawl survey, and the juvenile abundance survey
2) Developing a mark-recapture study to estimate the current extraction rate of recreational ice fishing on the Kennebec River and Merrymeeting Bay and other rivers and embayments that support recreational ice fishing
3) Restoring stream connectivity and access to historical spawning grounds with monitoring to assess pre- and post-construction conditions and smelt populations
4) Assessing threats to smelt habitat and evaluating connections between degraded habitat and local smelt population decline
5) Stocking rainbow smelt larvae marked with oxytetracycline into historical smelt spawning streams that maintain good habitat, while maintaining the genetic structure as identified by this project and annually monitoring stocking success.

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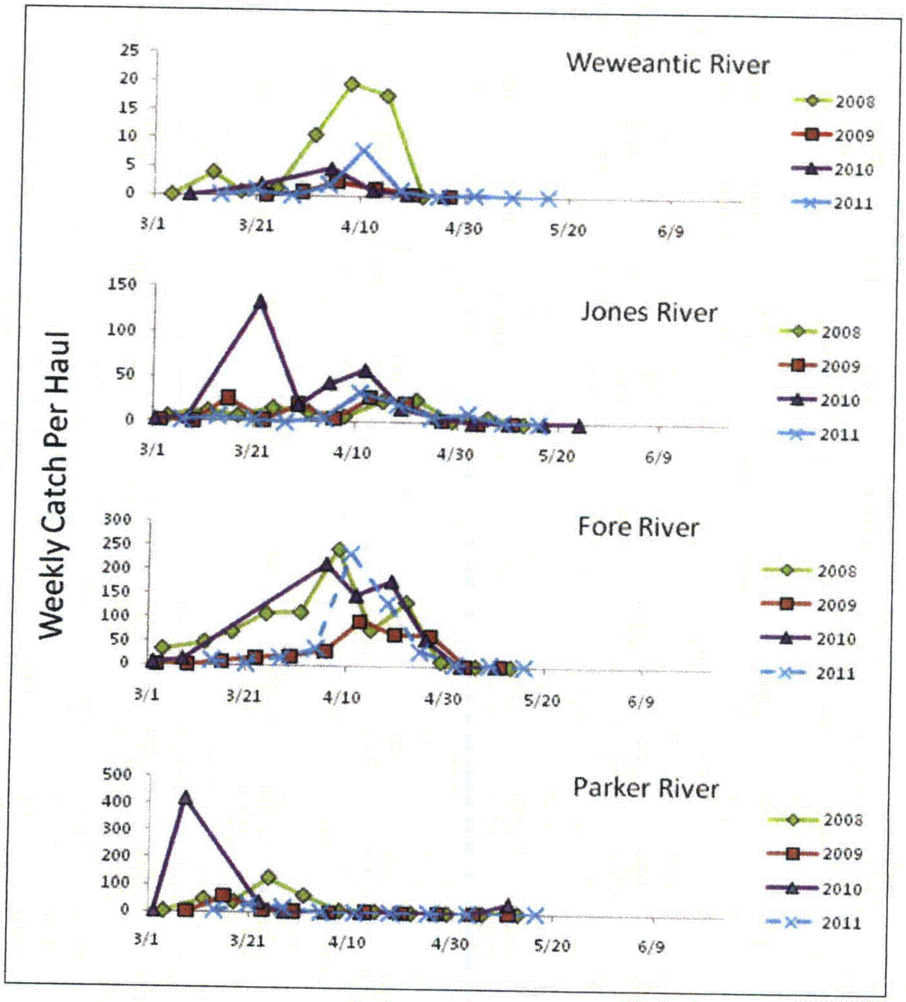

Figure A.1.1. Catch-per-unit-effort (number of smelt per haul) at selected Massachusetts fyke net stations, 2008-2011.

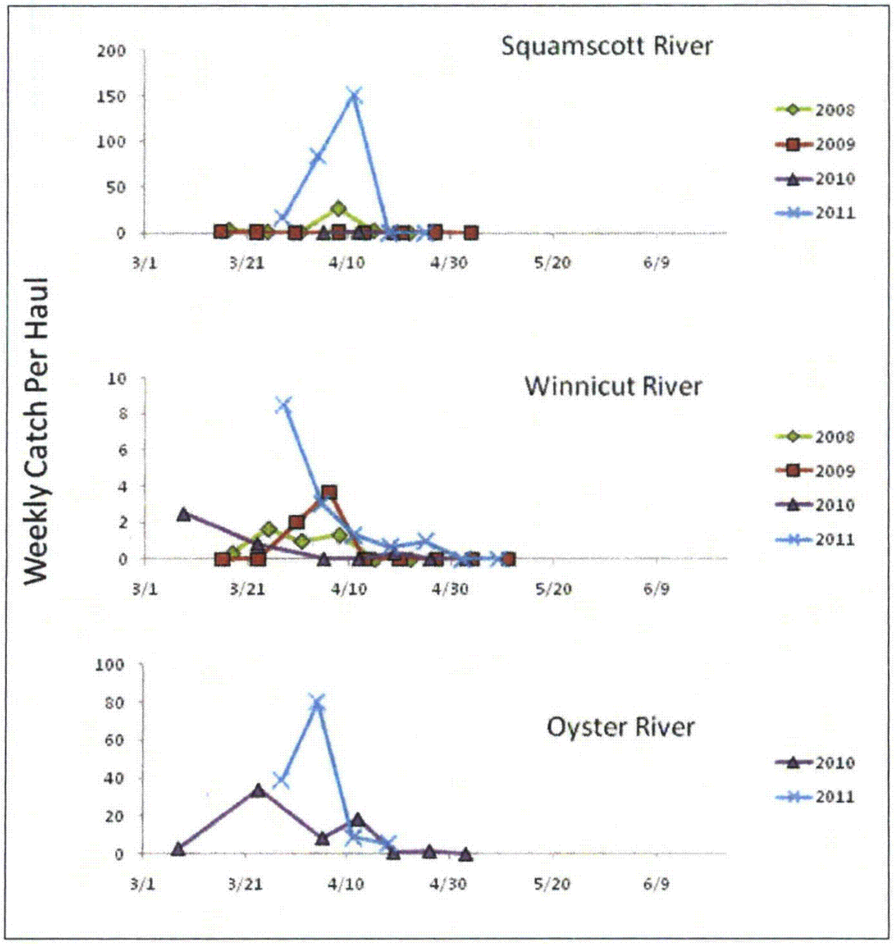

Figure A.1.2. Catch-per-unit-effort (number of smelt per haul) at New Hampshire fyke net stations, 2008-2011.

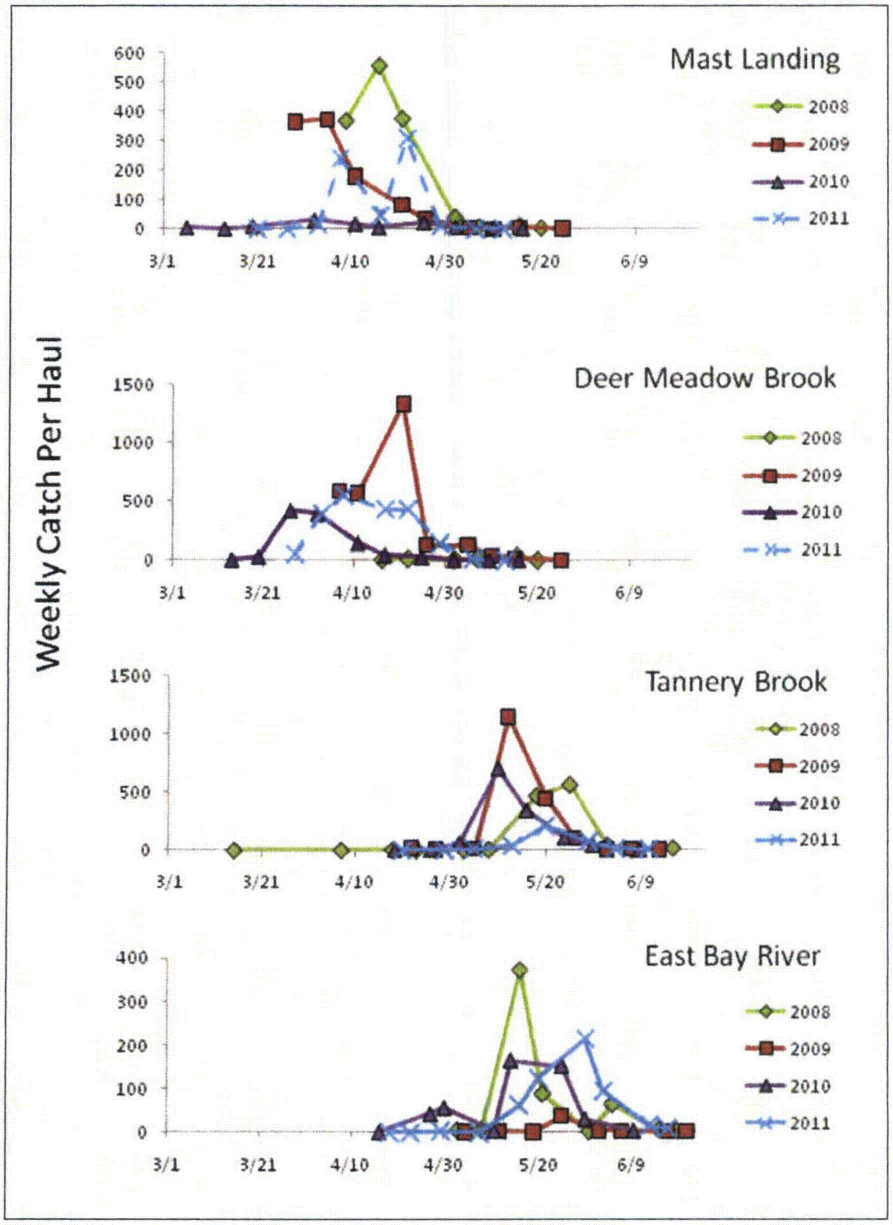

Figure A.1.3. Catch-per-unit-effort (number of smelt per haul) at selected Maine fyke net stations, 2008-2011.

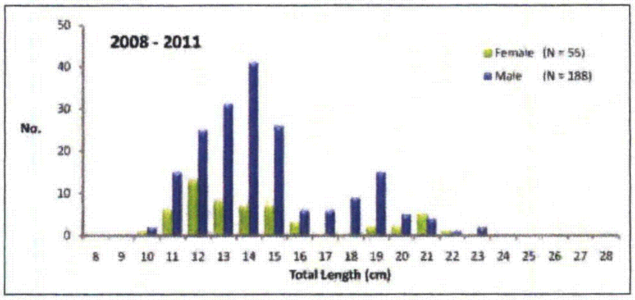

Figure A.1.4. Length frequency of rainbow smelt caught in the Weweantic River, MA, fyke net, 2008-2011.

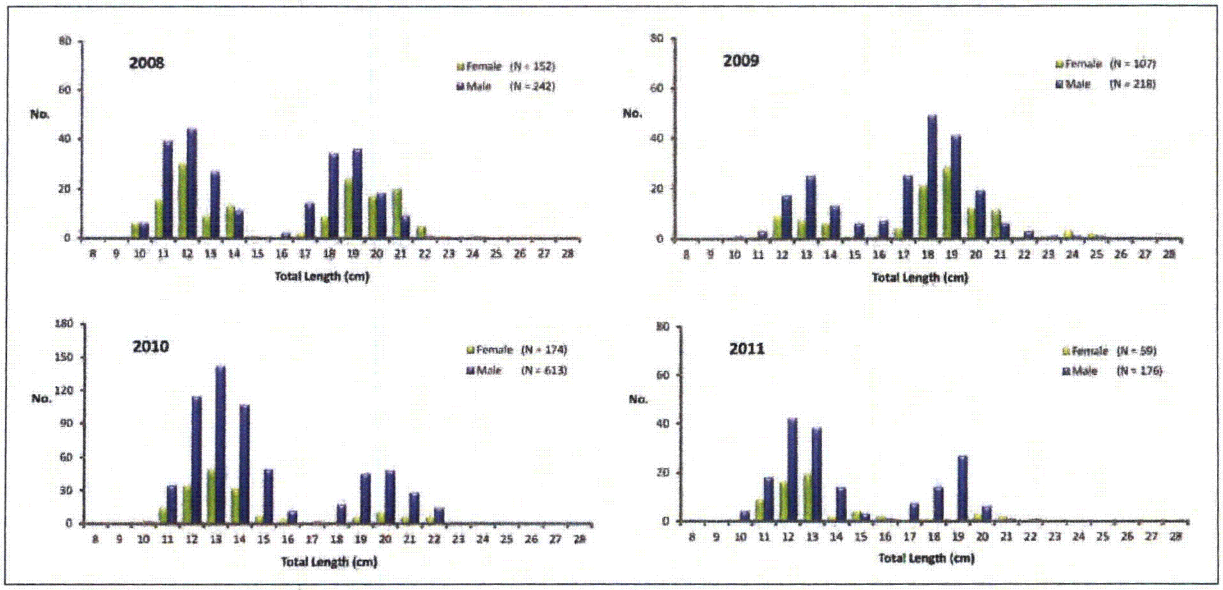

Figure A.1.5. Length frequency of rainbow smelt caught in the Jones River, MA, fyke net, 2008-2011.

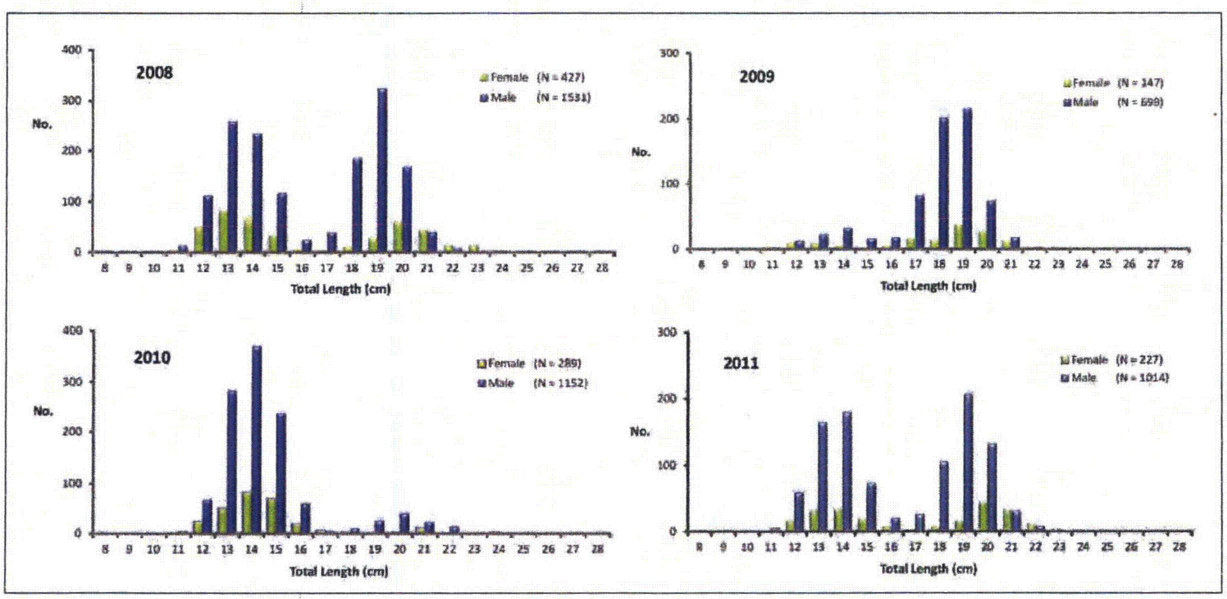

Figure A.1.6 Length frequency of rainbow smelt caught in the Fore River, MA, fyke net, 2008-2011.

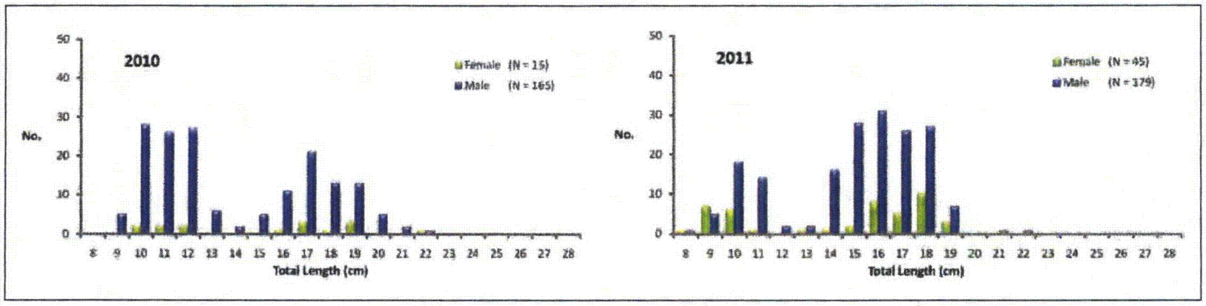

Figure A.1.7. Length frequency of rainbow smelt caught at the Oyster River, NH, fyke net, 2010-2011.

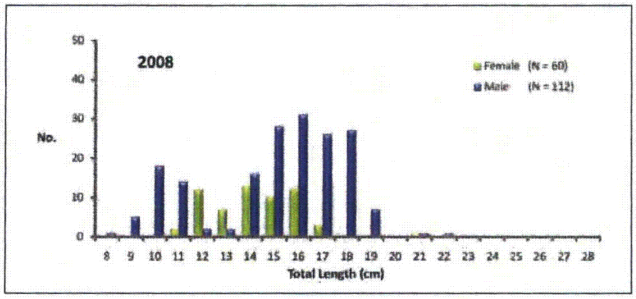

Figure A.1.8. Length frequency of rainbow smelt caught at the Lamprey River, NH, fyke net, 2008.

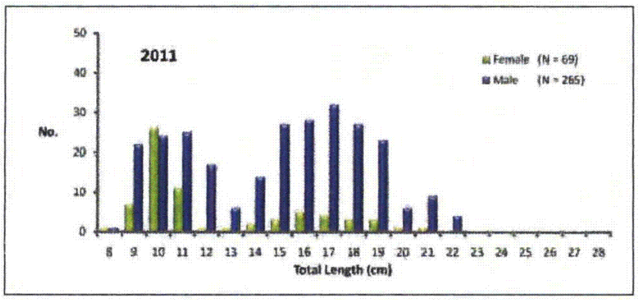

Figure A.1.9. Length frequency of rainbow smelt caught at the Squamscott River, NH, fyke net, 2011

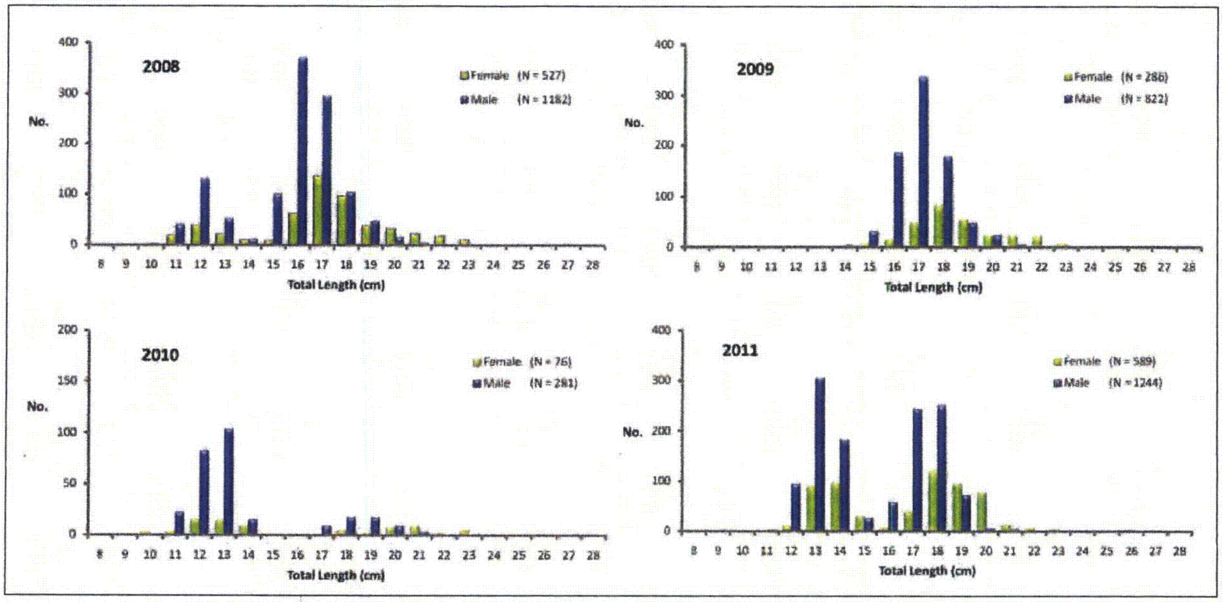

Figure A.1.10. Length frequency of rainbow smelt caught at Mast Landing, ME, fyke net, 2008-2011.

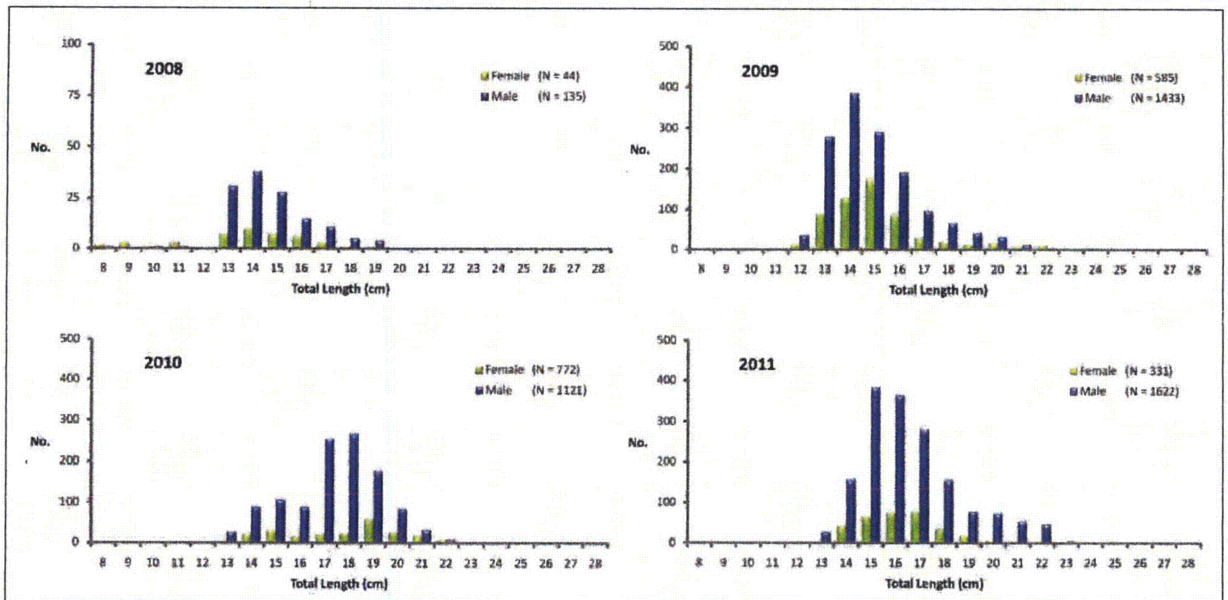

Figure A.1.11. Length frequency of rainbow smelt caught at Deer Meadow Brook, ME, fyke net, 2008-2011.

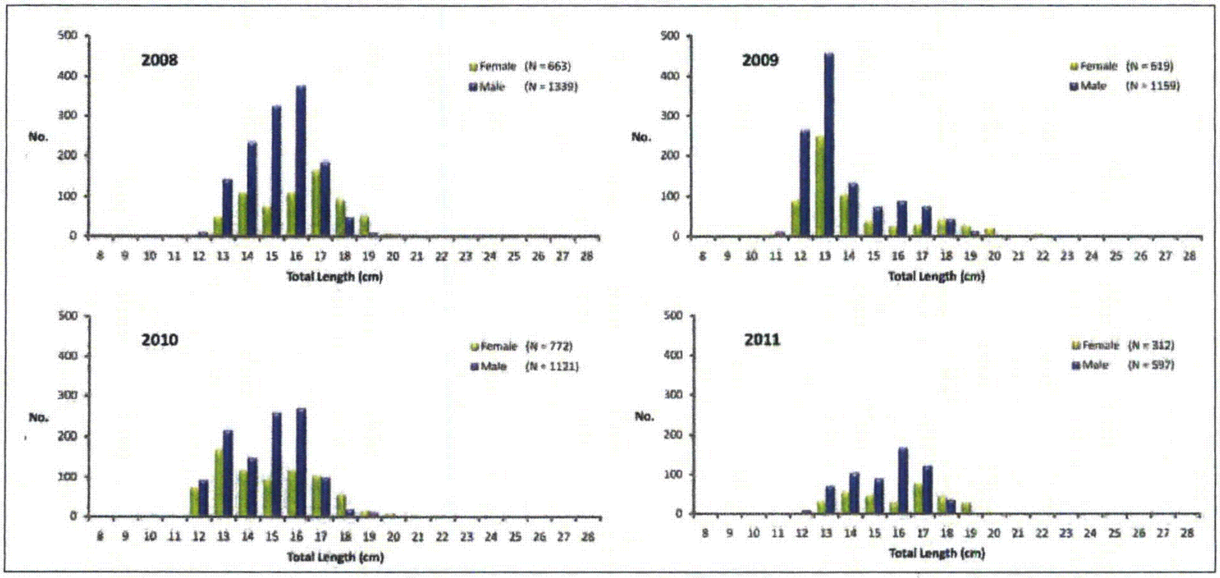

Figure A.1.12. Length frequency of rainbow smelt caught at Tannery Brook, ME, fyke net, 2008-2011.

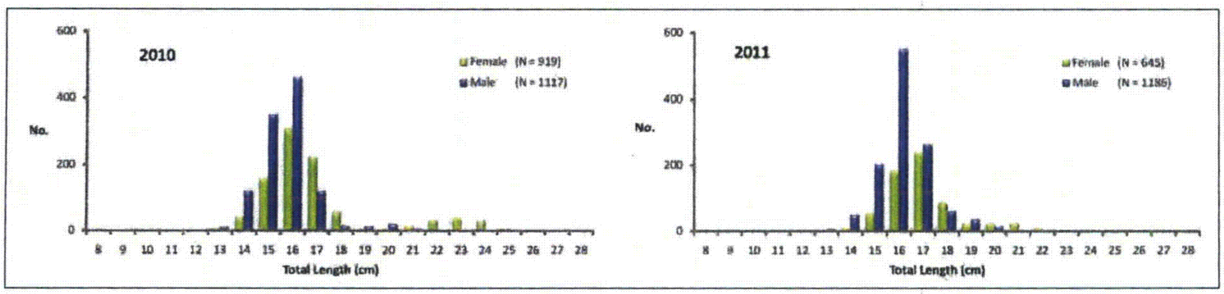

Figure A.1.13. Length frequency of rainbow smelt caught at Schoppee Brook, ME, fyke net, 2010-2011.

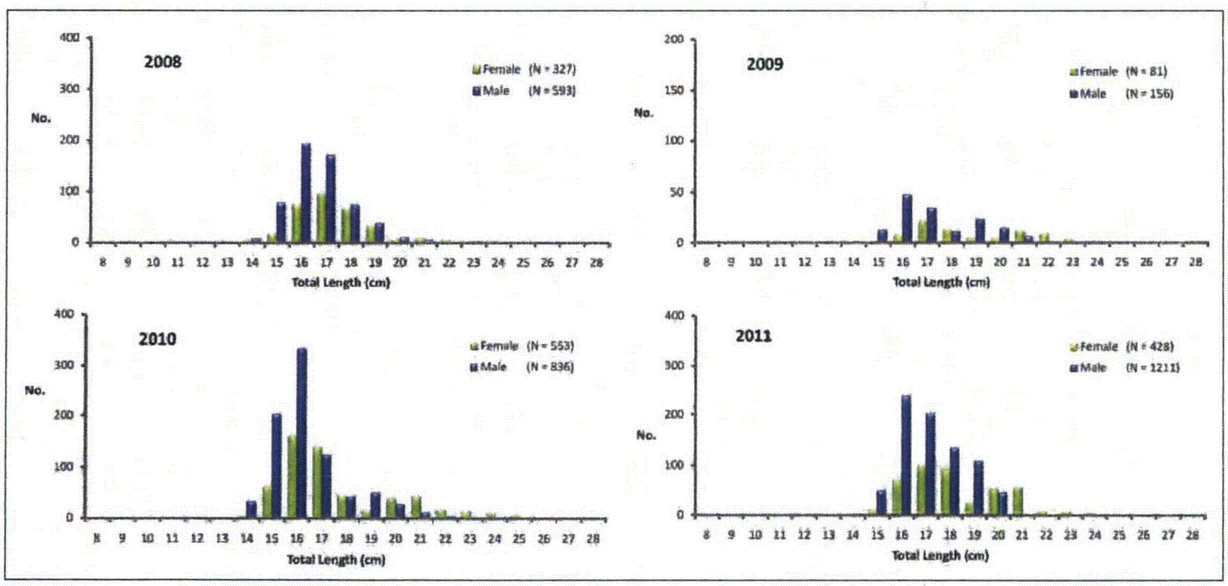

Figure A.1.14. Length frequency of rainbow smelt caught at East Bay Brook, ME, fyke net, 2008-2011.

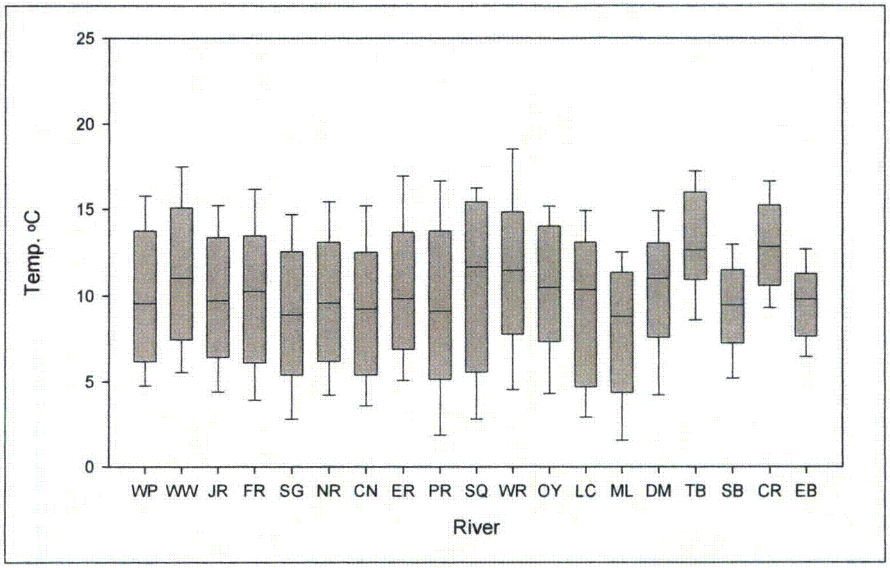

Figure A.2.1. Water temperature data distributions for 19 smelt sampling stations in study area. The top of the box plots is the 75th percentile and the bottom is the 25th percentile. The line within the box is the median and the error bars represent the 10th and 90th percentiles. The stations are arranged on the x-axis from the southernmost MA station to the northernmost ME station. Station medians were found to be significantly different with Kruskal-Wallis test (KW = 93.21, df = 18, p < 0.001).

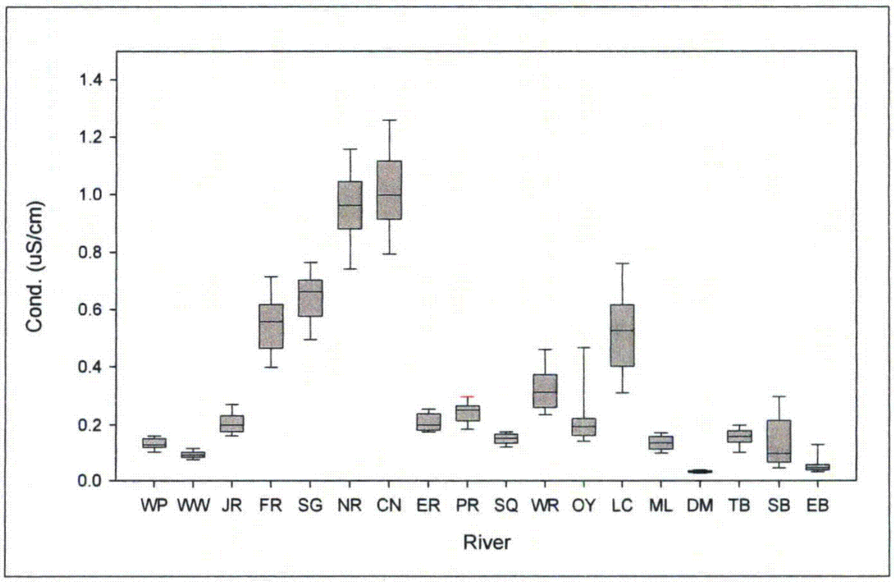

Figure A.2.2. Specific conductivity data distributions for 18 smelt sampling stations in study area. The top of the box plots is the 75th percentile and the bottom is the 25th percentile. The line within the box is the median and the error bars represent the 10th and 90th percentiles. The stations are arranged on the x-axis from the southernmost MA station to the northernmost ME station. Station medians were found to be significantly different with Kruskal-Wallis test (KW =1374.4, df = 17, p < 0.001).

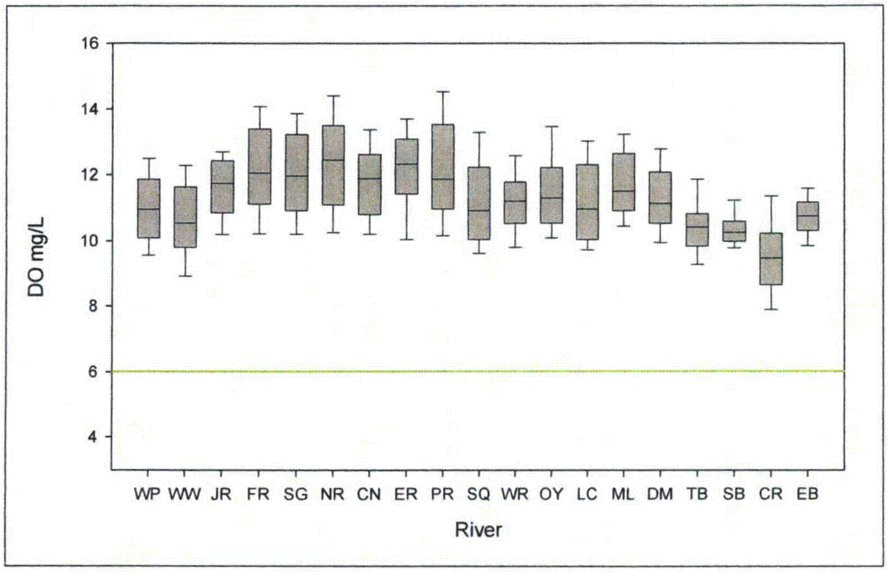

Figure A.2.3. Dissolved oxygen (mg/L) data distributions for 19 smelt sampling stations in study area. The top of the box plots is the 75th percentile and the bottom is the 25th percentile. The line within the box is the median and the error bars represent the 10th and 90th percentiles. The stations are arranged on the x-axis from the southernmost MA station to the northernmost ME station. Station medians were found to be significantly different with Kruskal-Wallis test (KW = 439.51, df = 18, p < 0.001). The green line marks the MassDEP DO criterion (6.0 mg/L) for protecting Aquatic Life.

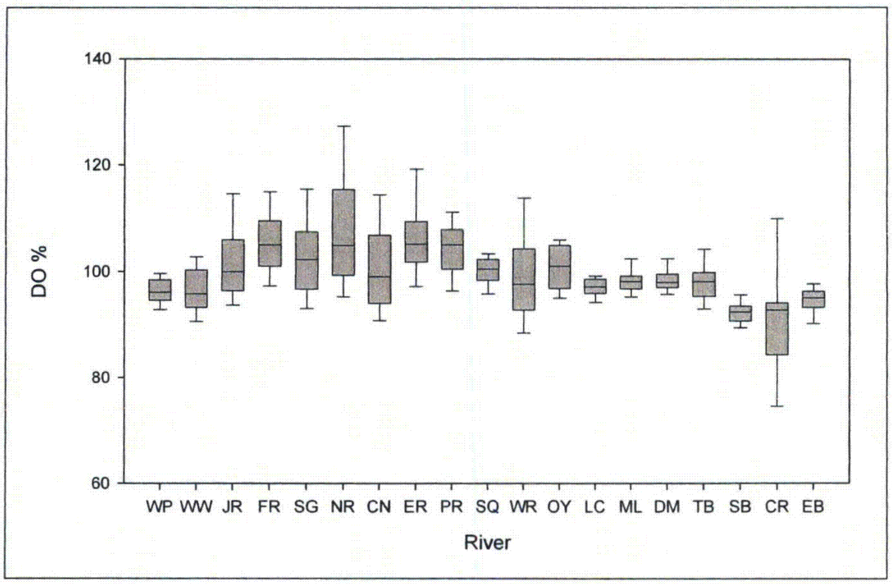

Figure A.2.4. Dissolved oxygen (% saturation) data distributions for 19 smelt sampling stations in study area. The top of the box plots is the 75th percentile and the bottom is the 25th percentile. The line within the box is the median and the error bars represent the 10th and 90th percentiles. The stations are arranged on the x-axis from the southernmost MA station to the northernmost ME station. Station medians were found to be significantly different with Kruskal-Wallis test (KW = 439.51, df = 18, p < 0.001).

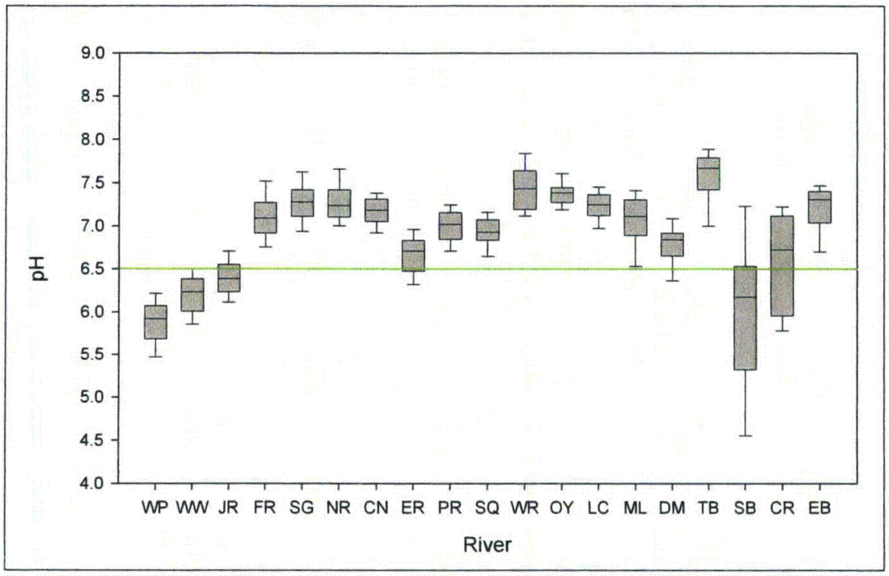

Figure A.2.5. Water pH data distributions for 19 smelt sampling stations in study area. The top of the box plots is the 75th percentile and the bottom is the 25th percentile. The line within the box is the median and the error bars represent the 10th and 90th percentiles. The stations are arranged on the x-axis from the southernmost MA station to the northernmost ME station. Station medians were found to be significantly different with Kruskal-Wallis test (KW = 1041.3, df = 18, p < 0.001). The green lines mark the lower MassDEP pH criterion (≥6.5 and ≤ 8.3) for protecting Aquatic Life.

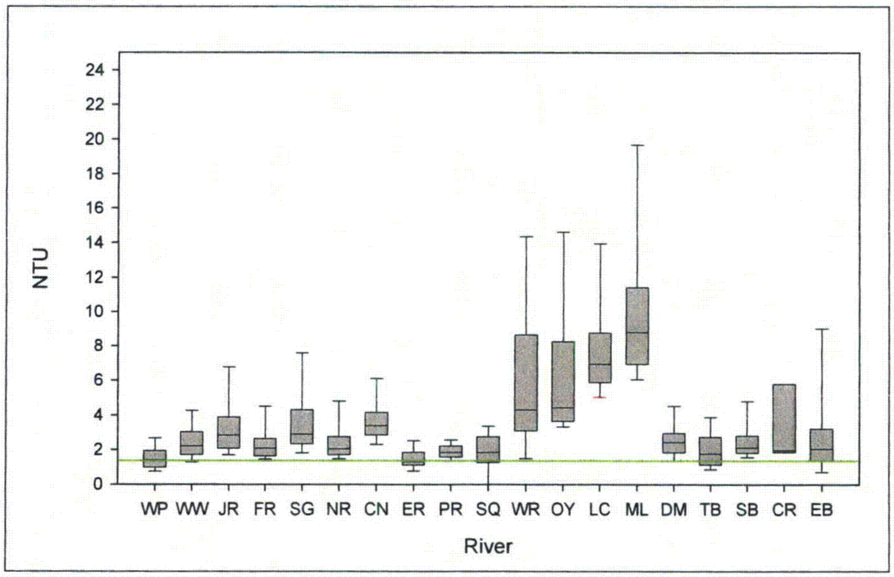

Figure A.2.6. Turbidity (NTU) data distributions for 19 smelt sampling stations in study area. The top of the box plots is the 75th percentile and the bottom is the 25th percentile. The line within the box is the median and the error bars represent the 10th and 90th percentiles. The stations are arranged on the x-axis from the southernmost MA station to the northernmost ME station. Station medians were found to be significantly different with Kruskal-Wallis test (KW = 660.8, df = 18, p < 0.001). The green line marks the EPA turbidity criterion for minimally impacted water quality (≤ 1.7 NTU).

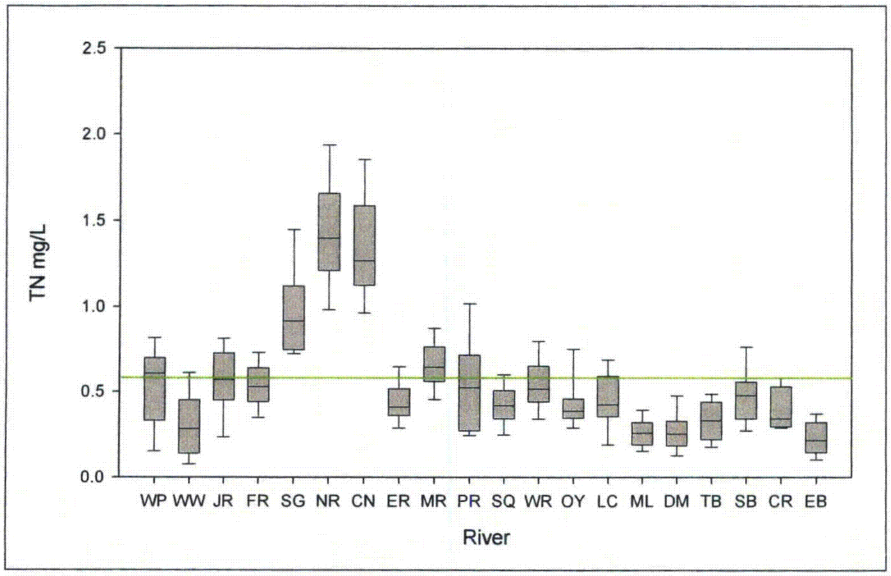

Figure A.2.7. Total nitrogen (TN) data distributions for 20 smelt sampling stations in study area. The top of the box plots is the 75th percentile and the bottom is the 25th percentile. The line within the box is the median and the error bars represent the 10th and 90th percentiles. The stations are arranged on the x-axis from the southernmost MA station to the northernmost ME station. Station medians were found to be significantly different with Kruskal-Wallis test (KW = 408.4, df = 19, p < 0.001). The green line marks the EPA total nitrogen criterion for minimally impacted water quality (≤ 0.57 mg/L).

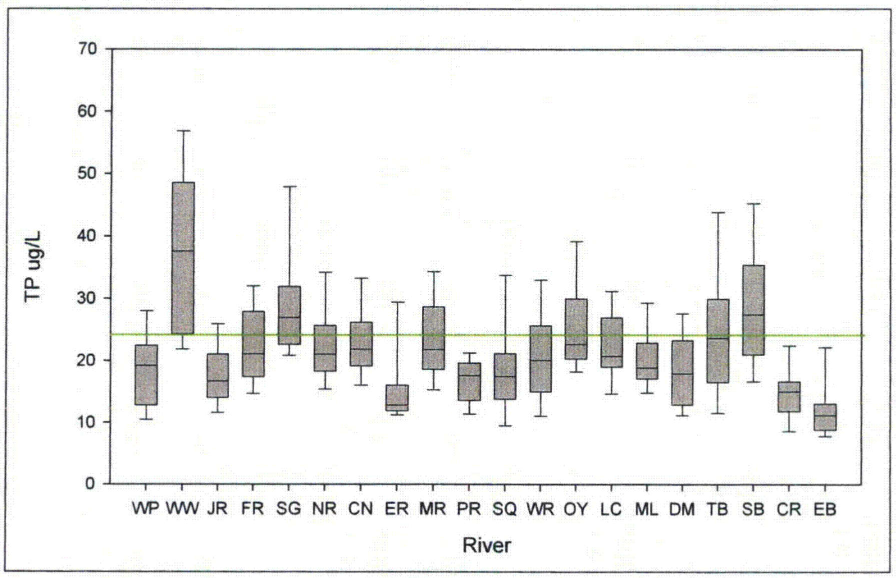

Figure A.2.8. Total phosphorus (TP) data distributions for 20 smelt sampling stations in study area. The top of the box plots is the 75th percentile and the bottom is the 25th percentile. The line within the box is the median and the error bars represent the 10th and 90th percentiles. The stations are arranged on the x-axis from the southernmost MA station to the northernmost ME station. Station medians were found to be significantly different with Kruskal-Wallis test (KW = 174.7, df = 19, p < 0.001). The green line marks the EPA total phosphorus criterion for minimally impacted water quality (≤ 23.75 ug/L).

For a copy of this report online, please visit
www.restorerainbowsmelt.com
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For a printed copy, please contact your state marine agency:

Massachusetts Division of Marine Fisheries
Website: *http://www.mass.gov/dfwele/dmf/*
Boston Offices: (617) 626-1520
Gloucester Regional Office: (978) 282-0308
New Bedford Regional Office: (508) 990-2860

New Hampshire Fish and Game Department
Website: *http://www.wildlife.state.nh.us/*
Durham Marine Fisheries Division: (603) 868-1095

Maine Department of Marine Resources
Website: *http://www.maine.gov/dmr/index.htm*
Sea Run Fisheries Division: (207) 287-9972
Bureau of Marine Sciences: (207) 633-9500

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New York State Department of Environmental Conservation
Office of General Counsel, 14th Floor
625 Broadway, Albany, New York 12233-1500
Fax: (518) 402-9018 or (518) 402-9019
Website: www.dec.ny.gov

Joe Martens
Acting Commissioner

January 28, 2011

VIA ELECTRONIC MAIL
AND HAND DELIVERY

Hon. Maria E. Villa
Hon. Daniel P. O'Connell
Administrative Law Judges
New York State Department of
Environmental Conservation
Office of Hearings and Mediation Services
625 Broadway, 1st Floor
Albany, New York 12233-1550

Re: *Entergy Nuclear Indian Point Units 2 and 3*
CWA Section 401 WQC Application Proceeding
NRC – Atomic Safety and Licensing Board's Dec. 3, 2010 FSEIS

Dear ALJs Villa and O'Connell:

This letter constitutes Department staff's filing in compliance with the *Ruling on Proposed Issues for Adjudication and Petitions for Party Status* dated December 13, 2010, issued in the Entergy Indian Point §401 WQC proceeding ("Issues Ruling"), and with item 3 of the Scheduling Order attached to the Issues Ruling. Specifically, page 9 of the Issues Ruling and item "3" of the Scheduling Order directed Department staff to:

> ". . . advise the ALJs and the parties as to whether the Nuclear Regulatory Commission, Atomic Safety and Licensing Board's December 3, 2010 Final Supplemental Environmental Impact Statement ('FSEIS') is sufficient for Department Staff to make the findings required by Section 617.11 of 6 NYCRR."[1]

It is Department staff's position after due deliberation that, in conjunction with or as otherwise supplemented by the Final Environmental Impact Statement by the Department concerning the Applications to Renew SPDES Permits for Three Hudson River Power Plants accepted June 25, 2003, along with the Department's records of proceedings (administrative hearing records) for both the Entergy Indian Point SPDES permit (DEC No.: 2-5522-00011/00004) and Entergy Indian Point §401 WQC application (DEC Nos.: 3-5522-00011/0030 and 3-5522-00105/00031), as well as with the NRC's record of proceeding (hearing file and record) for Entergy's license renewal for Indian Point Units 2 and 3 (Docket

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[1] Department staff notes that the December 3, 2010 FSEIS was prepared by staff of the NRC, not by the Atomic Safety and Licensing Board, and that such FSEIS is not yet actually "final."

Nos. 50-247-LR and 50-286-LR; ASLBP No. 07-858-03-LR-BD01), including but not limited to any contentions, attachments, reports, declarations, comments, and administrative hearings relating to or arising from the publication by the NRC Staff on December 3, 2010, of the FSEIS for the renewal of the Indian Point nuclear operating licenses, the NRC Staff's FSEIS (insofar as it may be further supplemented or amended by future proceedings noted herein) would be sufficient for the purpose of making findings as required by 6 NYCRR §617.11. Department staff notes that, consistent with the provisions of 6 NYCRR §617.15(c), a final decision by a Federal agency is not controlling on any agency decision on the proposed action, but may be considered by the agency. In addition, consistent with the provisions of 6 NYCRR §617.11(e), Department staff further notes that, because the Indian Point nuclear facilities are located in the coastal area (as defined in 6 NYCRR §617.2[f]), the agency cannot make a final determination on the proposed action until there has been a written finding that the action is consistent with applicable policies set forth in 19 NYCRR §600.5.

Thank you for your courtesies and attention to this matter.

Very truly yours,

Mark D. Sanza
Assistant Counsel

Via U.S. Mail and E-Mail:

Elise N. Zoli, Esq.
John C. Englander, Esq.
Goodwin Procter, LLP
Exchange Place
Boston, Massachusetts 02109

ezoli@goodwinprocter.com
jenglander@goodwinprocter.com
rfitzgerald@goodwinprocter.com

Rebecca Troutman, Esq.
Riverkeeper, Inc.
20 Secor Road
Ossining, New York 10562

rtroutman@riverkeeper.org

Melissa-Jean Rotini, Esq.
Assistant County Attorney
County of Westchester
Room 600, 148 Martine Avenue
White Plains, New York 10601

mjr1@westchestergov.com

Richard L. Brodsky, Esq.
2121 Saw Mill River Road
White Plains, New York 10607

richardbrodsky@gmail.com

Daniel Riesel, Esq.
Sive, Paget & Riesel, P.C.
460 Park Avenue, 10th Floor
New York, New York 10022

driesel@sprlaw.com

Steven Blow, Esq.
Assistant General Counsel
New York State Department of Public Service
Agency Building Three
Empire State Plaza
Albany, New York 12233-1350

steven_blow@dps.state.ny.us

Sam M. Laniado, Esq.
David B. Johnson, Esq.
Read and Laniado, LLP
25 Eagle Street
Albany, New York 12207-1901

sml@readlaniado.com
dbj@readlaniado.com

Michael J. Delaney, Esq.
Director, Energy Regulatory Affairs
New York City Department of Environmental Protection
59-17 Junction Boulevard, 19th Floor
Flushing, New York 11373-5108

mdelaney@dep.nyc.gov

Robert J. Glasser, Esq.
Robert J. Glasser, P.C.
284 South Avenue
Poughkeepsie, New York 12601

Bob.glasser@robertjglasserpc.com

Via E-Mail Only:

Ned Sullivan, President
Hayley Mauskapf, Esq.
Paul Schwartzberg
Scenic Hudson, Inc.

nsullivan@scenichudson.org
hmauskapf@scenichudson.org
Schwartzberg@scenichudson.org

Karl S. Coplan, Esq.
Daniel E. Estrin, Esq.
Pace Environmental Litigation Clinic, Inc.

kcoplan@law.pace.edu
destrin@law.pace.edu

Deborah Brancato, Esq.
Phillip H. Musegaas
Riverkeeper, Inc.

dbrancato@riverkeeper.org
phillip@riverkeeper.org

Geoffrey H. Fettus, Esq. Natural Resources Defense Council	gfettus@nrdc.org
Frank V. Bifera, Esq. Hiscock & Barclay, LLP	fbifera@hblaw.com
Kelli M. Dowell, Esq. Entergy Services, Inc.	kdowell@entergy.com

EDMS#390924v1