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Comment On: NRC-2008-0672-0029
Entergy Nuclear Operations, Inc.; Indian Point Nuclear Generating Unit Nos. 2 and 3; Draft Supplemental Environmental Impact Statement; Request for Comment

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Submitter Information

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Organization: NYS Dept of Environmental Conservation
Government Agency Type: State
Government Agency: NYS Dept of Environmental Conservation

General Comment

See attached file(s)

Attachments

Hattala et al 2011

Oak Ridge Lab 1979

Limburg&Waldman2009

Limburg&Moran 1986

Limburg et al 2006

Kahnle&Hattala 2010

SUNSI Review Complete
Template = ADM – 013
E-RIDS= ADM -03
Add= M. Wentzel (mjw2)

Barnthouse 2013

Barnthouse & Van Winkle 1988

NMFS Colosi letter 12Oct2010

Bladey letter

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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March 4, 2016

Ms. Cindy Bladey
Office of Administration
Mail Stop: OWFN-12-H08
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

RE: Comments on the Generic Environmental Impact Statement for License Renewal of Nuclear Plants, 5 Supplement 38, Volume 5, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3, Draft 6 Report for Comment (NUREG–1437).

Dear Ms. Bladey:

On behalf of New York State Department of Environmental Conservation ("NYSDEC" or "Department"), please accept the following comments regarding the U.S. Nuclear Regulatory Commission's ("NRC") *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, 5 Supplement 38, Volume 5, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3, Draft 6 Report for Comment* dated December 2015 (NUREG–1437) ("Draft GEIS"). NYSDEC appreciates the efforts of NRC staff to augment the record of the Final Generic Environmental Impact Statement so that it may consider new information received. The Department also appreciates the opportunity to comment on these proposed changes.

I. Introduction

As you are likely aware, the Department has previously provided comments on the draft and final NRC documents as they relate to the impacts associated with relicensing Indian Point to operate an additional 20 years. (See, August 20, 2012 E. McTiernan letter to C. Bladey; May 26, 2011 Comments on the Final Supplemental Environmental Impact Statement; March 18, 2009 Comments to the NRC on the Draft Supplemental Environmental Impact Statement.) These previously submitted and timely comments are relevant to this latest draft GEIS considering the analyses used by NRC staff in developing Section 4.0 of the 2015 Draft GEIS to determine adverse impact to aquatic organisms are identical to those used in previous drafts. In particular, I draw your attention to Section III *Analysis of Aquatic Impacts* presented in the Department's March 18, 2009 comments. The following comments primarily respond to the re-evaluation of the aquatic impacts presented in Section 4.0 and summarized in Section 9.0 of the 2015 Draft GEIS.

II. The NRC continues to apply the incorrect metric (*i.e.*, impacts to the overall fish populations) to determine if relicensing Indian Point for 20 years will result in an adverse environmental impact to the aquatic natural resources of the Hudson River.

12-L15-1

NRC staff continue to take a general fisheries approach to assess potential impacts of the Indian Point cooling water intake structure ("CWIS"). In this latest Draft GEIS, the NRC Staff continue to assess the severity of impact based on the *overall population,* and not on the *massive numbers of actual organisms* that have been, are currently, and will continue to be impinged and entrained as long as Entergy operates the once-through cooling system at Indian Point. (See also, March 18, 2009 NYSDEC Comments to the NRC on the Draft Supplemental Environmental Impact Statement *at* p. 9.) NYSDEC, the U.S. Environmental Protection Agency, and the United States Court of Appeals for the Second Circuit have rejected a population analysis as the measurement of the aquatic impacts caused by once-through cooling. Both NYSDEC and the U.S. EPA define the adverse environmental impact caused by a CWIS as the number of fish and shellfish impinged and entrained. (See, U.S. EPA 2014 at p. 48303; NYSDEC Department Policy CP-52 *at* p. 2; Riverkeeper, Inc. v U.S. EPA, 475 F.3d 83, 109 (2d Cir. 2007)(Riverkeeper II), 475 F.3d at 124, 125 fn.36.) For the operation of the Indian Point CWIS, this equates to an annual adverse environmental impact of *over 1 billion fish* of all life stages.

The Department does not agree with the NRC that the adverse impact caused by the impingement and entrainment of fish at Indian Point should be assessed at the population level. (See, March 18, 2009 NYSDEC Comments on the NRC's Staffs Draft Supplemental Environmental Impact Statement *at* p. 9-11.) Besides the fact that the Department, the U.S. EPA, and the U.S. Court of Appeals have all agreed that such an analysis is not appropriate, attempting to determine if the impingement and entrainment of a single power plant has caused impacts on fish populations is an impossible endeavor. Barnthouse and Van Winkle (1988) concluded that determining the long-term impacts to fish populations caused by the operation of a CWIS was unattainable (*at* p. 188). For more than 40 years, a multitude of studies have attempted and failed to detect population level impacts caused by the impingement and entrainment of fish at power plants (Barnthouse 2013). Before the Hudson River monitoring program was started, federal agency scientists cast serious doubts as to whether any population impact resulting from once-through cooling could be detected. (See, Oak Ridge National Laboratory Sept. 28, 1979 letter to the U.S. EPA *at* p. 2.) Thirty four years later, Barnthouse (2013) could not find any example in the published literature where such an impact had been conclusively demonstrated. However, Barnthouse (2013) did not conclude that failing to demonstrate a direct impact proved that one does not truly exist now nor does it prove that no adverse impact may exist in the future. (See, Barnthouse (2013) *at* p. 154-155.) The fact that no link has been found likely relates to the issues raised by the Oak Ridge Laboratory scientists in 1979.

Given this dismal record in attempting to determine the long-term impacts power plants have on fish populations through the impingement and entrainment of fish, it makes little sense that the NRC would choose this very same approach for assessing the long-term impacts relicensing Indian Point would have on Hudson River fish. It was simply not appropriate for the NRC to ignore the Department's conclusion that Indian Point does cause an adverse environmental impact on Hudson River fish considering the Department has the proper expertise and authority to make such a determination of adverse impact. As previously stated, the Department's conclusions are based on the fact that Department staff have been collecting and analyzing Hudson River aquatic organism data and impingement and entrainment data from Hudson River power plants for decades. Given this fact, the Department is entitled to substantial deference in its determination that the continued level of impingement and entrainment at Indian Point does indeed cause an adverse environmental impact on Hudson River fish. 12-L15-1 cont'd

III. New York State Department of Environmental Conservation, New York State Department of State, and the National Marine Fisheries Service all have determined that the impingement and entrainment caused by Indian Point's once-through cooling system results in significant adverse impacts on fish and other aquatic organisms. 12-L15-2

The Department is encouraged that NRC staff recognizes the Department's concern with the current status of some Hudson River fish populations. The NRC points to Department documents regarding the status and proposed management of blueback herring. (See, 2015 Draft GEIS at p. 29 line 40 though p. 30 line 28.) The NRC points out that it agrees with NYSDEC's findings that the Hudson River blueback herring population has declined and the trend in blueback herring, alewife, and American shad populations may indicate a change in overall stability in the Hudson River system. The Department also concurs with the NRC that water withdrawals are a significant threat to the recovery of anadromous fish species such as blueback herring and American shad. As the NRC noted, the National Marine Fisheries Service ("NMFS") recently determined that, "...any protection measures [from Maine/Canada to Florida] such as improved fish passage *or a reduction of water withdrawals* may also provide a benefit to river herring." (See NMFS 2013, Federal Registrar Vol. 78 No. 155 *at* p. 48966; emphasis added.) Department fisheries scientists have identified cooling water withdrawals as a threat to the recovery or Hudson River American shad (see, Kahnle and Hattala 2010 *at* p. 1) and have determined that the impingement and entrainment caused by cooling water withdrawals on the Hudson River must be reduced or eliminated. (See, Kahnle and Hattala 2010 *at* p. 5.) The published literature also identifies cooling water withdrawals by Hudson River power plants as a significant threat to the population status of river herring and American shad (Limburg and Waldman 2009, Limburg *et al.* 2006).

In the 2015 Draft GEIS, NRC staff neglected to recognize the update to the Hudson Highlands Significant Coastal Fish and Wildlife Habitat ("SCFWH") recently finalized by the NYS Department of State ("NYSDOS"). This update added the reach of river from which Indian Point withdrawals cooling water (*i.e.,* River Segment 4) to the boundary of the Hudson Highlands SCFWH because it is a major spawning area for Hudson River striped bass. In fact, the striped bass population in this area contributes to the commercial and recreational fisheries in New York State. Furthermore, both Atlantic and shortnose sturgeon species frequent this deep water area, and based on recent radio tracking surveys conducted by the Department fisheries scientists, these species are frequently found near the Indian Point security exclusion zone located on the east shore of the Hudson River. In the Significant Coastal Fish and Wildlife Habitat Assessment for the Hudson Highlands SCFWH, NYSDOS states that "[e]ntrainment and impingement causes *significant mortality* to all life stages of fish, including endangered species" (*at* p. 3; emphasis added). This determination is supported by the results of impingement, entrainment and environmental studies conducted on the Hudson River for more than 40 years. The results of these studies have been published in many peer reviewed scientific papers and books (<u>see</u>, for example, Levinton and Waldman 2006, Smith 1992, Smith 1988, and Barnthouse *et al*. 1988).

12-L15-2 cont'd

On November 6, 2015 the NYSDOS objected to Entergy's consistency certification for the Indian Point NRC license renewal application. NYSDOS found that the relicensing of Indian Point would result in the "*significant and direct loss to populations* of numerous fish species as a result of impingement and entrainment." (<u>See</u>, Indian Point Coastal Zone Management Act Consistency Determination *at* p. 22.) NYSDOS stated that "...Indian Point's CWIS alone destroys more than 150,000,000 striped bass larvae each year through entrainment. River herring and American shad are entrained in large numbers in the CWIS at Indian Point. Hudson River fish studies, conducted by the utility operators under the Hudson River Settlement Agreement, concluded that the CWISs at Indian Point entrain approximately 13,380,000 American shad and nearly 500,000,000 river herring larvae and small juvenile fish each year. Documentation shows that both sturgeon species have been impinged and killed at Indian Point. Based in part on Indian Point historical data, NMFS estimated that between 1975 and 1990, over 1,100 Atlantic and shortnose sturgeon have been impinged and killed on the Indian Point CWISs. In addition to effects on these fish species, impingement/entrainment affects a broad array of other aquatic organisms, all integral components of the Hudson River ecosystem." (<u>See</u>, Indian Point Coastal Zone Management Act Consistency Determination *at* p. 22; citations omitted.)

NMFS, NYSDEC, NYSDOS have all pointed to the impingement and entrainment by the Indian Point CWIS as a significant cause of mortality to Hudson River fish. Since all three of these agencies agree that this mortality must be reduced or eliminated to protect Hudson River Essential Fish Habitat, assist in the recovery of American shad and river herring, protect commercially important striped bass, and protect federally endangered sturgeon species, the NRC must not ignore these findings by relicensing Indian Point without significant mitigation. Since the NRC agrees with the NYSDEC and NMFS that the withdrawal of Hudson River water for cooling purposes poses a significant threat to the Hudson River blueback herring population, the NRC should accept NMFS recommendation and require Entergy to convert the existing open loop cooling system to closed-cycle cooling. (<u>See</u>, NMFS P. Colosi, Jr. 2010 Letter to the NRC *at* p. 9.) This technology has been identified by NYSDEC and NMFS as the best technology available to minimize the adverse environmental impact Indian Point has on Hudson River fish.

IV. The Department does not agree with Entergy's claim that new information on impingement and entrainment was actually provided to the NRC.

12-L15-3

It is the Department's understanding that the purpose of Section 4.0 presented in the 2015 Draft GEIS is to respond to purportedly "new information and analysis" that according to Entergy "indicated that potential impacts to certain aquatic species as a result of projected entrainment and impingement at Indian Point Nuclear Generating Unit Nos. 2 and 3 (IP2 and IP3) during the license renewal period would change..." (<u>See</u>, Draft Supplemental 38 Vol. 5 at p. 25 lines 8-11.) According to the Draft GEIS, Entergy claimed to have provided "new information regarding entrainment, impingement, and field data..." *See,* Draft GEIS *at* p. 25 lines 42 to 44. Simply put, there is no new information for the entrainment and impingement of fish at Indian

Point. As the Department pointed out to the NRC in comments it provided in 2012, the "foundational data base for entrainment and impingement at Indian Point Units 2 and 3 is more than 25 years old…." (*See*, E. McTiernan Aug. 20 2012 letter to C. Bladey *at* p. 1.) Entergy may have sent the NRC information based on a new analysis either using historical data or perhaps new fish abundance data collected by Entergy's consultants, but Entergy could not have provide new information regarding entrainment and impingement. 12-L15-3 cont'd

V. The changes presented in Section 4.0 of the 2015 Draft GEIS are a result of conflicting opinions among the NRC and Entergy's experts but are not based on substantially new information. 12-L15-4

The proposed changes presented in Section 4.0 of the Draft GEIS appear to be no more than a dispute between the NRC and Entergy's biological experts on the proper assumptions, calculations, and data to be used in an attempt to determine whether or not a 20-year license extension would result in an adverse environmental impact to Hudson River fish populations. This latest attempt made by both Entergy's biologists and the NRC staff has resulted in two additional, contradictory results for the majority of the 18 representative important species ("RIS") considered. This process of continually changing the output of the population models provides ample proof that attempting to estimate the potential impacts 20 years of operating Indian Point will have on Hudson River fish populations is simply a misguided effort. Based on the information provided in the Draft GEIS, it is clear that Entergy's biologists and NRC staff cannot agree on the assumptions, the variables, nor the years of data that should be used. Furthermore, though Entergy and the NRC may have altered their conclusions as to which fish populations may be impacted, this does not change the fact that the continued operation of Indian Point's Unit 2 and Unit 3 CWIS impinges and entrains over *1 billion* fish annually. NYSDEC has long recognized this adverse environmental impact as being significant and has concluded that this impact must be minimized or eliminated.

This purported "new information" Entergy provided to the NRC was primarily a criticism of the NRC's staff methods for determining the level of impact (*i.e.*, small, medium, or large) that 20 additional years of continued operation of the Indian Point CWIS would have on Hudson River fish populations through entrainment. The AKRF 2014 report submitted to the NRC on behalf of the applicant purported that the NRC's methods were "highly conservative" leading to incorrect conclusions of "large" impacts. (*See*, AKRF 2014 *at* p. 9.) AKRF concluded that the entrainment mortality rates estimated by the NRC were "overstated." (*See*, AKRF *at* p.9.) In order to provide assurance that the analyses used to generate the new information the permittee was providing to the NRC had been put through a "thorough quality control review", AKRF states on page 6 of their 2014 report that an "independent external review" of the AKRF analyses was conducted. This external review was conducted by Dr. John Young of ASA Analysis and Communication, Inc. It is the Department's understanding that Dr. Young of ASA Analysis and Communication, Inc. is on Entergy's Biological Team and has worked with Dr. Heimbuch of AKRF, Inc. on preparing previous analyses and comments on the NRC's biological analyses (*see*, Entergy 2009 *at* p. 2). Though the Department provides no opinion on Dr. Young's ability to review and evaluate such work, his inclusion on Entergy's Biological Team does bring into question the level or degree of independence his review provides. A more transparent independent, external review would require enlisting the services of a third party with no direct financial or administrative ties to the NRC nor the applicant.

12-L15-4 cont'd

Table 4-2 on page 37 of the Draft GEIS indicates that the NRC has now conducted the same analyses twice and that Entergy's consultants have undertaken the analyses at least once in an attempt to determine the level of impact relicensing will have on 18 RIS species. The three sets of results presented in Table 4-2 do not agree for the following 12 species: alewife, Atlantic menhaden, Atlantic sturgeon, blueback herring, gizzard shad, hogchoker, rainbow smelt, shortnose sturgeon, striped bass, weakfish, white perch, and blue crab. There were only six representative important species considered by the NRC where the results of the three attempts at conducting the analyses remained unchanged. This inconsistency of results presented by the NRC gives no comfort to the Department that NRC staff have any idea what the likely impacts extending Indian Point's operating license for 20 years will have on Hudson River fish.

VI. The recent submittal of "new information" provided to the NRC is just a continuation of Entergy's unsubstantiated claim that the operation of Indian Point's once-through cooling system has no effect on Hudson River fish populations.

12-L15-5

On behalf of Entergy, AKRF states that the "methods used by the 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 lead to conclusions of "Large" impacts." _See_, AKRF 2014 *at* p. 9. The latest submission of "new information" by Entergy's consultant is a continued attempt to minimalize the adverse environmental impact the operation of Indian Point has on the overall health of the Hudson River fish community. Entergy's consultants continue to point the blame on the documented declines of several Hudson River fish population on all possible explanations but one: the indiscriminate mortality of over 1 billion fish annual caused by the operation of Indian Point Units 2 and 3 once-through cooling systems. As evidence, they point to their failure to find a direct link between the operation of Indian Point and the decline in fish populations even though they are fully aware of the near impossible task to discover such a link. Given the established record of not being able to detect population effects caused by impingement and entrainment and the fact that failure to detect an impact does not mean one does not exist, it would behoove the NRC to select the metric used by both the U.S. EPA and the NYSDEC, namely Indian Point's direct impingement and entrainment of over 1 billion fish every year.

VII. NYSDEC questions the accuracy of the NRC's estimated historic entrainment at Indian Point but disagrees with Entergy that the results are "highly conservative."

12-L15-6

To determine if Entergy's recent claim that the NRC results were highly conservative is correct (_see_, AKRF 2014 *at* p. 9), Department staff compared the NRC's estimated entrainment contained in Appendix A (_see_, Draft GEIS Table A-7 *at* p. A-15) for seven species whose actual entrainment was reported in the Hudson River Entrainment Abundance Reports covering the years from 1983 to 1987. The results of this comparison are provided in the following table:

12-L15-6 cont'd

Species	Entrainment Years 1983 to 1987 Reported	NRC Estimate	Percent Difference
Striped bass	61,907,000	225,209,000	263.8
White Perch	22,956,000	189,087,000	723.7
Bay anchovy	1,536,144,000	1,583,424,000	3.1
American shad	19,173,000	18,811,270	-1.9
River herring	679,882,000	301,991,600	-55.6
Atlantic tomcod	9,332,000	32,884,000	252.4
Total	2,329,394,000	2,351,406,870	0.9

For four of the species, the NRC's methods do indeed overstate the entrainment that was reported in the 1980s Hudson River Entrainment Abundance Reports (*i.e.*, striped bass, white perch, bay anchovy, and Atlantic tomcod). However, for three species of greatest management concern for NYSDEC, American shad and river herring (includes both alewife and blueback herring), the NRC methods actually *underestimated* what the utility consultants reported to the Department back in the 1980s. Since the NRC is relying on their estimates of entrainment presented in the Draft GEIS to determine the level of adverse impact relicensing will have on 17 Hudson River fish populations, the fact that their estimates of these seven species differ from what has been considered fact for over 30 years adds to the uncertainty of the conclusions made by the NRC on the potential impacts operating the Indian Point existing once-through cooling system for an additional 20 years will have on aquatic organisms.

VIII. The NYSDEC has determined that the continued operation of the Indian Point cooling water intake structure causes a significant adverse environmental impact on Hudson River fish.

12-L15-7

The operation of Indian Point's CWIS indiscriminately kills massive numbers of fish, of all life stages annually. Since impingement and entrainment has not been measured at Indian Point since 1990, the historic data must be used to determine the adverse impact Indian Point had. Simply put, there is no "new information" for entrainment data available for the NRC to consider. The following table presents the baseline[1] entrainment for seven representative important species using the *most recent and complete information on species specific entrainment densities* (1983-1987):

[1] Baseline entrainment is the number of organisms entrained if Indian Point were operating their cooling water intake system at full design capacity. In the 1980s, Indian Point would take unit outages during the time of the year when the majority of entrainment was known to occur at Indian Point (May through August), taking an average of 42 unit outage days annually over the 10 year term of the Hudson River Settlement Agreement. These outages effectively reduced the number of organisms entrained at Indian Point. Currently, Entergy typically operates the cooling water intake system well over 90 percent of design capacity during the period of the year from May through August resulting in nearly baseline entrainment.

Species	1983	1984	1985	1986	1987	TOTAL
	Year					
Bay anchovy	632,540,000	947,885,000	659,570,000	294,431,000	460,342,822	2,994,768,822
American shad	450,000	26,239,000	0	332,000	18,000	27,039,000
Striped bass	13,017,000	24,490,000	24,286,000	25,935,000	16,499,000	104,227,000
Atlantic tomcod	10,000	432,000	12,978,000	385,000	453,000	14,258,000
White perch	7,551,000	11,531,000	13,281,000	4,368,000	2,247,000	38,978,000
River herring	308,779,000	407,074,000	1,793,000	116,576,000	2,002,000	836,224,000
TOTAL	962,347,000	1,417,651,000	711,908,000	442,027,000	481,561,822	*4,015,494,822*

It is important to note that only the above seven species were the focus of these reports and that many other species were also entrained in the 1980s. Even so, over the 5 years presented in the table above, more than *4 billion* fish eggs, larvae, and juveniles were entrained at Indian Point. In 2003, the Department released the Final Environmental Impact Statement ("FEIS") for issuing draft SPDES permits for three Hudson River power plants including Indian Point. Using the known entrainment numbers from the 1980s and adjusting them for current river densities and Indian Point operating levels, the estimated "current" annual entrainment presented in the 2003 FEIS for Indian Point is as follows: 12-L15-7 cont'd

Species	Number Entrained
Bay anchovy	326,666,667
American shad	13,380,000
Striped bass	158,000,000
Atlantic tomcod	No Data
White perch	243,333,333
River herring	466,666,667
TOTAL	*1,208,046,667*

The estimated annual entrainment of 1.2 billion fish is nearly a 50 percent increase over the average annual baseline entrainment that was measured from 1983 to 1987 (803,098,964) for these seven representative important species of fish. Based on this latest estimate, if the NRC were to allow Indian Point to continue operating the existing once-through cooling system for 20 years, the potential adverse environmental impact on Hudson River ecosystem will be the massive mortality of *24 billion* Hudson River fish. The Department simply does not find this level of adverse impact acceptable and neither should the NRC.

IX. The final conclusions presented by NRC staff in Section 9 on the overall potential impact relicensing will have on Hudson River fish is misleading. 12-L15-8

Based on the results of the NRC analyses, NRC staff have changed the potential impacts of impingement and entrainment on Atlantic and shortnose sturgeon from "small" to "likely to adversely affect." (*See*, Table 4-2 at page 37&38.) The NRC has also determined that the relicensing would result in "LARGE" impacts to both blueback herring and rainbow smelt. Yet the summary table provided in Section 9.0 of the Draft GEIS states that there would only be "SMALL to MODERATE" impacts on aquatic ecology (*see*, Table 9-1 *at* p. 131). This summary designation of impacts appears to favor the 10 species the NRC purports only a "SMALL" impact and the one species with a designated "MODERATE" level of impact. The summary ignores that fact that for some of the RIS, NRC staff concluded a "LARGE" or a "likely to adversely affect" impact would result from relicensing. If Table 9-1 is indeed a summary table, the range of impacts presented in this table must reflect the results of all of the species considered. 12-L15-8 cont'd

The NRC concludes that the relicensing of Indian Point will result in a "MODERATE" impact to Hudson River fish. This conclusion minimizes the fact that the NRC concurs with NMFS that the continued operation of the once-through cooling system at Indian Point will adversely affect Atlantic and shortnose sturgeon and have a "LARGE" impact on blueback herring and rainbow smelt. The fact is that for some species of fish, including federally listed endangered species, the NRC has concluded that relicensing Indian Point *will* result in an adverse impact. Therefore, it is incumbent on the NRC to accurately reflect this in their overall conclusions. Furthermore, Entergy should be required to mitigate these adverse impacts if the NRC decides to grant a 20 year extension on their operating license.

X. The Department requests the NRC to require closed-cycle cooling if Entergy is granted a 20 year extension of its operating license. 12-L15-9

It is of the opinion of NYSDEC that the analytical methods used by NRC staff to determine the level of adverse impact relicensing Indian Point would have on Hudson River fish are based on an incorrect metric (*i.e.*, fish populations), are misleading and inaccurate, and only provides speculative results at best. Furthermore, the NRC's conclusions that the impacts on Hudson River fish would be "MODERATE" inaccurately presents their findings. NYSDEC, NYSDOS, and NMFS have already determined that Indian Point will continue to have an adverse environmental impact on the Hudson River aquatic community as long as the applicant continues to impinge and entrain fish through the operation of the existing once-through cooling system. Therefore, the NYSDEC respectfully requests that if the NRC were to decide to extend the operating license for Indian Point that the NRC require the installation and operation of a closed-cycle cooling system. Short of closure, either seasonally[2] or permanently, the installation and operation of a closed-cycle cooling system is the *only* feasible option to assure that the continued operation of the Indian Point Nuclear Power Plant would result in a minimal adverse impact on the fish community of the Hudson River.

Respectfully submitted,

Kathleen Moser

Kathleen M. Moser

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[2] The majority of the entrainment caused by Indian Point operations occurs between May and August. Under the Hudson River Settlement Agreement, Indian Point was required to take 42 unit outage days on average for the 10 year term of the HRSA between May 10 and August 10. It has long been recognized that the majority of the entrainable lifestages of fish appear in the area of Indian Points CWIS during this period. Though such an alternative falls short of the reductions that would result with a closed-cycle cooling retrofit, if Indian Point were to reinitiate outages during this time period, measurable reductions in entrainment would result.

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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 hás 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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1 CONTENTS

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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 $L\infty$. 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.

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

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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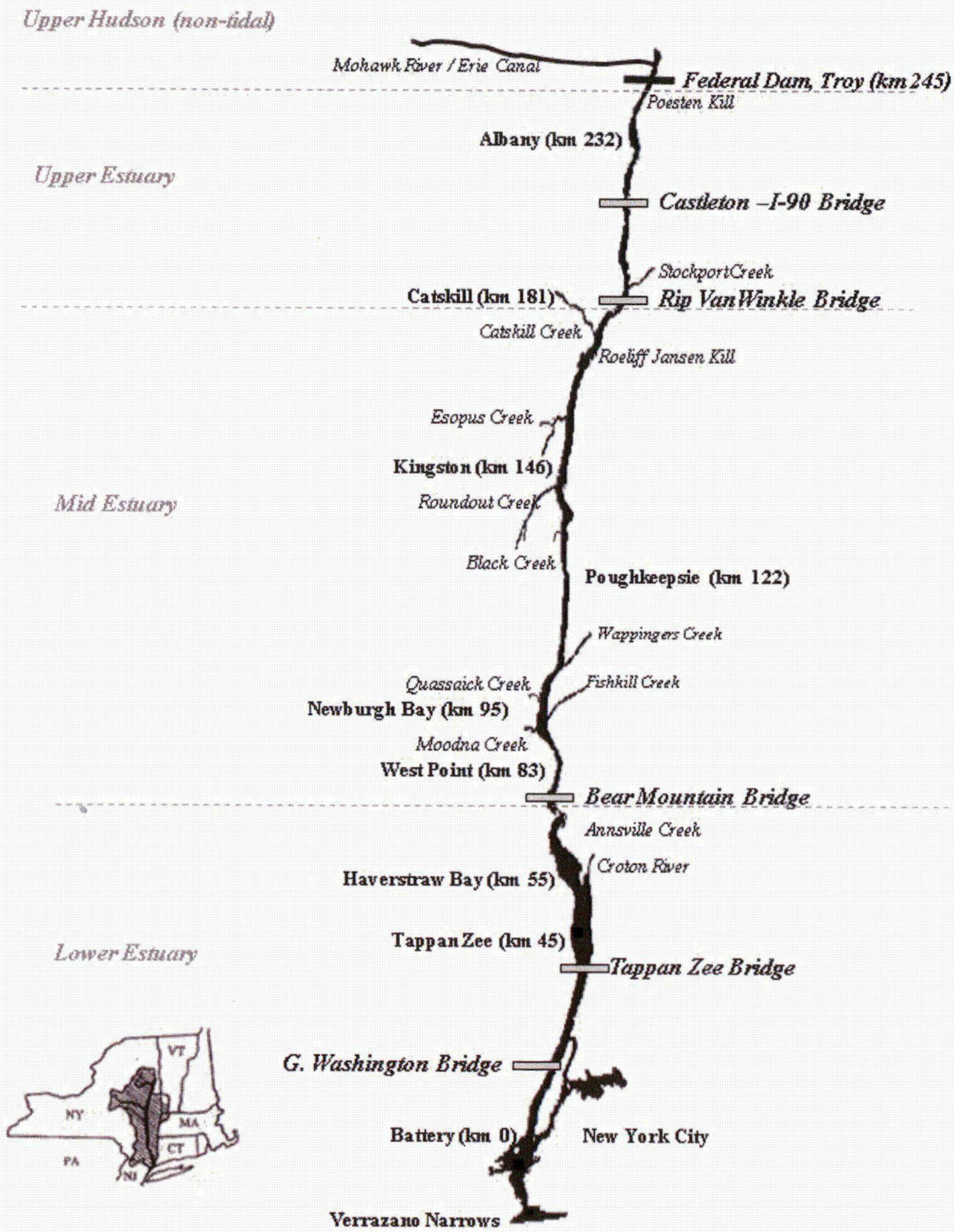

Figure 1 Hudson River Estuary with major spawning tributaries for river herring. (see Appendix Table A for complete list)

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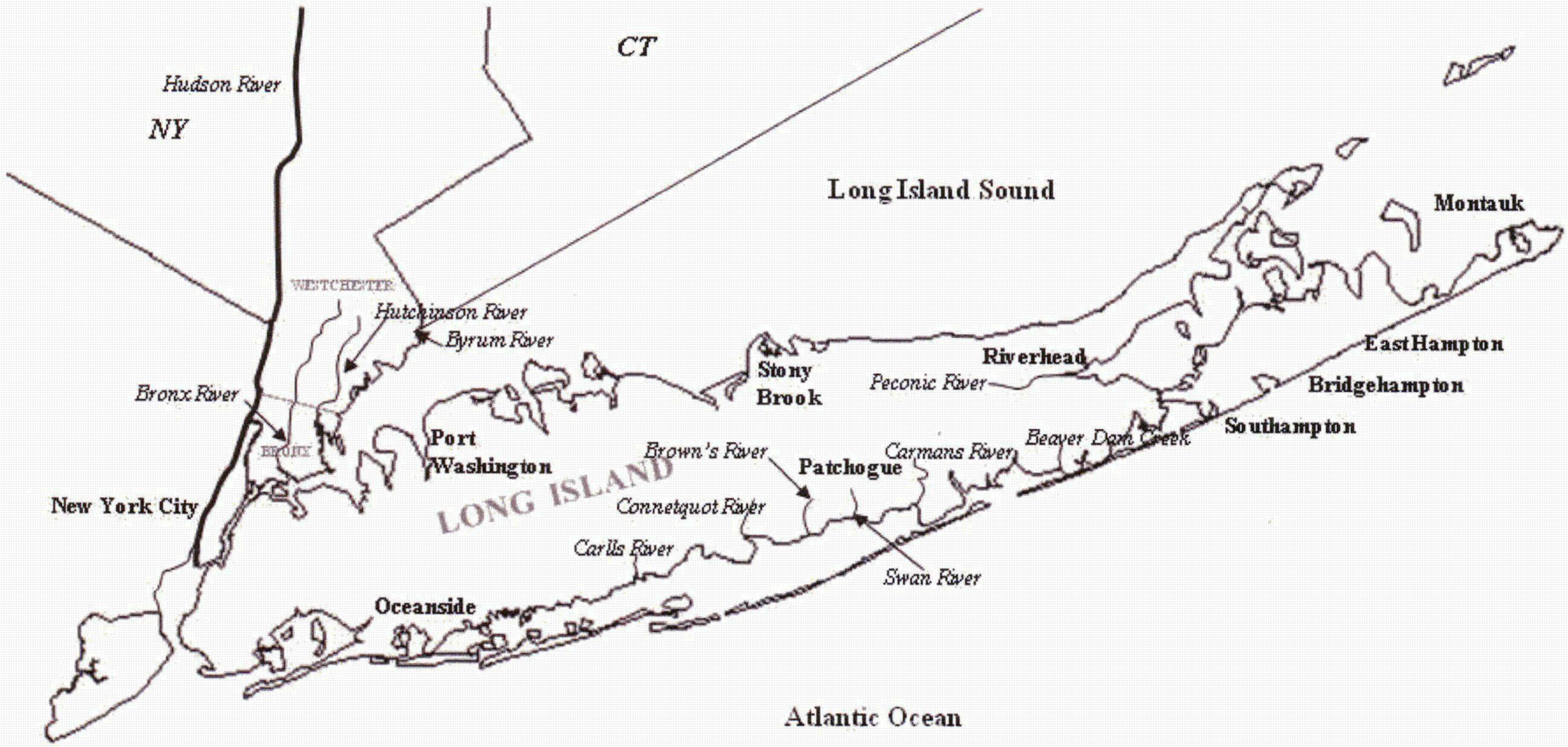

Figure 2 Long Island, Bronx and Westchester Counties, New York, with some river herring (primarily alewife) spawning streams identified (See Appendix Table A for list)

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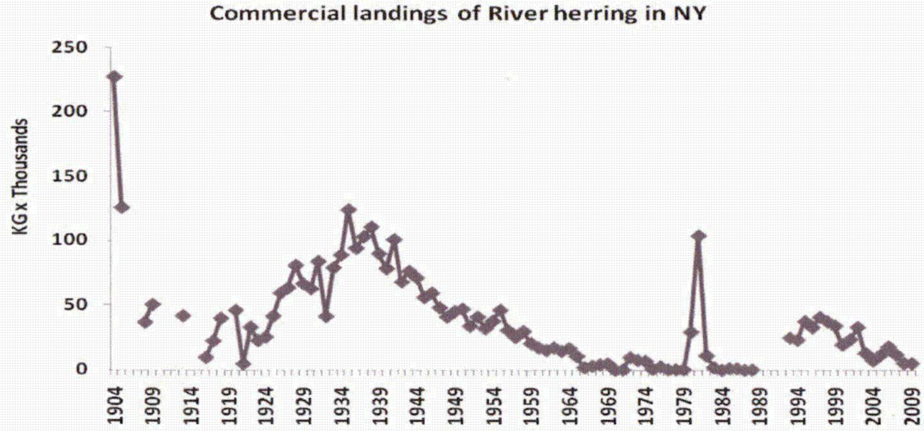


Figure 3 Commercial landings of river herring from all waters of New York State.

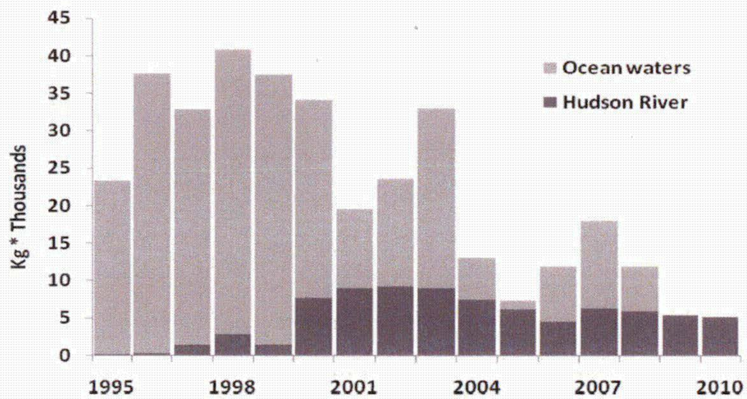


Figure 4 Commercial landings of river herring in the Hudson River and NY Ocean waters.

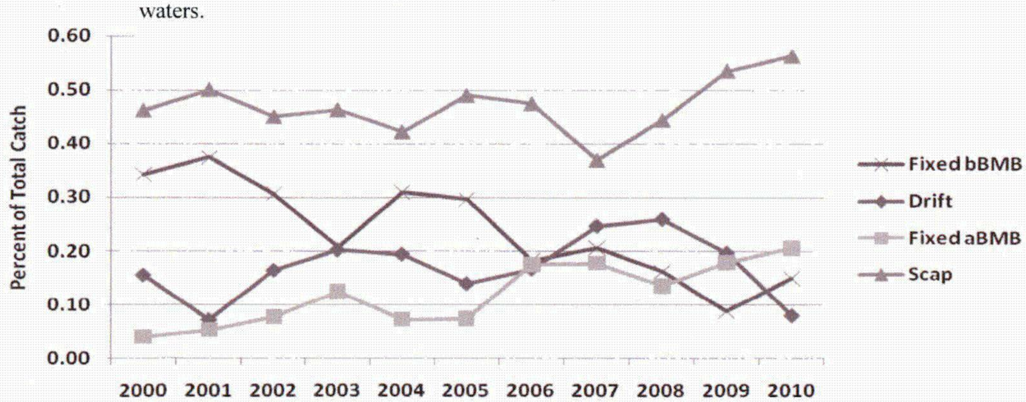


Figure 5 Percent commercial catch by gear of river herring in the Hudson River (a/b BMB=above and below Bear Mountain Bridge).

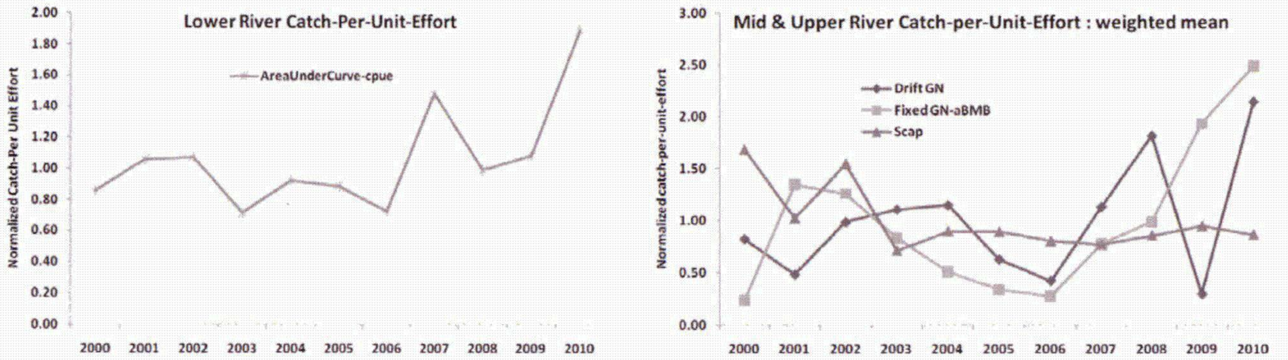


Figure 6 Catch per Unit Effort (number of fish per hours fished) by area of the river and gear. Lower estuary = below Bear Mountain Bridge [rkm 75]; Mid & Upper estuary = above the Bear Mountain Bridge.

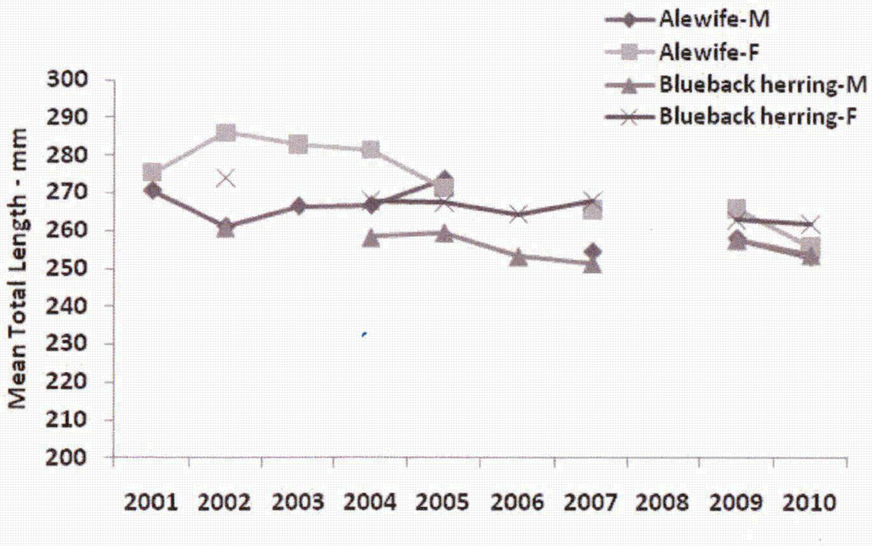
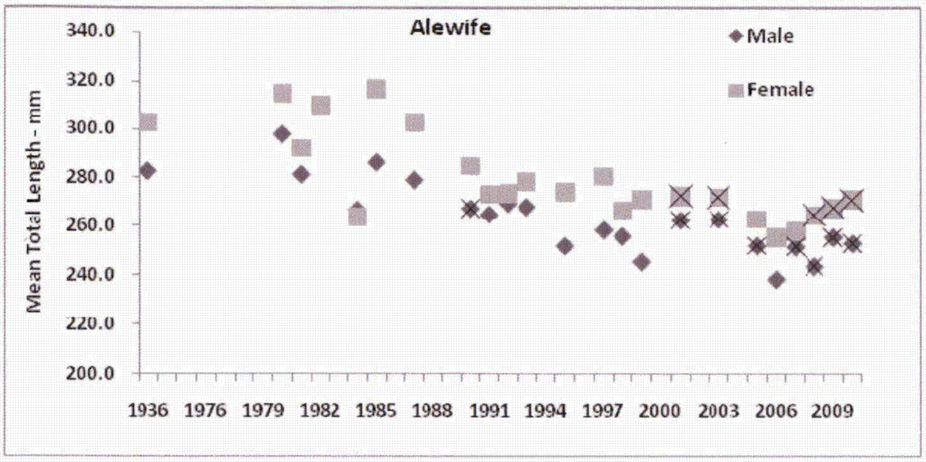


Figure 7 Mean total length of river herring collected from commercial fishery monitoring trips in the Hudson River Estuary



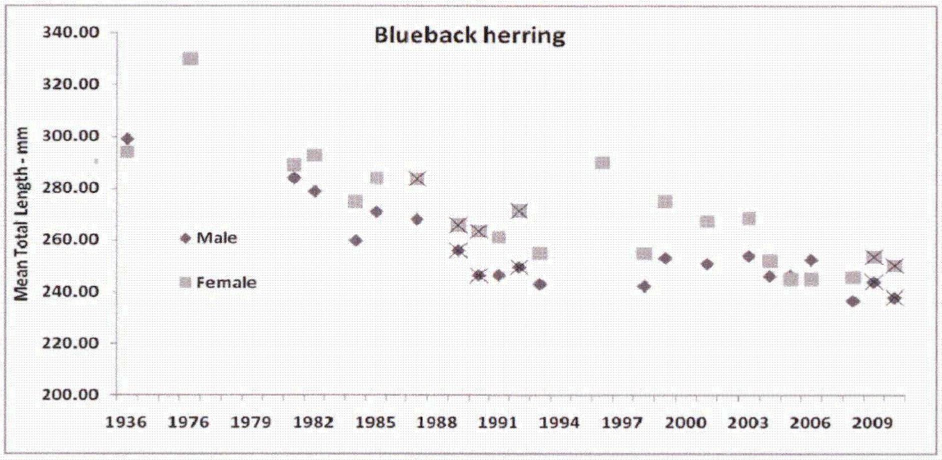


Figure 8 Mean total length of river herring in the Hudson River Estuary. Symbols with an "X" indicate adequate sample size (N>34) to characterize the stock.

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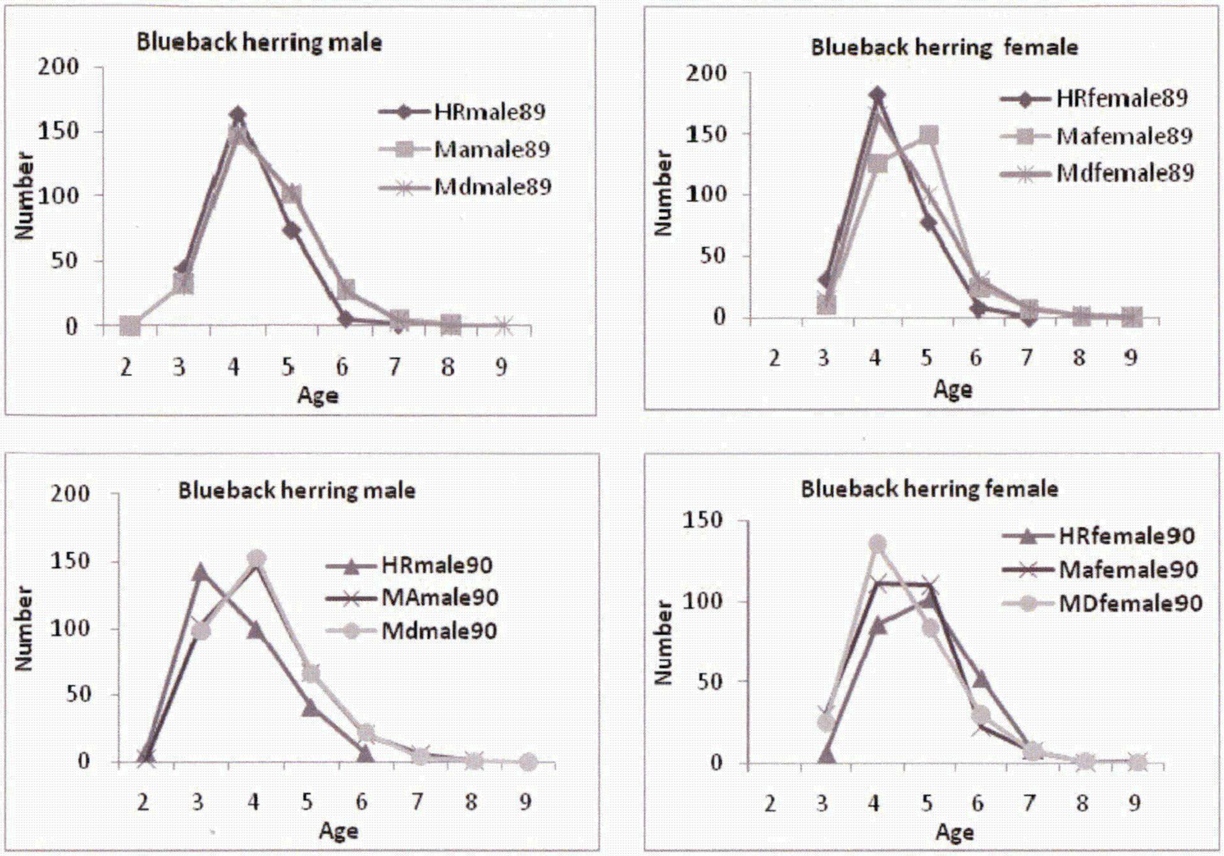
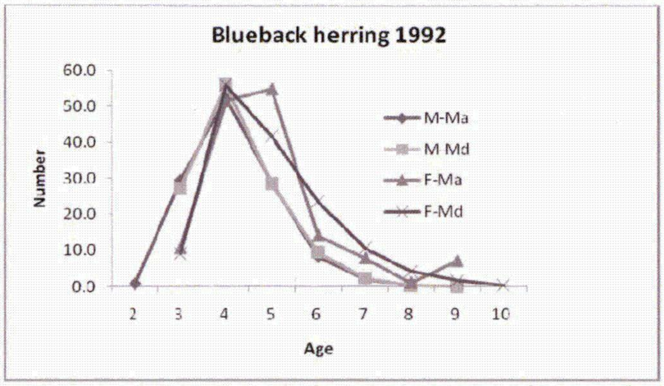
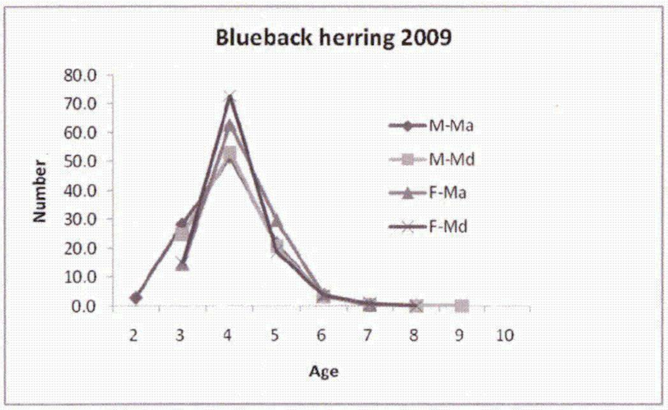


Figure 7 Hudson (HR) age structure and estimated age structure of Hudson River blueback herring based on length-at-age keys from Massachusetts (MA) and Maryland (MD) blueback herring.





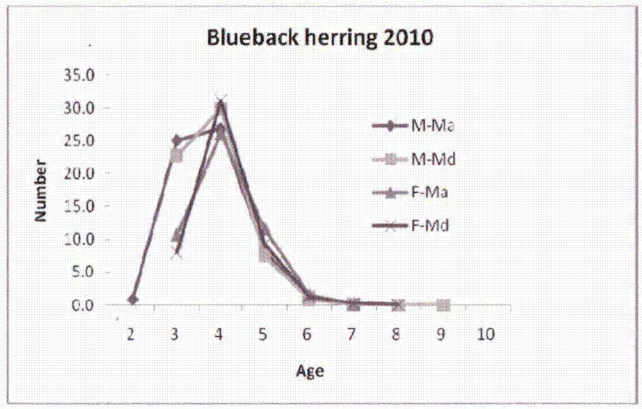


Figure 10 Estimated age structure of Hudson River blueback herring based on length-at-age keys from Massachusetts (MA) and Maryland (MD).

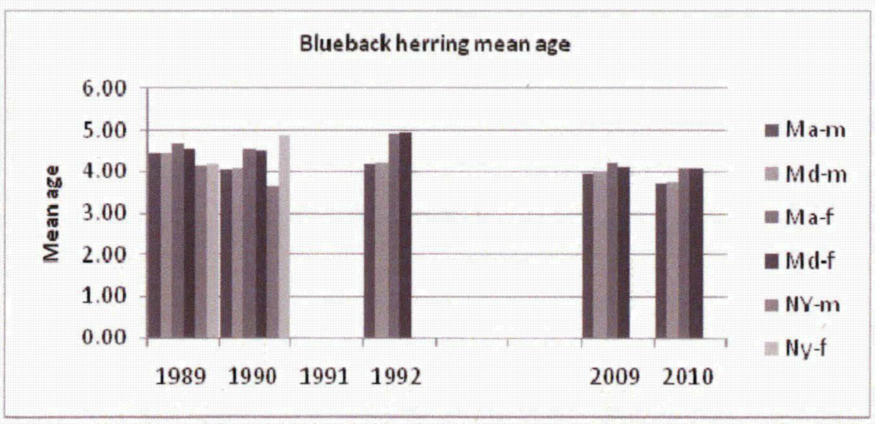


Figure 11 Mean age of Hudson River blueback herring based on length-at-age keys from Massachusetts (MA) and Maryland (MD).

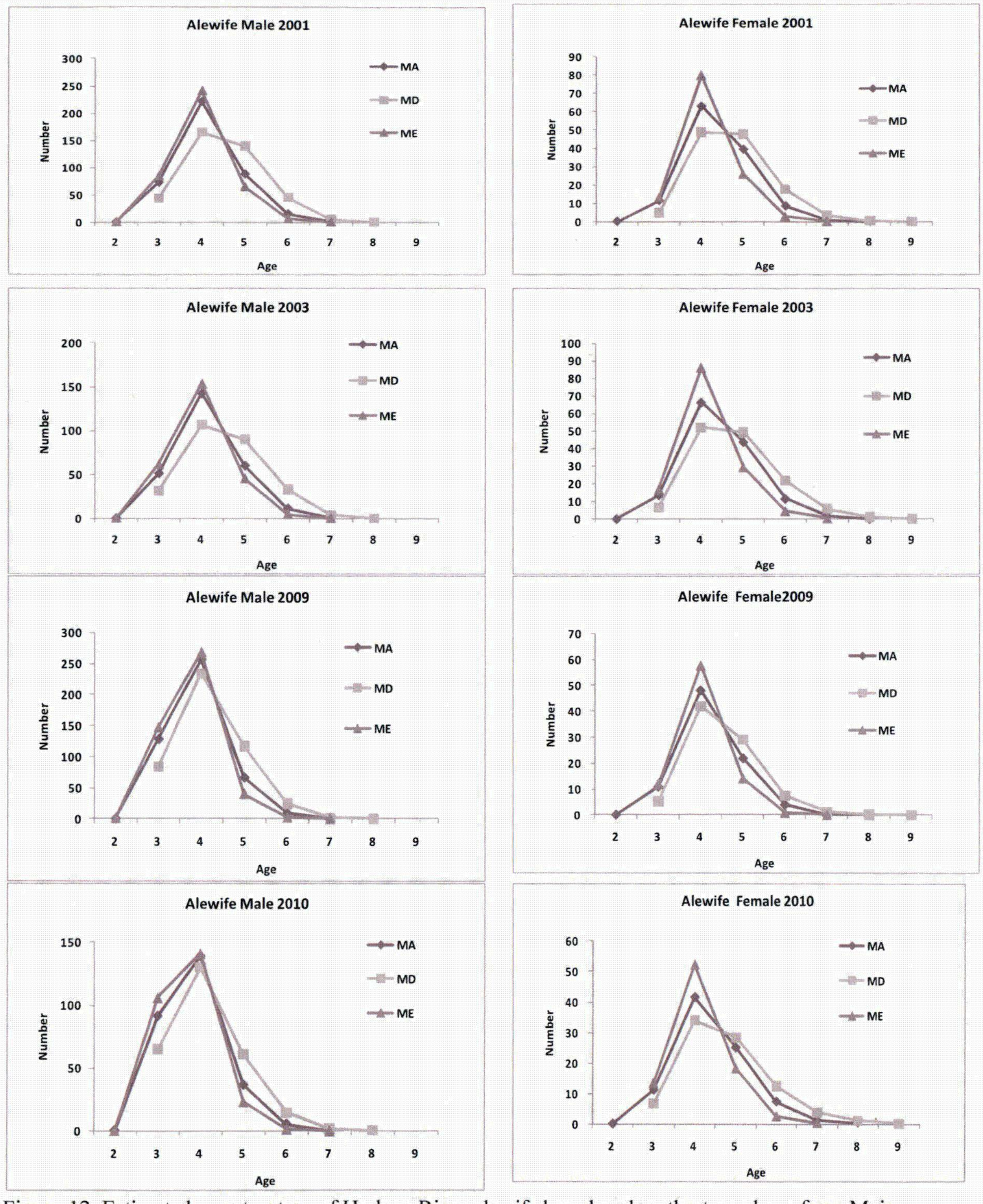


Figure 12. Estimated age structure of Hudson River alewife based on length-at-age keys from Maine (ME), Massachusetts (MA) and Maryland (MD).

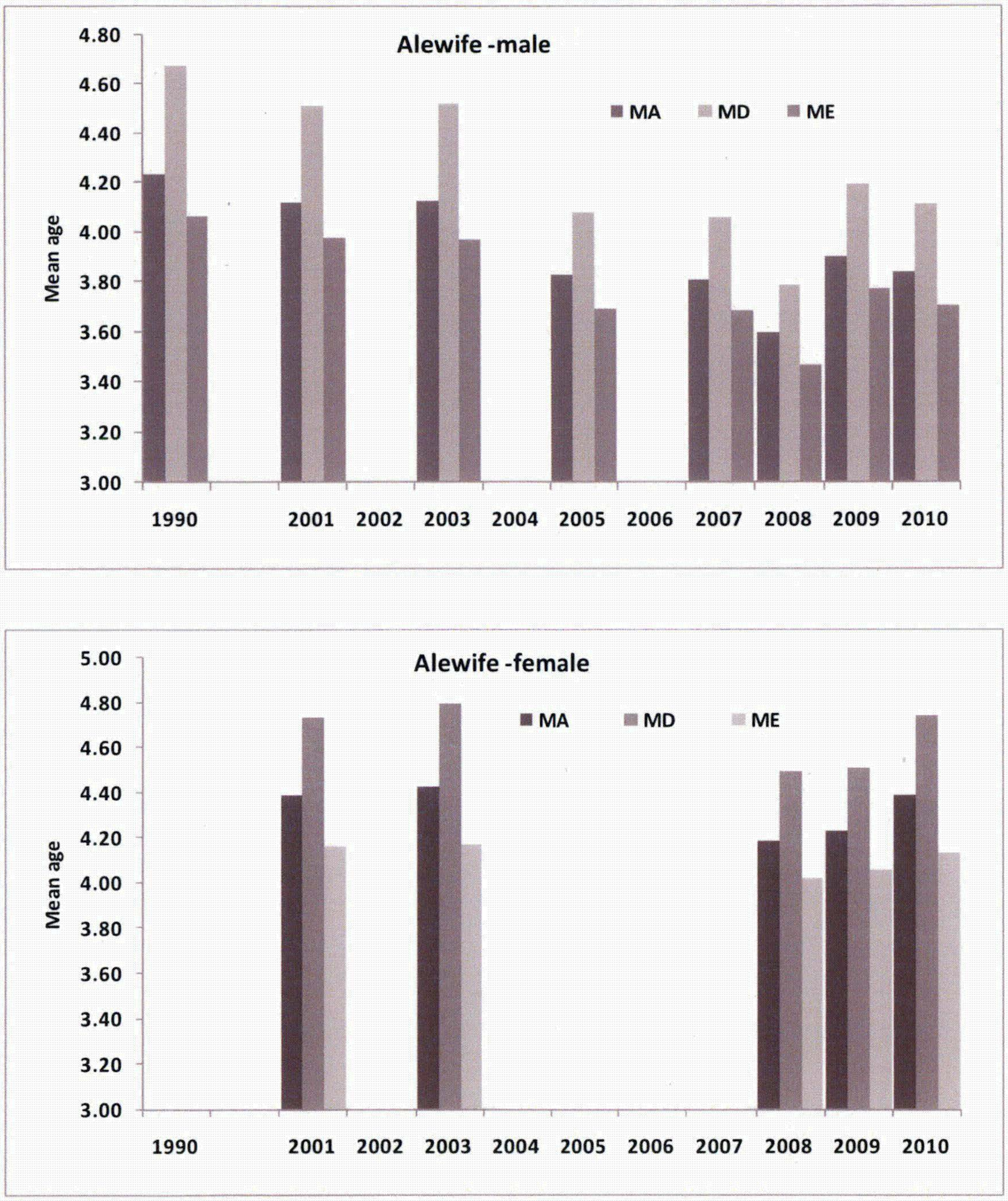
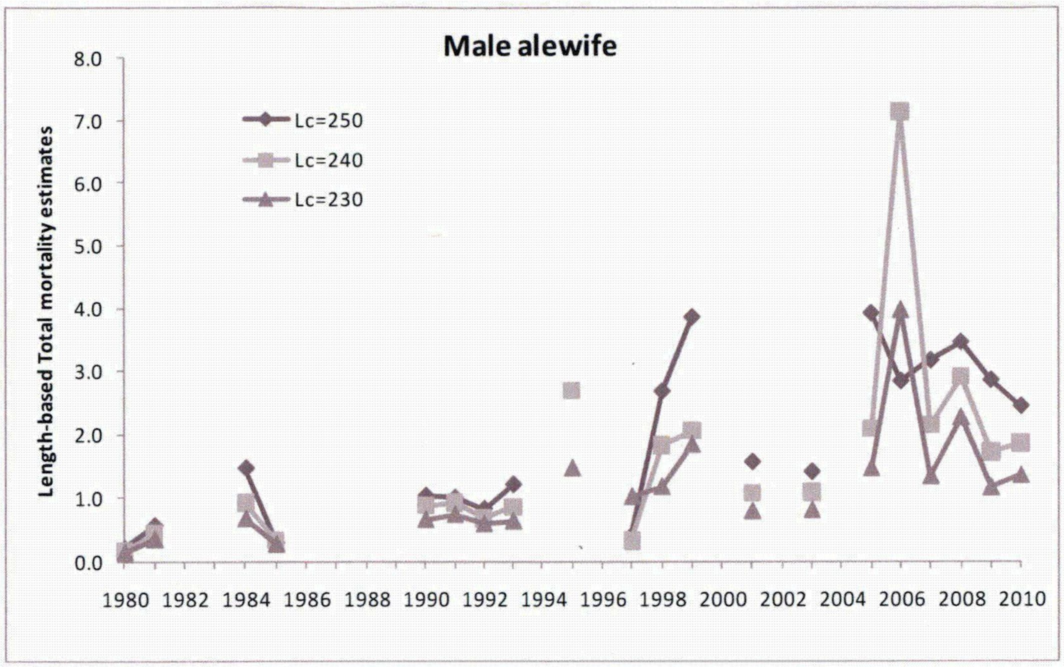


Figure 13. Mean age of Hudson River alewife, ages estimated from age-length keys from Maine (ME), Massachusetts (MA) and Maryland (MD).



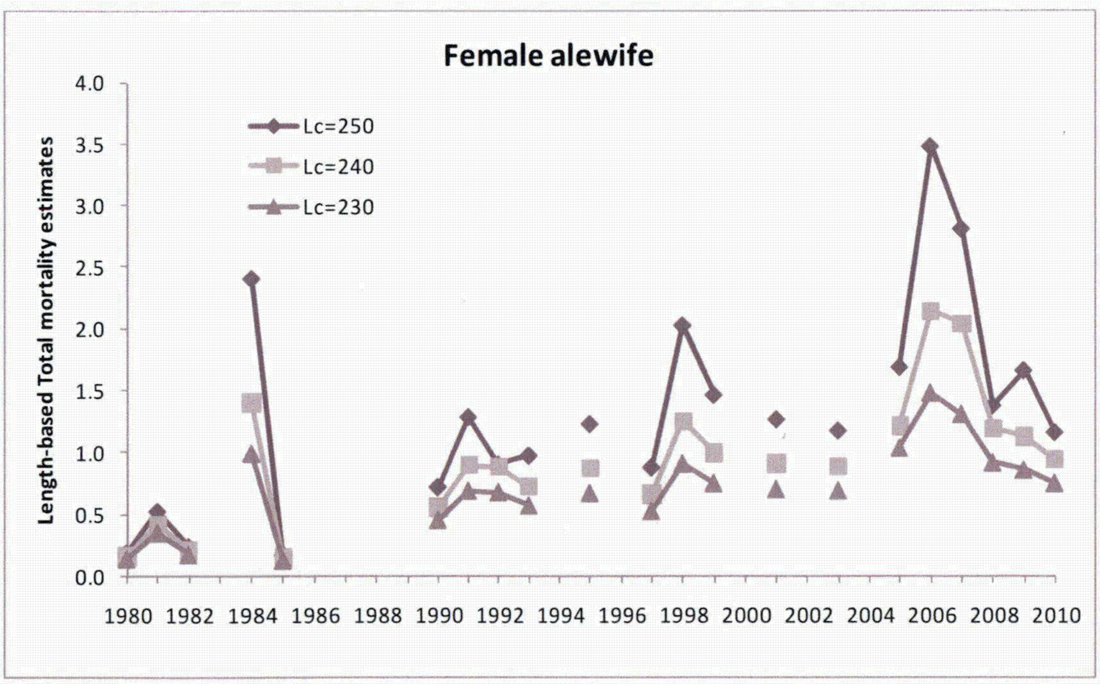
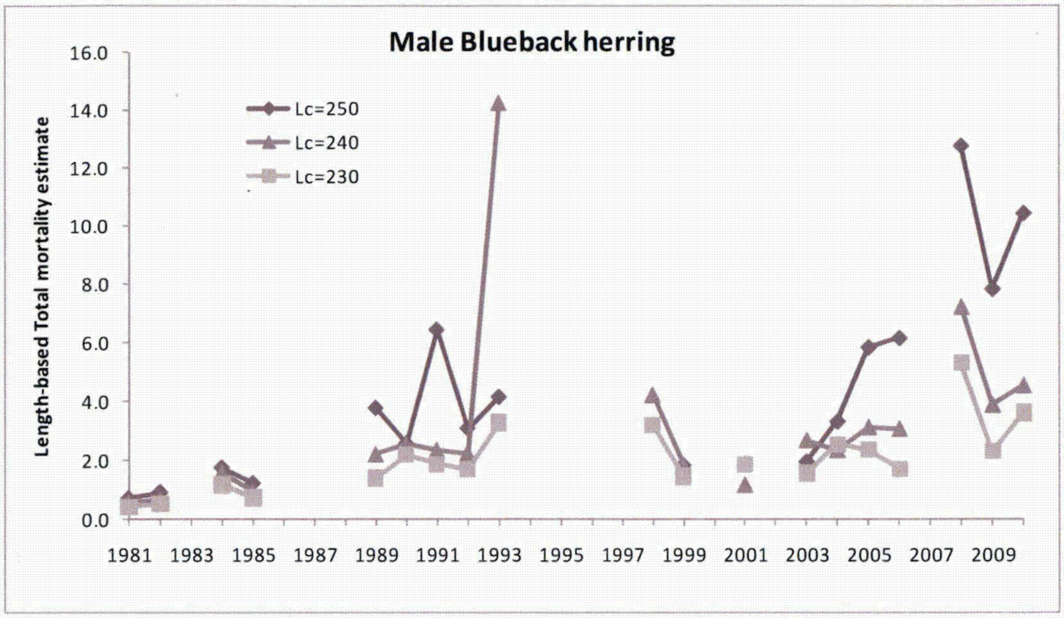


Figure 14. Length-based mortality estimates for Hudson River alewife. Lc =minimum length of fish caught in the sample gear.



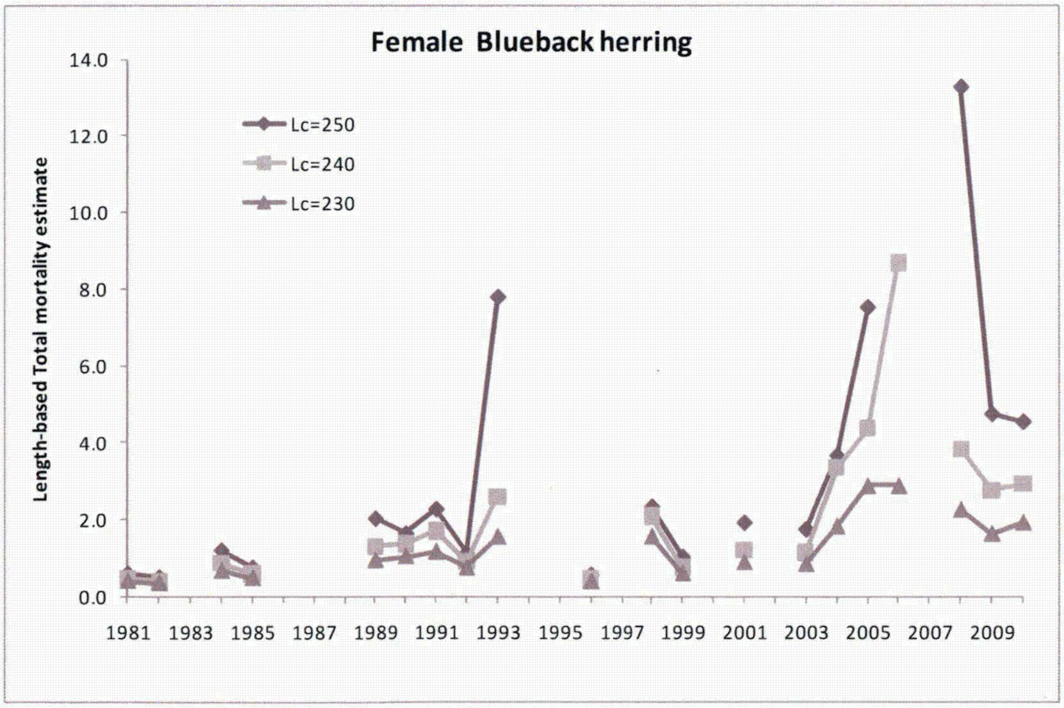
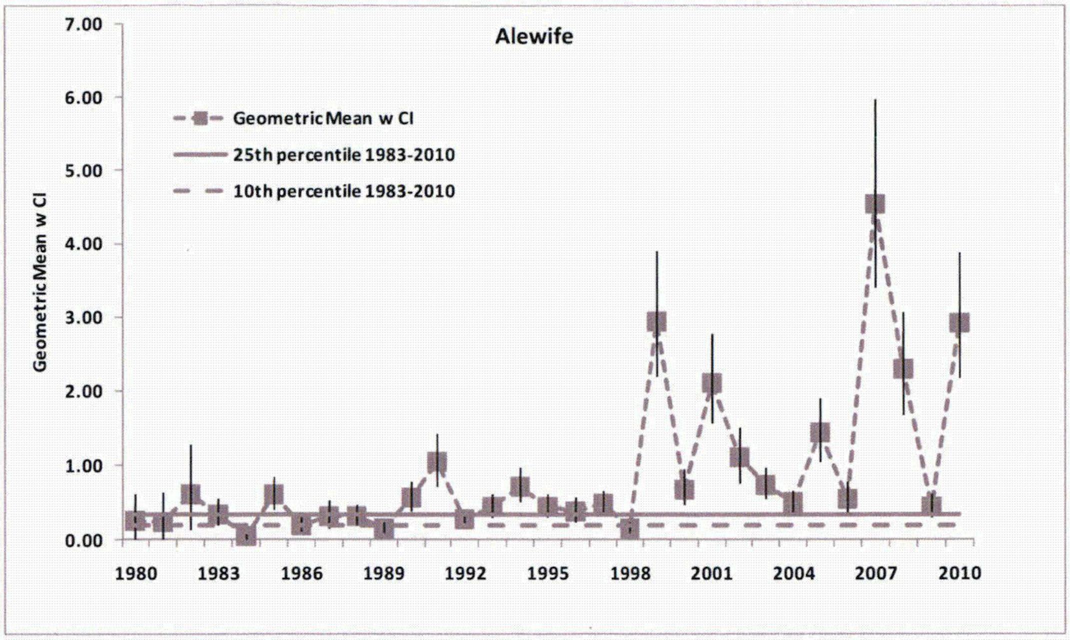


Figure 15 Length-based mortality estimates for Hudson River blueback herring. Lc =minimum length of fish caught in the sample gear.



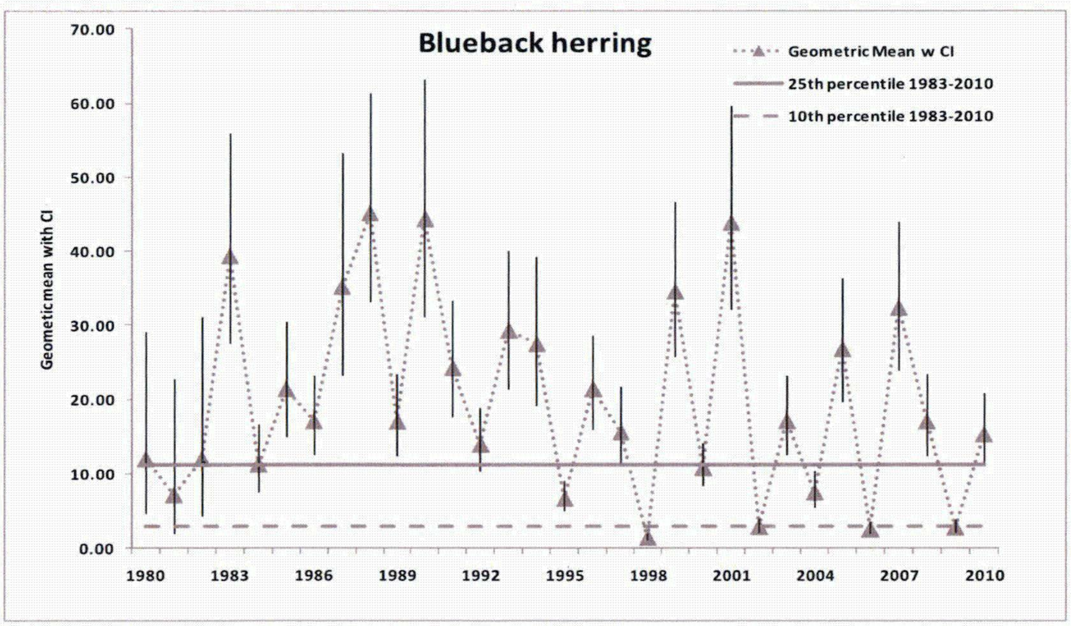


Figure 16. Annual young-of-the-year indices (with 95% CI) for alewife and blueback herring collected in the Hudson River Estuary.

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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

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

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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

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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

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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.

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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	

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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)

<u>Long Island streams</u>: 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.

Monitoring Program

TLE

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
NUCLEAR DIVISION
POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37830

Date Rec'd
4/23/80

September 28, 1979

Joel Golumbek
U.S. Environmental Protection
Agency, Region II
26 Federal Plaza
New York, N.Y. 10007

Dear Joel:

The settlement of the Hudson River Case recently proposed by the utilities contains provisions for a continuing riverwide sampling program designed to obtain annual estimates of the abundance of juvenile striped bass. Presumably, results of this program would be used to detect reductions in striped bass year class strength due to continued once-through cooling system operation. Before any such program is instituted, especially if decisions about future mitigating measures are to be contingent on the results obtained, EPA needs to know the magnitude of the impact it is possible to detect from data of this kind and the probability that an unacceptable level of impact could be detected within a reasonably short time span. We have been investigating this problem using the existing data for white perch and striped bass, and we have obtained some very sobering results that you should be aware of.

We have studied the power of the statistical test used to detect differences between the means of sets of pre-impact and post-impact abundance indices. We have assumed that a reduction in mean year class strength, if it occurs, takes place all at once, so that before time t_0 year class strength fluctuates around a mean of $\overline{X}$ and after t_0 it fluctuates around a mean of $(1-b)\overline{X}$, where b is the fractional change in mean year-class strength. If there has in fact been a reduction in mean year class strength, the probability that it will be detected depends on the magnitude of the reduction, the number of years of pre- and post-impact data available, and on the year-to-year variability of the data. Our analyses of three Hudson River data sets (white perch impingement rates and beach seine indices for white perch and striped bass) show that it is surprisingly difficult to detect even large reductions in mean year class strength.

Some highlights of our results are presented in the attached table. We have argued in our direct testimony that impingement rates can be used as measures of white perch abundance. Using the impingement data collected during the years 1973-77 as pre-impact data, we estimate that, no matter how many years of post-1977 data are available, the chance of detecting any reduction in mean year class strength smaller than 48% is less than 50%. With only 10 years of data beyond 1977, the smallest reduction detectable with a probability of 50% or higher is 58%. The probability that a fractional reduction in white perch year class strength as high as 5[illegible]% could be detected from 10 additional years of impingement data is less than 40%.

TI's riverwide beach seine indices for white perch are somewhat better with regard to the detectability of impacts (we set aside for the moment our doubts about the validity of these indices as measures of white perch abundance). Even so, the smallest reduction detectable with a 50% probability, given 10 years of beach seine data beyond 1973 (we assume that the post-impact period began in 1974, the year Bowline and Indian Point Unit 2 came on line), is 44%. The beach seine data for striped bass appear to be useless for the purpose of detecting declines in year class strength due to power plant impacts. The smallest impact that could be detected with a 50% probability, no matter how many years of post-1973 beach seine data become available, is more than 70%. With 10 years of additional data, there is no impact short of extinction that could be detected with a probability as high as 50%. The chance of detecting a 50% reduction after 10 years is less than 25%.

If, as is more likely, year class strength declines gradually as a result of power plant impacts rather than all at once, reductions in abundance would be even harder to detect than our results indicate. To the extent that the high variability observed in the data reflects actual fluctuations in white perch and striped bass year class strength (as opposed to sampling error), it is unlikely that even very serious reductions in these populations, especially striped bass, could be detected using these or any similar abundance indices. We believe that any claims made by the utilities that these populations can be reliably monitored and that any impacts resulting from once-through cooling can be detected before serious depletion has occurred should be viewed with a great deal of skepticism.

Sincerely,

L. W. Barnthouse
Research Associate

LWB:cgg

615-574-7393

615-574-7842 Douglas Van Stebshan

cc: H. Gluckstern
C. P. Goodyear

PROBABILITIES OF DETECTING REDUCTIONS IN WHITE PERCH AND STRIPED BASS YEAR CLASS STRENGTH DUE TO POWER PLANT IMPACTS.

Data Set	Minimum Fractional Reduction Detectable With 50% Probability Given Many Years of Post-Impact Data[a]	Minimum Fractional Reduction Detectable With 50% Probability Given 10 Years of Post-Impact Data	Probability Of Detecting 50% Reduction Given 10 Years of Post-Impact Data
White Perch Impingement Rates[b]	0.48	0.58	$0.35 < P < 0.40$
White Perch Beach Seine Indices[c]	0.33	0.44	$0.55 < P < 0.60$
Striped Bass Beach Seine Indices[d]	0.73	0.98	$0.12 < P < 0.25$

[a]This minimum fractional reduction detectable is approached asymptotically as the number of years of post-impact data increases to infinity. Smaller reductions have a less than 50% probability of being detected and larger reductions a greater than 50% probability.

[b]Impingement data sets collected during 1973-1977 at Bowline Lovett, Indian Point Unit 2, Roseton, and Danskammer were used as pre-impact data.

[c]From Table IV-31 of TI's 1976 Year Class Report. 1965-1973 were assumed to be pre-impact years.

[d]From Table 3 of Exhibit UT-49. 1965-1973 were assumed to be pre-impact years.

Dramatic Declines in North Atlantic Diadromous Fishes

KARIN E. LIMBURG AND JOHN R. WALDMAN

We examined the status of diadromous (migratory between saltwater and freshwater) fishes within the North Atlantic basin, a region of pronounced declines in fisheries for many obligate marine species. Data on these 24 diadromous (22 anadromous, 2 catadromous) species are sparse, except for a few high-value forms. For 35 time series, relative abundances had dropped to less than 98% of historic levels in 13, and to less than 90% in an additional 11. Most reached their lowest levels near the end of the observation period. Many populations persist at sharply reduced levels, but all species had suffered population extirpations, and many species are now classified as threatened or endangered. Habitat loss (especially damming), overfishing, pollution, and, increasingly, climate change, nonnative species, and aquaculture contributed to declines in this group. For those diadromous fishes for which data exist, we show that populations have declined dramatically from original baselines. We also discuss the consequences of these changes in terms of lost ecosystem services.

Keywords: diadromous fishes, overfishing, dams and other threats, habitat loss, shifting baselines

We examined the status of North Atlantic diadromous fishes, that is, those species that migrate between marine waters and continental watersheds to complete their life cycles. The North Atlantic basin receives the drainage of major rivers such as the St. Lawrence, the Mississippi, and the Rhine, and hundreds of smaller rivers, all of which host diadromous fishes. Diadromy occurs in two primary forms: anadromy, in which spawning takes place in freshwater, and catadromy, in which reproduction occurs at sea. Diadromous fishes comprise less than 1% of world fish fauna, but their value to humans far exceeds this portion. Many diadromous fishes such as salmons, sturgeons, and shads are not only economically important, but they also serve as crucial links for energy flow between fresh and marine environments (Helfman 2007).

Recent analyses have shown major declines in many North Atlantic obligate marine fishes (Christensen et al. 2003). For these species, declines generally take the form of population reductions to the level of commercial extinction, but not extirpation (Casey and Myers 1998). Unlike many marine fishes that have few but large, geographically widespread populations, most anadromous fishes have numerous but smaller river-specific populations (Powles et al. 2000). This renders them more susceptible to population-level extirpations, and, if these extirpations occur serially, species extinction may occur.

Diadromy as a life-history strategy has evolved in phylogenetically diverse fish groups (McDowall 1997). It appears to offer the benefits of lessened predation in early life stages, access to increased food resources in marine environments for individuals, and the potential for demographic and morphological sculpting to the particulars of each population's migratory circuit (McDowall 2001). These habitat-switching life histories may have evolved in response to geographic differentials in marine and freshwater productivity, with anadromous species dominating the higher latitudes where marine productivity far exceeds that of inland waters (Gross et al. 1988). But these more complicated life histories come with costs, including osmoregulatory and energetic demands for movement between two distinctly different environments. Moreover, occurrence both in freshwater and in the sea exposes populations to the uncertainties of environmental conditions in two realms.

Recent work has shown that migratory movements of diadromous fishes are far more complex than originally thought (e.g., Secor and Rooker 2000, Limburg et al. 2001). Many display spectacular long-distance migrations not only at sea but also as they traverse thousands of kilometers inland and ascend hundreds of meters in elevation. Because the spawning aggregations of diadromous fishes often place them within easy reach of humans, these runs have been particularly important sources of protein.

"Ecosystem goods and services" is a recently derived paradigm (Daily 1997, Ruffo and Kareiva 2009) used to demonstrate the value and benefits to humans of the natural world. Ecosystem services are defined as natural ecological functions

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or properties that support human well-being either directly or indirectly. In this paradigm, diadromous fishes have four special roles, although we will show that their importance in these functions has diminished greatly as a result of their population declines. First, provisioning of protein and other products is a primary ecosystem service of diadromous fishes because of their (historic) vast abundances, the high predictability of these runs, and the ease of their capture as they aggregate near or on their spawning grounds (Bolster 2008). Second, these fishes link continental and marine ecosystems, transporting embodied productivity from one to the other. Semelparous anadromous fishes (those that spawn once and then die) may act as keystone species (Willson and Halupka 1995): They have a major impact in their ecological communities because their carcasses are consumed directly by wildlife or stream infauna, or they decompose and release their nutrients to the water or riparian zones. Garman (1992) estimated that the nontidal James River, in Virginia, may have received annual biomass input from anadromous alosines of 1.55 kilograms (kg) per hectare (ha) (representing 3.6 million individuals in the run, with 70% mortality) before dams blocked their movements. Garman (1992) determined mean decomposition rates on the order of 10 days. These subsidies of "marine-derived nutrients" often serve as critical additions of energy and nutrients that fuel food webs well beyond the streams in which they died (Gende et al. 2002).

A third ecosystem service generated by diadromous species is the support of marine food chains through the addition of fish that emigrate from natal rivers to the sea, again transporting energy and nutrients, but in the reverse direction. At northern temperate latitudes, these fluxes are composed mainly of young fishes emigrating seaward. Nineteenth-century reports noted that the voluminous outpourings of young anadromous fishes provided important forage for marine species such as cod, *Gadus morhua,* tightly coupling inland production to coastal food webs (Stevenson 1899); today, such continental-marine linkages are broken to a large extent in the North Atlantic basin. This coupling also enabled fishers to harvest marine predators closer to shore without having to venture onto the high seas (Stevenson 1899).

Finally, diadromous species have played important roles for both indigenous and nonindigenous peoples. Because these fishes could supply great amounts of food after long periods with little to eat, they enjoyed high cultural status. For many coastal Native American communities, Atlantic sturgeon (*Acipenser oxyrinchus*), American eel (*Anguilla rostrata*), and other diadromous fishes had enormous practical and totemic importance (Bolster 2008). In modern American society, coastal communities still celebrate the return of American shad (*Alosa sapidissima*), hickory shad (*Alosa mediocris*), river herring (alewife, *Alosa pseudoharengus,* and blueback herring, *Alosa aestivalis*) (Waldman 2003), although these runs, and celebrations thereof, have diminished greatly.

Metrics of change

We synthesized information on the current status of North Atlantic diadromous fishes using these metrics: the number of original populations versus extant populations (table 1), temporal changes in population abundances or harvests (table 2, figure 1), and official conservation status (table 1). We identified 24 diadromous fishes in the North Atlantic. Of these, 12 are restricted to North America, 9 to Europe and Africa, and 3 are common to both shores. Each coast has only one strongly catadromous species, American eel and European eel (*Anguilla anguilla*). Information about the survival status of populations of diadromous fishes was obtained from the broadest and most recent sources available. The conservation status listed also was from the broadest possible listing identified.

Time-series data sets were collected mostly from published literature; two sets (European eel recruitment in Swedish rivers, and Atlantic salmon [*Salmo salar*] catches in the River Dee) were obtained from scientists in their respective fields of expertise (see the acknowledgments). Because few species have long time series of fisheries-independent data, catch statistics were the most commonly found time series. While fishery data are often subject to biases due to factors such as markets, fads, and misreporting (Ocean Studies Board 2000), in general, the species in our survey were in demand throughout most of the periods of observation.

We analyzed the time series in two ways. First, because of the variety of response variables (abundances, tons, catches per unit effort, recruitment indices), as well as the differences in absolute magnitudes of the variables, we normalized the time series so that the maximum value equals one and the minimum equals zero. These transformed data were then plotted (figure 1) for visual comparisons of trends. Second, because of the uncertainty about the meaning of individual data points (i.e., a peak in a time series in a particular year probably does not correspond to a peak in abundance or even to peak catch per unit effort expended), the untransformed data were smoothed by running averages corresponding to a particular species' generation time, thereby lessening the importance of individual points and emphasizing the trends over the time frame of the data. The slopes of the log transformation of these smoothed time series were computed and used to calculate the percentage change in relative abundance over the period of observation (table 2).

We had an especially rich and long set of American shad landings from the Atlantic States Marine Fisheries Commission (ASMFC 2007) that could be examined for evidence of multiple shifting baselines. These were normalized to the number of river kilometers available for spawning within each river system along the eastern US coast (ASMFC 2007).

Numbers of populations

For many species, data on historical and present numbers of populations are deficient; the availability of information appears positively associated with their commercial importance. Of the 14 anadromous species for which comparisons

Table 1. The original reproductive range of North Atlantic diadromous fish species, numbers of original and extant populations, and current highest institutional-level species conservation status.

Common name	Latin name	Original reproductive range	Number of original populations	Number of extant populations	Conservation status
Western Atlantic					
Sea lamprey	*Petromyzon marinus*	Florida to New Brunswick	116 (Beamish 1980)	DD	LC (IUCN 2008)
Shortnose sturgeon	*Acipenser brevirostrum*	Florida to New Brunswick	> 20 (NMFS 1988)	About 20 (NMFS 1988)	VU (IUCN 2008)
Atlantic sturgeon	*Acipenser oxyrinchus*	Mississippi to Quebec	> 35 (Waldman and Wirgin 1998)	About 35 (Waldman and Wirgin 1998)	NT (IUCN 2008)
Alewife	*Alosa pseudoharengus*	South Carolina to Newfoundland	DD	DD	SC (NMFS 2009)
Blueback herring	*Alosa aestivalis*	Florida to Nova Scotia	DD	DD	SC (NMFS 2009)
Hickory shad	*Alosa mediocris*	Florida to Maine	DD	DD	Status unknown[a]
Skipjack herring	*Alosa chrysochloris*	Texas to Florida	DD	DD	Stable (Warren et al. 2000)
American shad	*Alosa sapidissima*	Florida to Quebec	138 (Limburg et al. 2003)	68 (Limburg et al. 2003)	Lowest in history (ASMFC 2007)
Alabama shad	*Alosa alabamae*	Louisiana to Florida	DD	7 (Mettee and O'Neil 2003)	EN (IUCN 2008)
Atlantic whitefish	*Coregonus huntsmani*	Nova Scotia	2	1	VU (IUCN 2008)
Arctic char	*Salvelinus alpinus*	Newfoundland to the Arctic Ocean	DD	DD	LC (IUCN 2008)
Atlantic salmon	*Salmo salar*	Connecticut to Quebec	600 (of which 398 are DD; WWF 2001)	135 of 202 (WWF 2001)	LR/lc (IUCN 2008); needs updating
Rainbow smelt	*Osmerus mordax*	Delaware to Labrador	DD	DD	SC[a]
American eel	*Anguilla rostrata*	Brazil to Greenland	1 (panmictic)	1 (panmictic)	Highly depleted in Great Lakes drainage
Striped bass	*Morone saxatilis*	Louisiana to Quebec	About 50 (Fruge et al. 2006)	< 50 (Fruge et al. 2006)	Not overfished[a]
Eastern Atlantic					
Sea lamprey	*Petromyzon marinus*	Greenland/Norway to the western Mediterranean	DD	DD	Declining regionally
River lamprey	*Lampetra fluviatilis*	Finland to the western Mediterranean	DD	DD	DD (IUCN 2008)
European sea sturgeon	*Acipenser sturio*	Baltic Sea to the Black Sea	> 18 (Elvira et al. 2000)	1 (Elvira et al. 2000)	CR (IUCN 2008)
Allis shad	*Alosa alosa*	Spain to Germany	29 (Bagliniere et al. 2003)	16 (Bagliniere et al. 2003)	LC (IUCN 2008)
Twaite shad	*Alosa fallax*	Morocco to Lithuania	About 35 (Aprahamian et al. 2003)	About 30 (Aprahamian et al. 2003)	LC (IUCN 2008)
European eel	*Anguilla anguilla*	Morocco to Scandinavia	1 (panmictic)	1 (panmictic)	CR (IUCN 2008)
European whitefish	*Coregonus lavaretus*	Arctic Ocean to Denmark	DD	DD	VU (IUCN 2008)
Houting	*Coregonus oxyrinchus*	England to Germany	About 4 (Freyhof and Schöter 2005)	0 (Freyhof and Schöter 2005)	EX (IUCN 2008)
Arctic char	*Salvelinus alpinus*	Arctic Ocean to Sweden	DD	DD	See above
Atlantic salmon	*Salmo salar*	Portugal to Greenland	2015 (of which 206 are DD; WWF 2001)	1809 (of which 1572 are DD; WWF 2001)	See above
Sea trout	*Salmo trutta*	Russia to Portugal	DD	DD	LC (IUCN 2008)
European smelt	*Osmerus eperlanus*	France to Russia	DD (21 England) (Maitland 2003)	DD (14 England) (Maitland 2003)	LC (IUCN 2008)

CR, critically endangered; DD, data deficient; EN, endangered; EX, extinct; LC, least concern; LR, lower risk; LR/lc, lower risk taxa that do not qualify for conservation-dependent or near-threatened status; LR/nt, lower risk taxa close to qualifying as vulnerable; NT, near threatened; SC, species of concern; VU, vulnerable.

a. Agency designations by the National Marine Fisheries Service and the Atlantic States Marine Fisheries Commission.

Note: Populations are assumed to be reproducing; multiple tributary populations in a single drainage are considered part of one population.

could be made, all have reduced numbers of populations (table 1). Strongly managed North American fishes such as Atlantic sturgeon, shortnose sturgeon (*Acipenser brevirostrum*), and striped bass (*Morone saxatilis*) had lost few populations. Where data allow cross-continental comparisons, Atlantic salmon in Europe have suffered relatively fewer population extirpations (13%) than in North America (33%). Alosine herrings have lost moderate numbers of populations on both sides of the Atlantic, but as much as nearly half for American shad and allis shad (*Alosa alosa*). Anadromous whitefishes

Table 2. Characteristics of time series data for selected diadromous fishes.

Species	Unit of measurement	Maximum value	Year of maximum	Minimum value	Year of minimum	Period of record	Location	Slope	R^2 of slope	Percentage increase or decrease or (fitted)	Long-term increase or decline	Reference
Eastern Atlantic												
Alosa alosa	Abundance	277,637	1886	0	1933	1880–1934	Rhine River, Netherlands	–0.1519	0.87	–99.94	D (E)	Bagliniere et al. 2003
Alosa alosa	Abundance	115,974	1925	120	1988	1914–1990	Minho River, Portugal	–0.0710	0.82	–99.48	D	Bagliniere et al. 2003
Alosa alosa	Metric tons	860.7	1967	0	1992	1961–1993	Oued Sebou, Morocco	–0.1326	0.92	–98.13	D (E)	Bagliniere et al. 2003
Alosa alosa	Abundance	106,706	1996	2979	2007	1985–2007	Garonne River, France	–0.2195	0.93	–95.37	D	Migado (*www.migado.fr*)
Alosa fallax	Abundance	1,174,137	1938	283	1947	1893–1950	Rhine River, Netherlands	–0.5669 (*)	0.85	–99.80	D	de Groot 2002
Anguilla anguilla	Abundance	48,615	1976	375	2004	1975–2005	Imse River, Norway	–0.1139	0.93	–91.84	D	EIFAC/ICES 2006
Anguilla anguilla	Kilograms	8011	1953	30	1998	1950–2005	Swedish eel rivers	–0.0554	0.97	–92.60	D	EIFAC/ICES 2006
Anguilla anguilla	Kilograms	6215	1960	5	1997	1951–2005	Ems and Vidå River, Denmark	–0.0673	0.72	–95.48	D	EIFAC/ICES 2006
Anguilla anguilla	Metric tons	49.37	1979	0.88	2005	1960–2005	British Isles	–0.0588 (*)	0.96	–65.30	D	EIFAC/ICES 2006
Anguilla anguilla	Number per haul	138	1963	0.58	2001	1950–2005	Den Oever River, Netherlands	–0.0625	0.79	–94.70	D	EIFAC/ICES 2006
Anguilla anguilla	Kilograms	946	1974	0.831	2004	1964–2005	Ijzer River, Belgium	–0.1612	0.93	–99.51	D	EIFAC/ICES 2006
Anguilla anguilla	Metric tons	1137	1979	10.86	2005	1950–2005	French rivers	–0.0902 (*)	0.96	–88.52	D	EIFAC/ICES 2006
Anguilla anguilla	Metric tons	88.89	1981	0.51	2004	1953–2005	Iberian Peninsula	–0.1085 (*)	0.98	–90.81	D	EIFAC/ICES 2006
Anguilla anguilla	Metric tons	11	1975	0.02	2002	1975–2005	Tiber River, Italy	–0.2121	0.82	–99.06	D	EIFAC/ICES 2006
Acipenser sturio	Metric tons	58	1950	0.11	1966	1891–1980	Eider, Gironde, and Guadalquivir Rivers, Europe	–0.2372 (*)	0.93	–99.31	D	Williot et al. 2002
Acipenser spp.	Metric tons	765.3	1927	0.5	1991	1920–1999	Danube River	–0.0416	0.78	–93.58	D	Williot et al. 2002
Acipenser spp.	Metric tons	32,000	1977	2	2002	1913–2002	Ponto–Caspian	–0.077 (*)	0.92	–72.99	D	Williot et al. 2002, Pikitch et al. 2005
Lampetra fluviatilis	Metric tons	44	1890–1899	0.6	1980–1989	1887–1999	Southern Baltic Sea	–0.0343	0.45	–96.29	D	Thiel et al. 2005
Petromyzon marinus	Metric tons	130,252	1897	84	1979	1887–1999	Southern Baltic Sea	–0.0375	0.50	–97.98	D	Thiel et al. 2005
Lamprey	Scaled relative abundance	2.2	2004	–0.95	1994	1986–2005	Garonne and Adour Rivers, France	0.0758	0.73	+230	I	Beaulaton et al. 2008
Salmo salar	Abundance	5707	1928	552	2000	1928–2004	River Dee, Wales	–0.0206	0.69	–77.31	D	Aprahamian et al. 2008
Salmo salar	Abundance	104,000	1885	0	1957	1863–1957	Rhine River, Netherlands	–0.0526	0.70	–98.97	D	de Groot 2002
Salmo salar	Metric tons	3032	1967	912	1997	1960–2005	North Europe	–0.0217	0.79	–62.34	D	WGNAS 2006
Salmo salar	Metric tons	4604	1973	778	2005	1960–2005	South Europe	–0.0397	0.86	–83.25	D	WGNAS 2006
Salmo salar	Metric tons	160	1971	9	2002	1960–2005	Faroes and Greenland	–0.1736 (*)	0.89	–99.81	D	WGNAS 2006
Salmo trutta	Abundance	25,244	2004	5096	1987	1987–2007	Iceland	0.0439	0.93	+220	I	Gudbergsson 2007

Table 2. (continued)

Species	Unit of measurement	Maximum value	Year of maximum	Minimum value	Year of minimum	Period of record	Location	Slope	R^2 of slope	Percentage increase or decrease or (fitted)	Long-term increase or decline	Reference
Western Atlantic												
Acipenser oxyrhinchus	Metric tons	3294	1888	6	1924	1880–1994	North America	–0.0239	0.28	–91.05	D	Kahnle et al. 2007
Alosa sapidissima	Metric tons	22,408	1814	18	1892	1814–2005	North America	–0.0189	0.67	–97.14	D	ASMFC 2007
Alosa pseudo-harengus	Metric tons	16,148	1958	7.5	2006	1950–2006	North America	–0.0829	0.86	–98.76	D	NOAA Fisheries statistics
Alosa aestivalis	Metric tons	23,800	1969	109.9	2006	1950–2006	North America	–0.0963	0.90	–99.39	D	NOAA Fisheries statistics
Alosa mediocris	Metric tons	303.8	1952	5.6	1990	1950–2006	North America	–0.0323	0.36	–81.95	D	NOAA Fisheries statistics
Anguilla rostrata	Metric tons	1792.6	1979	290.9	2002	1950–2006	North America	–0.0533 (*)	0.99	–72.20	D	NOAA Fisheries statistics
Osmerus mordax	Metric tons	163	1966	0.1	1997	1950–2004	North America	–0.0852	0.67	–99.08	D	NOAA Fisheries statistics
Salmo salar	Metric tons	2864	1967	132	2005	1960–2005	North America	–0.0736	0.82	–96.36	D	WGNAS 2006
Morone saxatilis	Metric tons	6704	1973	100	1989	1950–2006	North America	0.1635	0.85	+1,368	I	NOAA Fisheries statistics

D, decline; E, extirpated; I, increase.

Note: Slopes were calculated from normalized data that had been smoothed with running averages corresponding to generation times, and then log-transferred. Generation times: alosines, salmons, and brown trout, 4 years; smelt, 2 years; striped bass, 6 years; lampreys, 9 years; eels, 10 years; sturgeons, 15 years. Slopes with an asterisk (*) indicate that they were calculated after a clear peak or nadir (e.g., after a "fishing up" period or following a collapse and subsequent recovery). Percentage increase or decrease is calculated with the fitted slope, and include the most recent years in the time series. Type of record was catch for all species except *Alosa alosa* (fish passage), *Anguilla anguilla* (recruitment index), and lamprey (fishery).

(*Coregonus* spp.) are in perilous condition: Only a small and now purposely landlocked population of *Coregonus huntsmani* persists in Nova Scotia and a European species, *Coregonus oxyrinchus*, has become extinct (Freyhof and Schöter 2005). Also, sea sturgeon (*Acipenser sturio*), once found in as many as 18 major rivers over much of Europe, now verges on extinction, remaining only as a small, struggling population in France's Gironde River (Williot et al. 2002).

Abundances of populations

Although some anadromous species have suffered numerous extirpations, the predominant pattern among these fishes has been for continuation of runs, but at drastically reduced levels that may be trending to inviability, as low as about 100 individuals for shortnose sturgeon in two populations (Kynard 1997). These declines have also been manifested—often profoundly so, especially with many long-exploited fish populations—in reduced biomass, age distributions, age at maturity, and maximum size and growth (Law 2007).

The length and quality of time series data sets vary, but the trend is nearly always the same: Diadromous fishes have declined, often to historic lows (figure 1, table 2). Of the 35 species or stocks for which we were able to obtain time series data sets, 32 had declined and only 3 had increased (table 2). Where long-term records exist, losses from baseline levels are often dramatic. American shad offers a good example, as data on the Potomac River date back to 1814, but the baseline for restoration efforts is derived from US Fisheries Commission records, which began in 1887 (figure 2a). The highest catch (51,136,364 kg) occurred in 1832 (figure 2b; Massman 1961). The Potomac could produce more than 22 million shad (3 kg in weight and 0.9 meters [m] in length, on average, versus approximately 1.8 kg and 0.5 m today) "in a good year" (Tilp 1978); today, only a minor recreational fishery persists there. Time series of American shad landings (normalized to kilometers of available river or estuary) for 10 major producing areas show a long-term exponential decline with a slope of –0.035 per year with all the data ($R^2 = 0.33, p < 10^{-5}$), or –0.033 per year if the early Potomac landings are excluded ($R^2 = 0.26, p < 10^{-5}$).

Comparisons of landings between diadromous fish taxon pairs from both sides of the Atlantic often show similar patterns (figure 1). These include moderate to sharp declines in the 1900s (some with occasional short-term recoveries), followed by low harvests or a mandated cessation of fishing, that continue to the present. Not only do most diadromous species exhibit precipitous declines over time, but the differences between maximum levels and recent

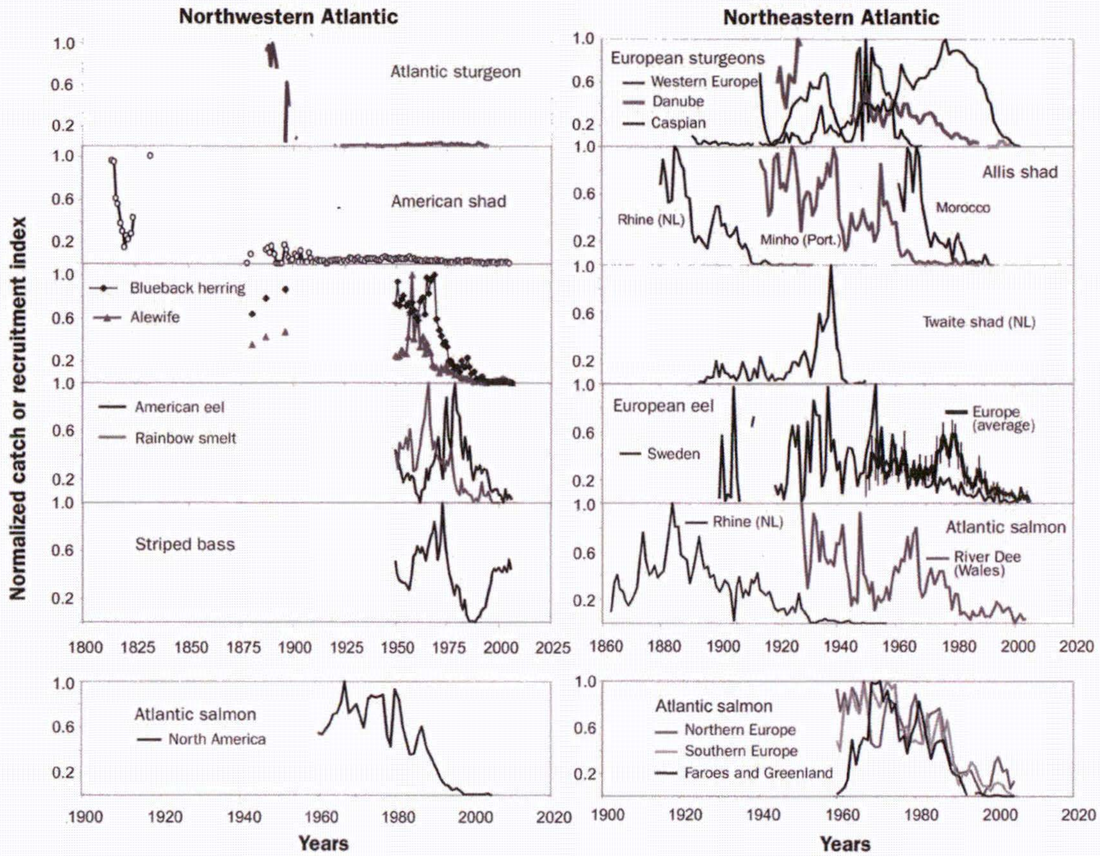

Figure 1. Normalized time series of indices of abundance of selected north Atlantic diadromous species. European eel includes standard errors of means for nine regions. The lower two panels compare Atlantic salmon. For type of index, maxima, minima, percentage change, and data sources, see table 2. Unless otherwise stated, northwestern Atlantic data are US summary statistics.

ones are even greater than what has been observed in many obligate marine species. Thirteen of the 35 time series in table 2 had declined by more than 98%; another 11 had declined by more than 90%. The few exceptions include the coastal migratory stock of striped bass, northern European populations of Atlantic salmon, and Icelandic populations of sea-run brown trout (*Salmo trutta*). This last example shows a marked increase in records over the smoothed observation period (1991–2007), and may be attributable to a true increase in population or an increase in sport fishing, or both (Gudbergsson 2007).

Conservation status

We believe the conservation status of anadromous fishes integrates knowledge of population persistence, abundance, and threats. Of the 12 exclusively North American species, the International Union for the Conservation of Nature (IUCN) Red List classifies 1 as endangered and 2 as vulnerable; the National Marine Fisheries Service lists 3 others as species of concern; and the ASMFC rates 1 more as having its lowest abundance in history, and is in the process of assessing 2 more species that are also likely at historic lows. Of the 9 eastern Atlantic species, 1 has gone extinct, 2 are now critically endangered (including the once abundant European eel), 1 is vulnerable, and 2 are listed by the IUCN as data deficient (table 1). At least one (*A. alosa*) appears to be in serious decline, although noted as "least concern" by the IUCN. Of the pan-Atlantic salmonids (Atlantic salmon and arctic char, *Salvelinus alpinus*), wild *S. salar* is at historic lows in North America, and overall, its status is in need of updating (IUCN 2008).

Threats

North Atlantic diadromous fishes must navigate a gauntlet of threats. The primary triad that affects most taxa is damming of rivers, overfishing, and pollution. However, there are now a host of threats beyond the three that have long been considered primary.

Dams and other habitat losses. Industrialization depended on rivers for water power, and many waterways became multiply dissected with dams. Dams often block access to historical spawning reaches, causing population reductions and extirpations. Few larger rivers remain undammed: It is estimated

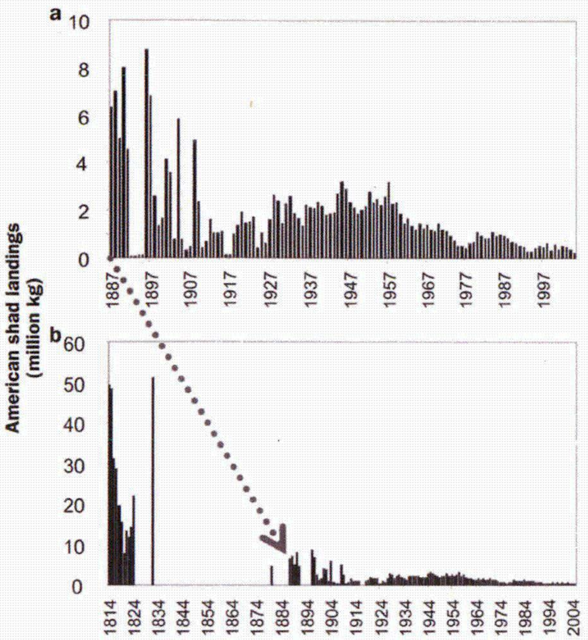

Figure 2. Example of how baselines shift. (a) Baseline for American shad restoration is typically referenced to 1887, when the US Fishery Commission began to collect statistics. (b) Earlier data show that levels for the 1887 baseline are considerably lower than they were in the past. Source: ASMFC (2007).

that in the United States alone, there are more than 80,000 dams of 6 feet in height or more, and perhaps as many as 2,000,000 of all sizes (Graf 2003). For example, within the Hudson River watershed there are 797 registered dams (Swaney et al. 2006); that figure does not include small dams (< 0.6 m tall), which also can hinder migration. In Spain, some dams have blocked fish movements continuously since the 2nd century, and the nations of Europe together have about 7000 large (more than 15 m) dams, most of which are situated on Atlantic drainages. Engineered solutions to fish passage in the form of ladders and lifts have been fitted to some dams, but generally passage is species specific, and the number of fish traveling through them is far fewer than it would be in the absence of dams; these dams also inhibit downstream migration of young. One useful metric of the effect of dams is the number of kilometers of river they occlude to migrants. For American shad, approximately 4000 of an original 11,200 km of spawning habitat have been lost to dams (Limburg et al. 2003); these dams have similar effects on other anadromous species.

Dams also have numerous other ecological effects on rivers, many of which may affect diadromous fishes directly or indirectly. Among these are the blocking of normal movements and changes in the community composition of resident fishes that interact with diadromous fishes; microevolution of populations isolated by barriers; pronounced alterations of water temperatures upriver and downriver; retention of nutrients and sediments; and, even where fish passage is successful, the imposition of the need to cross sometimes large, unnatural stillwater habitats (Helfman 2007). Dams that are operated for hydropower also cause direct mortality (death by turbines) and may radically alter water discharges (Helfman 2007)—and hence, habitat availability (water or no water)—on daily or even hourly timescales.

In addition to the large habitat changes wrought by dams, dredging and channelization may cause short-term stresses while these activities occur and, more important, long-term diminution of habitat quality through the changes they create. Culverts impede fish movements by species such as river herring in smaller systems. Gravel and water removals reduce habitat in many waterways. Because many anadromous fishes use rivers as nurseries, reductions in the extent and quality of marshes and other shallow water habitats may lessen productivity and, therefore, recruitment.

Overfishing. Harvest has strongly compromised diadromous fish populations. Atlantic sturgeon were taken at an extraordinary rate during the international caviar craze of the 1890s (Secor and Waldman 1999); with continued fishing and their low intrinsic rate of increase, many populations have shown little subsequent recovery, despite greater protection. In the Delaware River, the chief US fishery for Atlantic sturgeon, landings in 1901 were only 6% of their 1889 peak of more than 2000 metric tons (Secor and Waldman 1999). Atlantic sturgeon remain so scarce in the Delaware that it is not known whether any reproduction still occurs there.

Overfishing is a major factor in the nearly complete demise of the once-widespread European sea sturgeon (Williot et al. 2002). Extirpations led to a range contraction to just the Gironde estuary in France, and even when fishing was halted there in 1982, the population continued to decline. Despite regulatory protection, accidental bycatch threatens sturgeons on both the American and European coasts.

Alewives were once so numerous in northeastern US rivers that they were likened to "passenger pigeons of the sea" (Bolster 2006); their numbers have since plummeted, and several states have banned any takings. Runs in several large rivers from Maine to the Chesapeake Bay have declined by 99.9%; for example, at the Holyoke Dam on the Connecticut River, counts went from approximately 630,000 in 1985 to 21 in 2006. Bycatch at sea is one likely contributor, as subadults are taken along with the targeted Atlantic herring (*Clupea harengus*) fisheries. Another alosine that appears to be undergoing a similar collapse because of recruitment overfishing is the allis shad; juvenile recruitment in the Gironde, the center of its range, has been negligible for the past few years.

Extensive analysis of decadal trends in eel fisheries suggests that exploitation is a major factor in European eel decline (Dekker 2004), with many fisheries collapsed. Eels are targeted not only as immature (yellow phase, in lakes and running waters) or adolescent (silver phase, migrating toward the Sargasso Sea to spawn) but also as postlarval glass eels entering continental waters. The highly lucrative glass eel fishery is driven by demand in Southeast Asia, where imported American and European glass eels are pond-reared to market size. Glass eel fisheries sometimes harvest all available individuals at a particular locale, but in general the harvest has been 80% to 95% (Dekker 2004), which is still an alarming statistic.

Pollution. Water pollution also has reduced runs of diadromous fishes. Some river systems received so much raw or lightly treated human sewage—which induced low oxygen levels—that they became equivalent to "chemical dams" blocking spawning migrations. Examples include the Thames in the United Kingdom and the Delaware River in the United States (Chittenden 1971); however, both rivers have shown dramatic improvements as a result of new laws and management actions. Over the past few decades, shortnose sturgeon has made an unusually robust recovery in the Hudson River not only because of its placement on the US endangered species list but also because the population's original spawning location near the head of tidewater was reoxygenated through measures to control sewage, which stemmed from the Clean Water Act of 1972 (Waldman 2006). However, late 20th-century exurbanization (sprawl development) has led to more impervious surface cover in many drainage basins, further altering water quantity and quality.

Contaminants such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons, and heavy metals may induce difficult-to-quantify sublethal effects in fishes in riverine environments. Highly biomagnified levels of PCBs in boreal regions are causing concerns for Artic char. Laboratory experiments with Arctic char have shown that these compounds impair hypo-osmoregulatory ability and reduce growth rate and survival upon transfer to seawater (Jørgensen et al. 2004). Also, European and American eel reproduction may be compromised by fat-soluble, teratogenic organic compounds (Palstra et al. 2006), which are translocated into developing embryos from maternal lipid stores.

Acidification from atmospheric deposition of contaminants has been devastating for some Atlantic salmon stocks. In Norway, 18 populations are extirpated and 8 more are threatened, with others sustained only by liming rivers to raise pH (Sandøy and Langåker 2001).

Climate change. Climate change is altering species distributions. The boreal rainbow smelt *Osmerus mordax*, which in the 1880s ran in US rivers as far south as the Delaware, was extirpated from the Hudson in the 1990s (Waldman 2006) and is becoming scarce everywhere south of Maine. Meanwhile, gizzard shad (*Dorosoma cepedianum*), a euryhaline clupeid of no commercial value and uncertain ecological effects, has been colonizing rivers northward, establishing in large numbers in the Hudson in the 1970s and recently reaching as far as Maine (Waldman 2006).

Warming also appears to be shifting the phenologies of anadromous fishes towards earlier spawning runs. Monitoring in Maine revealed that the median capture date for Atlantic salmon in the Penobscot River advanced by 1.3 days per year between 1986 and 2001, and by 1.2 days per year between 1983 and 2001 for alewife in the Androscoggin River (Huntington et al. 2003). The consequences of such acceleration are unknown, but the rapidity of the change has the potential to disrupt these fishes' established ecological relationships at various life history stages.

In the future, warming may intensify the severity of floods and droughts, lessening the frequency of successful annual reproduction for anadromous fishes. In Europe, models predict that, collectively, 22 species will lose 336 suitable catchments and gain only 113 as a result of the most likely climate change scenario (Lassalle and Rochard 2009). The Gulf sturgeon (*Acipenser oxyrinchus desotoi*) depends on limited numbers of cool thermal springs to survive hot summer temperatures in Gulf of Mexico rivers (Carr et al. 1996); warming may impose even greater stresses on this scarce and federally threatened subspecies.

Warming will also impose complex and difficult-to-forecast shifts in the relationships between freshwater and saltwater habitats. Both American and European eels have evolved to capitalize on the transport and trophic resources of the Gulf Stream. However, the recent effects of climate change on this current may be contributing to the declines seen in both eel species in freshwaters (Wirth and Bernatchez 2003). In Arctic regions, warming may increase the productivity of inshore marine habitats used by anadromous fishes, but this may be counterbalanced by decreased flows in spawning rivers. Increased productivity of inland waters may also reduce facultative anadromy for plastic species such as Arctic char, with higher proportions of populations opting for freshwater residency (Reist et al. 2006).

Other threats

Electric generating plants and other facilities that withdraw water from rivers may kill high numbers of early life stages of diadromous fishes through entrainment and by impinging larger individuals against intake screens; power plants may also alter local temperature regimes though discharges of warm water (Barnthouse et al. 1988). Disease, competition, and genetic introgression with escapees from aquacultured Atlantic salmon threaten wild stocks in northeastern North America and Scandinavia (Naylor et al. 2005). Progeny of Atlantic sturgeon used in experimental culture have been opportunistically stocked in the wild (St. Pierre 1999) while ignoring protocols for the maintenance of appropriate effective population sizes. Similarly, research-culture escapees of a nonnative sturgeon species now compete in the Gironde with the few remaining sea sturgeon (Maury-Brachet and Rochard 2008). Many invasive and nonnative species also disrupt lotic ecology. Introduction of black bass (*Micropterus* spp.) and other piscivores increased the predation regime for juvenile alosines and other young diadromous fishes in US rivers. Invasive zebra mussels (*Dreissena polymorpha*) have altered the Hudson River's spring production cycle, to the detriment of its alosines (Strayer et al. 2004).

Conclusions

Few of the North Atlantic's diadromous fishes face any of the abovementioned threats in isolation; rather, it is likely that reasons for the losses we have outlined are multifactorial, and possibly synergistic. Many of these declines have been steady and insidious, fitting well into the "shifting baselines" paradigm, whereby new generations of managers accept that recent environmental conditions and levels of species reflect historical conditions and levels, and set restoration goals accordingly (Humphries and Winemiller 2008, Waldman 2008). Loss of historical baselines contributes to marginalization of the species, as social customs relating to bygone (collapsed) fisheries also perish, and ecosystems unravel at rates that go unnoticed.

Especially troublesome is the outright loss of many populations and their genetic legacies in the face of changing environments. The high phylogenetic diversity of these 24 species and the differences in life histories, geographic ranges, and commercial values conspire to make generalized solutions impossible. There is a strong need for better information on the population-specific status of many species of low commercial interest. Harvests of some species have been reduced and moratoria have even been applied, but usually not until abundances had become dangerously low. Atlantic coast populations of migratory striped bass are one of the few successful recoveries for an anadromous species, but the severe measures needed to generate this recovery were not taken until the stock fell to crisis levels (Richards and Rago 1999). Even with moratoria, populations may fail to recover (e.g., *A. sturio* in the Gironde, *A. sapidissima* in Chesapeake Bay), suggesting changes occurring systemwide are collectively hindering recovery.

Fishermen and other stakeholders need to elevate their long-term interests in a species' welfare over their own short-term economic interests, with the understanding that the more the populations are fished, the less the likelihood of recovery (and the lengthier the period of recovery), and hence the more damage to the future sustainability of the fishery. A laudatory example of an early intervention is the moratorium imposed in late 1997 on Atlantic sturgeon fishing in US waters in response to indications that some populations were rapidly declining because of suddenly increased fishing pressure (Waldman 2006). Almost exactly a century after the international caviar craze left many US stocks sharply reduced or decimated, the few remaining commercial Atlantic sturgeon fishermen acquiesced to an ambitious protection plan that prohibits their take for up to 40 years—two generations for this slowly maturing species.

The environmental movement has resulted in a reduction of new sources of pollution in the United States and Europe, but many rivers still have a legacy of contaminants produced from the Industrial Revolution through the mid-1900s. Although cleanup actions have been helpful for some species in some places, the single broadest and most useful recovery action has been to remove dams wherever possible. This is especially true for large mainstem dams. For example, when the Edwards Dam on Maine's Kennebec River was removed in 1999, the benefits to the full suite of this river's diadromous fishes were almost immediately visible as the fishes reoccupied their historical spawning grounds. Where dams cannot be removed, it is far preferable to install fish passage devices, despite their flaws, than to impede the movements of all diadromous fishes in a river. Research to enable passage of anadromous species that shun conventional fish ladders, such as sturgeons, should also be encouraged.

Viewed collectively, North Atlantic diadromous species underwent similar sequences of events that led to their declines (figure 3). Although quantitative data are largely lacking, anecdotal evidence from diaries, journals, and other historical accounts suggests that pristine populations of diadromous fishes were staggering in their plenitude (Waldman 2008), and formed the basis of important fisheries. Gradually, some populations became extirpated, but the pace of extirpations through the mid-20th century was slow enough to forestall great alarm (but note that overfishing of American shad in the 19th century spurred concerted management efforts).

The cumulative impacts resulted in declines, but these declines in themselves have had another unintended consequence: namely, a loss of standing or "saliency" among issues considered important by society at large. As species became scarce, fisheries declined, and often demand dropped off. Other watershed uses gained prominence. As demand dwindles and constituencies are lost, it becomes increasingly difficult to motivate and secure funding for adequate management and restoration measures. This downward spiral of

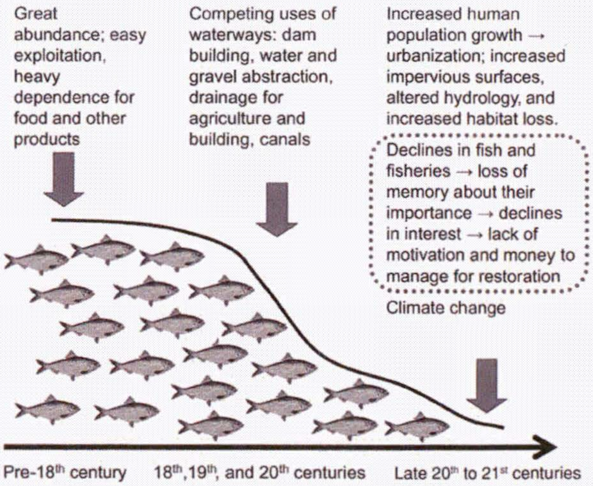

Figure 3. Conceptual diagram of the general history and factors leading to declines in North Atlantic diadromous species. Most species were heavily exploited before industrialization and physical alteration of waterways; further watershed alterations due to human population expansion and climate change increased habitat loss. Gradually, the declines also led to the loss of institutional and societal memory about past abundance and importance (outlined for emphasis).

events lacks a term, but we suggest that it is a kind of *ecosocial anomie*, a breakdown both of expectations of what species should be present in healthy populations, and societal loss of interest. The result is not only the loss of populations and species but also the loss of services the species provided when their inland ecosystems were more intact.

The stories of individual stocks that perished or are commercially extinct are numerous, but it is clear that the diminishment of diadromous fishes, taken as a group, represents one of the greatest corruptions of the ecological connections between North American and European watersheds and the North Atlantic ecosystem. Although management needs to consider the specifics of each species and population, the causes of decline we have outlined appear to be general and widespread. If there is to be a future for this group, societies must make difficult decisions concerning the trade-offs between maintaining healthy populations within healthy ecosystems and taking actions that degrade and imperil those systems. The emerging field of ecosystem service quantification may provide a means to enhance restoration, since it highlights those services that depend on ecosystem function as well as provisioning services. If ecosystem service quantification becomes mainstreamed (Cowling et al. 2008), local and regional decisionmaking would have an alternative to conventional cost-benefit schemes. These alternatives would support ecosystem and habitat restoration. It may take decades to bring back diadromous species, but restoring the watersheds and their connectivity with coastal marine ecosystems is a critical first step in that direction.

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6
Synthesis and Evaluation

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What has been depicted in the preceding chapters is a portrait of the Hudson River under somewhat haphazard management. Three distinct types of threats to the Hudson ecosystem were at issue, representing direct reductions of animal populations (power plant operation), removal of toxic substances (PCB pollution), and habitat destruction (Westway construction). Each situation that we have chosen to study has had the same characteristics: 1) scientific investigations have been used to help gather information, to clarify phenomena, or to explain effects; 2) none of the findings have gone unchallenged; so that 3) aspects of all of these impacts have gone to trial; and 4) action, if any, has proceeded by court edict more often than not.

For all three Hudson case studies, no ultimate legal resolution of the environmental issues occurred. The passage of the National Environmental Policy Act (NEPA) in 1969 and the Clean Water Act (CWA) in 1972 provided the legislative basis for litigation over power plant impact on Hudson River fisheries. Today, although 15 years have passed and a temporary truce has been called, the power plant controversies legally remain in limbo. In 1990, when the temporary agreement expires, the issue of cooling towers in the Hudson estuary may once again become the subject of a major legal contest. Also, the PCB case is legally unresolved, even though PCBs were recognized as a major problem in 1975.

Parallel to the legal issues, none of the major scientific disputes have ever been definitively laid to rest. In our Hudson River case studies, we found that the inability of science to contribute efficiently to major regulatory decisions was due to two aspects of the impact assessment process. First, the limitations of science were not acknowledged by regulatory and judicial bodies, so that scientists were asked to provide precise, unequivocal answers to questions that could not be answered in that fashion. Second, scientists often became trapped in advocacy roles, at times interpreting their analyses with their employers' implicit biases and carrying on exercises in frustration when, as expert witnesses, they contradicted one another in the courtroom.

In Chapter 1, five questions were raised about various aspects of the environmental assessment work done on the Hudson over the past 15 years. These were addressed to some degree in subsequent chapters dealing with different case studies, but we restate and answer them more completely here.

1. *Have appropriate aspects of the Hudson ecosystem been emphasized? Have the data collected been proven adequate for the estimation of the impacts under consideration?*

This double question receives a mixed answer. For each impact, the laws and regulations were interpreted in such a way that the resulting studies were, in fact, appropriately focused. (In each case, fish were the primary object of attention.) Yet other interpretations of the laws could have been made and other ecosystem features could have been carried out more thoroughly. In the final analysis, each of the scientific studies carried out for impact assessment represented compromises between the goal of answering all relevant questions and the availability of two essential resources—money and time.

For example, studies of the actual effects of PCBs in the Hudson ecosystem, complementing the extensive environmental fate studies, would have created a stronger basis for making a decision on what to do with the remaining load of PCBs in the river. However, such studies are costly, and effects may be subtle and require long periods of observation before they become manifest. For this reason, environmental assessment and regulation of PCBs have been carried out on the basis of a concentration in consumable biomass allowed by the U.S. Food and Drug Administration (FDA).

In a second example, taken from the power plant impact assessments, the federal Atomic Safety and Licensing Appeals Board (ASLAB) gave the utilities five years to prove that once-through cooling at Indian Point Unit-Two was an acceptable alternative to cooling towers. That seemingly generous time allowance was sufficient only for obtaining estimates of direct power plant effects on individual year-classes of five fish species (L. Barnthouse, pers. comm.). Again, the information that could be gathered was used to the fullest extent possible to make the final decision agreed upon in the Hudson River Settlement.

Adequacy and quality of data were also major issues in all of the cases we profiled. A parallel issue was that of unethical interpretation or suppression of data. A major mechanism of "quality control" in both the power plant and Westway cases was the scrutiny the data received in the courtroom. Certainly the quality of the data was improved by cross-examination.

Nevertheless, much of the collected data failed to yield clear-cut answers; often, questions had to be narrowed in scope to be tractable, particularly in the power plants case. Asking questions of a biological nature leads to answers, but those answers are associated with considerable uncertainty. Populations comprising a biological system of interest are inherently variable with respect to organismic physiology and behavior. Variation in the physical environment overlays further patterns, which may be reflected in organisms as clear signals, noise, or something in between. When the system of interest is large and complex, as is the Hudson River, variability in each of the individual components makes the job of first understanding and ultimately predicting the outcome of a disturbance to the system a difficult one. For instance, Barnthouse *et al.* (1984) explain that they were unable to predict long-term effects of once-through cooling on the Hudson fisheries not because of lack of effort, incompetence of the scientists, or use of an inappropriate model, but because of an insufficient understanding of underlying biological processes. Given their limited understanding of the Hudson River system, however, their evaluation of available methods for mitigating impacts was a reasonable undertaking. Their answers to this more tractable question contributed significantly to the arrangement of the Hudson River Settlement (Barnthouse *et al.*, 1984).

Anthropogenic impacts frequently take the form of disturbances outside the realm of natural fluctuations of a system. Therefore, prediction of impacts is further hindered by the need to extrapolate beyond the normal range of variations into a realm unfamiliar to the scientist. This aspect of uncertainty contributed to the difficulty experienced by Hudson River investigators in characterizing and predicting effects of human disturbance. As much as 10 to 20 years later, as in the case for impacts of cooling water uptake, the long-term effects from the anthropogenic disturbances still cannot be quantified with confidence.

2. *If the data were not adequate for impact estimation, what could have been done differently?*

In every case—power plants, PCBs, and the Westway—results of scientific investigations yielded answers that led to even more questions. An extensive data base on the growth and distribution of striped bass in the estuary did not solve the question of long-term power plant impacts on that population, in large part because the dynamics of striped bass populations could not be understood and verified in the amount of time available. In a similar vein, many measurements and models of PCBs in the Hudson's sediments and water column yielded (and may continue to yield for some time) evidence that may be interpreted by several theories of PCB transport and transformation—each having a different implication for management.

It is clear that much more time and effort could have been expended on all assessments, if available. It is also true that those resources are not likely to become much more available than at present under the current assessment structure. There are several alternatives that could be resorted to. One would be to narrow the scope of the impacts sought, as was done in the power plants and Westway cases. This alternative may yield a quicker, more precise answer in the short-term; but unless the question is chosen well, there is a danger that more important impacts will be overlooked. Another alternative would be to establish a mechanism by which a solid baseline of data could be collected and updated for the entire estuary; specific impact assessments could then make use of that data base, complementing it with studies adapted to the particular situation.

3. *Was the environmental impact assessment (EIA) work subjected to continual peer review, rather than reviewed solely after the fact for publication purposes? Was the work ever reviewed at all?*

As McDowell pointed out in Chapter 3, much of the data collected remained buried in in-house reports and was never analyzed. However, it appears that those data that actually were used in decision-making were fairly well reviewed, often during litigative procedures. In this way, the environmental assessment protocols were a success. In fact, it is because of the extensive reviewing that so many new questions emerged; it is also why studies later in the course of impact assessments contained much greater detail than did earlier investigations.

4. *Did the EIA work carry any regulatory clout? If adverse impacts were predicted, would the regulatory agency of concern be able to alter the design of the proposed project to minimize effects?*

Under certain circumstances, assessment studies did have the ability to affect the outcome of a project proposal. If the results of a study stood up under general extensive review, and if adverse effects were predicted, then changes were made in project designs. To date, however, this has occurred only when both sides in a dispute have felt that they would be better off by entering what inevitably became a compromise agreement. It did not occur when the agency charged with the responsibility to decide on a project also carried out the environmental assessment studies. This was demonstrated in the Westway case, when the U.S. Army Corps of Engineers' own studies predicted adverse environmental impacts; and yet the Corps tried to issue the final requisite permit for the construction to begin. A special study by the Committee on Government Operations of the U.S. House of Representatives found the state of decision-making in the Westway issue to be highly biased, in part because of the Corps' collaboration with the Federal Highway Administration (FHWA) and New York State's Department of Transportation (DOT)—two groups with vested interests in Westway (Committee on Government Operations, 1984). Their final recommendation to Congress included a proposal to transfer authority to grant dredge-fill permits under section 404 of the CWA from the Corps to the Environmental Protection Agency (EPA).

Congress did not choose to empower NEPA with authority to act on findings of adverse impacts. Therefore, environmental assessment is ultimately part of a political process. Even when scientific investigations are relatively divorced from the political arena (not always true), their results are weighed together with other factors when decisions are made about a given project's merit.

5. *What is to be done now with the collected data, and how can they best be complemented in future monitoring/assessment studies?*

The Hudson River Foundation, created as one of the terms of the Hudson River Settlement, has discussed placing all data collected during the assessment work in a computerized data base system that would be accessible to any interested party (J. Cooper, pers. comm.). Unfortunately, much of the information was archived in obscure places and many of the original samples were discarded. Storage of large amounts of field samples is problematic, but can be an important aspect of impact assessments that extend over a number of years as they have in the Hudson River. If samples are discarded after a short time, they cannot be reanalyzed or verified in the future when refinements in analytical techniques improve the quality of information obtained. This has been a problem for some of the PCB studies (J. Sanders, pers. comm.).

Present-day monitoring of the Hudson River is carried out in several programs that are the responsibility of New York State. These include monitoring young-of-the-year (y-o-y) and juvenile fish entrainment and impingement by power plants, a toxic substances program, and water quality monitoring. These programs have been largely designed to build on earlier studies and to maintain a long-term record of the quality of life in the estuary.

In the remainder of this chapter, we summarize features of environmental assessment and management that can aid impact evaluations in the future. Some of these features arose spontaneously in the case of the Hudson River and other estuaries. Several concepts are drawn from a document (Limburg *et al.*, 1984) describing the major consensus, regarding estuarine impact assessment methods, from a series of workshops held on the subject.

Environmental Assessment of Estuarine Ecosystems: Past, Present, and Future

After more than 12 years of practice, the institutionalized procedure of developing EIAs has come under a great deal of scrutiny, both from the legal (Trubeck, 1977; Anderson, 1973) and scientific perspectives (e.g., Friesema, 1982; Kibby and Glass, 1980; Rosenberg *et al.*, 1981). Rosenberg *et al.* (1981) surveyed over 50 EIA studies in a variety of categories, and judged their success in the following areas: "1) definition of scientific objectives, 2) background preparation, 3) identification of main impacts, 4) prediction of effects, 5) formulation of usable recommendations, 6) monitoring and assessment, 7) sufficient lead time, 8) public participation, 9) adequate funding, and 10) evidence that recommendations were used." Estuarine impact and power plant impact assessments were given average scores in their evaluations; however, in general, the assessments were characterized by poor research design, lack of coordination among studies, questionable ethics, difficulty in accessing literature on similar impacts, etc. (Rosenberg *et al.*, 1981).

In a less rigorous, but nevertheless insightful, critique, Kibby and Glass (1980) examined the specific reasons why so many of the environmental impact statements (EIAs) had so little worth. The major faults of many EISs, according to Kibby and Glass (1980), could be summarized as:

1. Too much collection of irrelevant data;
2. Inclusion of data that were collected but never used in the evaluation process;
3. Presentation of circuitous lines of reasoning that either evaded the issues or even appeared to mislead the reader;
4. Lack of detailed information about certain essential processes; and
5. Lack of time to carry out the assessments.

Interestingly, the collective Hudson River EIAs bore all of these traits. Some of them even persisted well past 1976—the year that Kibby and Glass presented their findings at a symposium. Thus, many of the problems of the EIS procedure appear to be well entrenched and difficult to remove.

Ecosystems Studies for Impact Assessment

The virtue of using ecosystems approaches to impact assessment has been discussed at length in the past decade. Leggett (1981) summarized a workshop debate dealing with population-level vs. community-ecosystem-level approaches to power plant impact assessments. There, the population-level advocates emphasized the "acceptability" of these assessments in court, the greater yield of numerical data per unit time and effort, and the fact that the public relates more readily to a single species issue (usually about fish) than to the ecosystem. On the other side were scientists who advocated community-ecosystem approaches as necessary to understand long-term environmental impacts, because they would be felt by society much longer than immediate economic ones. Therefore, it was argued that the latter approaches could better carry out the spirit of NEPA.

What is meant by a "systems approach" to environmental study? A term borrowed from engineering, a systems approach implies that a certain conceptual framework is provided to organize our understanding of complex situations. It includes: 1) a delineation of boundaries that should be relevant to the problem at hand (i.e., the problem should define the system of interest); 2) questions that are posed to understand the structure of the ecosystem; and 3) the approach that is used to investigate the functions of various parts of the system. For ecosystems, it may be appropriate to evaluate impacts at several different scales (population, community, ecosystem) more or less concurrently.

Current Role of Ecosystem Studies in Estuarine Impact Assessments

If properly executed and couched in an ecosystem perspective, EIS assessments can tell much about what long-term impacts on a system are likely to be. From this, it is possible to estimate effects on communities and populations, sometimes in the shorter term. Limburg *et al.* (1984) give some examples of assessments wherein that approach succeeded fairly well in predicting impacts or in isolating the cause of environmental deterioration, as in the case of the Chesapeake Bay (Chesapeake Bay Program, 1983; Orth and Moore, 1983). There, deterioration occurred over a vast area and a long (30-year) time span; thus, the effects were hardly isolated and could not have been detected by the examination of single populations alone. (Ecosystem monitoring has also proven to be invaluable in detection of the decline of many European and North American forests.) Other estuarine ecosystem assessments that have helped in regional planning include work on: 1) the Narragansett River and Bay (Kremer and Nixon, 1978) (sewage management); 2) the Severn estuary in western England (Longhurst, 1978) (construction of locks for flood control); 3) the Crystal River in Florida (Kemp, 1977; McKellar, 1977) (effects of a nuclear power plant's effluent on estuarine bays); and 4) the James River estuary in Virginia (O'Connor *et al.*, 1983) (fate and transport of Kepone). In the Hudson, the ecosystem studies of the fate of PCBs continue to be crucial to decisions concerning remedial action.

In much of the research done on the Hudson, reference was made to the ecosystem that provides support for organisms and processes. However, with the exception of the PCB case, the systems approach was mostly given perfunctory attention in EIS work before being dismissed in favor of population studies. In Chapter 2, we have assembled much of the existing information on the food web and environmental parameters, from which it is obvious that the Hudson is as diverse and alive as most major east coast estuaries; in fact, it may be better off than others, such as the Chesapeake. Much of the information has come from basic research studies, which reached a peak in the mid-1970s with the momentum generated by such interest groups as the Hudson River Environmental Society. Such studies need to be encouraged, expanded, and updated where necessary. In particular, more ecosystems work is needed in the upper portion of the river (above the Troy Dam).

Research Needs and Useful Approaches

In Chapter 1, we stated that our concept of "ecosystem approach" included the investigation of population-level, community-level, and ecosystem-level properties, where appropriate. In retrospect, most of the scientific investigations carried out for impact assessment on the Hudson could have been incorporated into broader ecosystem studies that would help to address questions of long-term and cumulative impacts. However, there is a noticeable scarcity of published data on *how the Hudson ecosystem works;* most of the assessment studies simply failed (intentionally or unintentionally) to link the facts together into an understandable story.

In this section, we present several methods of evaluating ecosystems for potential impacts. These range from the simple and aggregated to the specific and detailed. As outlined in Limburg *et al.* (1984), the actual assessments may be carried out in a tiered fashion, with certain tests or observations made first, followed by a choice of more involved investigations. Measurements within an ecosystem study should identify effects and/or concentrations and gradients through populations, communities, and ecosystem compartments. Human impacts also must be weighed against the background of natural phenomena. Figure 6.1 is a visual representation of the kinds of groupings relevant to the study of estuarine problems. It is important to note the hierarchical format and exchanges within and between different functional groups. A species population should be understood in the context of its interaction at a higher level of organization; for example, how a dominant polychaete species contributes to nutrient cycling in a benthic community. Assessment should also be made of biotic-abiotic relationships. Temperate estuaries are generally dominated by the physical forces of tides, upriver freshwater flow, and seasonal gradients. To what extent do these abiotic forces produce patterns of adaptation in the biota? To what extent are anthropogenic factors controlling? Where will an anthropogenic change cause a "bottleneck" in the system?

Integrative, ecosystem-level measures received little attention in the Hudson studies. However, such measures can provide a relatively simple way to obtain information about the general status of the ecosystem, particularly when the status is compared over space or time and when the impacts potentially pose large-scale problems. If pathways of energy and/or material transfer were shown to be fundamentally altered, as a result of human activity, such a finding would have major implications for the future of at least a portion of the ecosystem. For instance, impacts resulting in loss of seagrass beds would affect water flow, sediment exchange rates, floral and faunal communities, and human recreational and economic activities.

As examples of useful, albeit aggregated, approaches to ecosystem assessment, community metabolic studies provide a gross measure of energy fixation and its partitioning in the system. This, in turn, indicates the general levels of energy potentially available for processing in the food web, as well as whether the system as a whole is a net yielder or producer of biological capital. Sirois (1973) recommended the diagnostic use of community metabolic studies (production and respiration) for characterizing ecosystem response to pollution stress. He was able to identify stressed communities on the basis of the ratio of production to respiration (P/R) along a gradient from the Tappan Zee (RM 26) to New York Harbor (RM −2). The method can also be successfully used to detect absolute and relative effects of thermal loadings from power plants (e.g., Knight and Coggins, 1982). In a report on near-field effects of once-through cooling at the Roseton Power Plant, LMS (1977) found that measurements of primary productivity (measured as ^{14}C uptake) clearly demonstrated entrainment effects; yet these findings were apparently given little weight in the overall assessment of impacts.

Trophic analyses should be coupled with metabolism studies in order to understand how biological components interact with each other and also with their physical environment. This is very important to fully comprehend transfers of carbon, nutrients, and toxic substances, and also consequences of alterations of these flows. The preliminary trophic analyses that were carried out to estimate PCB transfers in the food web (Hydroscience, 1979) fell short of their goal partly because of poor estimates of biomass in the system. Even the biomasses of major fish stocks in the Hudson have never been estimated, except by the crudest of calculations (Sheppard, 1976).

Many states now require EIAs to include the study of several species that are considered representative of the ecosystem where the impact of a project will be felt (Limburg *et al.*, 1984). We regard this "Representative Important Species" (RIS) approach as a positive move away from single species studies. RIS is by no means a complete assessment, but it can be considered a first step toward an expanded evaluation of the system state. RIS studies should be carried out in such a fashion that broader ecosystems questions, which may involve linkages between organisms and abiotic parts of their environment, can be formulated and addressed. Even representative important components, such as the benthic or submerged

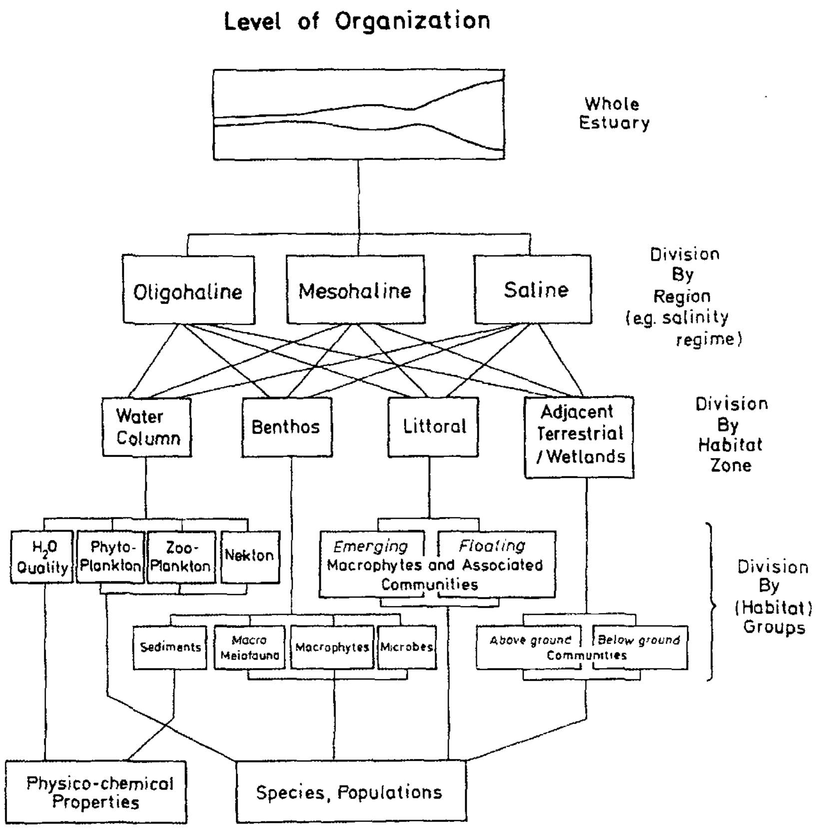

Figure 6.1. Suggested perceptual scales of organization in estuaries and attributes to consider when assessing potential anthropogenic impacts. This is meant as a guide rather than as a strict set of rules; the evaluator should be able to identify those ecosystem components most likely to be affected, and should select for study ecological attributes that will best reflect impact (Limburg *et al.*, 1984).

aquatic vegetation subsystems, could and should be directly assessed for impacts. An example might be the impact of high levels of cadmium (as in Foundry Cove in the lower Hudson) on the ability of benthic fauna to cycle nutrients.

Another way to characterize ecosystems is by means of energy or materials budgets. Budgets go a step beyond trophic analyses in that they involve abiotic components of the ecosystem as well (such as sediments). Knowledge of where energy (as fixed carbon) and major nutrients (nitrogen, phosphorus, and silica) enter and leave the system, and how they are moved about within, is crucial to understanding the ecosystem's func-

Table 6.1. Ecological attributes to consider along with organizational scales as shown in Figure 6.1.

Within the estuarine system

Biological

• Distribution of species, species richness, or some other measure of diversity or community structure;

• Major and minor species constituents (representative important species, endangered and/or rare species, nuisance species);

• Biomass, turnover times and interactions (if any) of dominant species or other species of interest;

• Metabolic processes or indices, e.g., gross and net primary production (P_G and P_N); respiration (R); P/R ratios; bioaccumulation, transformation, or depuration of toxic chemicals; nutrient cycling;

• Behavior capable of altering structure or function of ecosystem component(s).

Chemical

• Availability of nutrients for biological production;

• Nutrient dynamics (cycling through various ionic states and compounds, through system components or parts thereof);

• Mediation of chemical dynamics by physical processes (see below);

• Fate and effect of introduced, toxic substances.

Physical

• Tidal excursion and range;

• Light availability, water transparency and color, compensation depth

• Current velocities;

• Temperature, salinity, pH, alkalinity, etc.

External to the estuary, and/or shared

• Magnitudes and dynamics of fresh and saltwater in- and effluxes;

• Major imports and exports of materials (including species, organic material, chemicals, etc.);

• Anthropogenic influences (examples are: power plants; shoreline development, sewage, dredge-and-fill; agricultural erosion and runoff).

(From Limburg et al., 1984.)

tions. For example, in the Hudson, we know that over 50% of the nitrogen inputs come from sewage sources, and that only 2 to 27% of this is consumed in primary biological production (Garside *et al.*, 1976). The same sort of budgeting is important for tracing the fate of toxic chemicals, as was seen in Chapter 4.

In Chapter 2, we discussed some of the budgets that have been put together for energy (e.g., McFadden *et al.*, 1978; Gladden *et al.*, 1984) and nutrient flows in the estuary. Data are available from Hammond (1975), Simpson *et al.* (1975), and Deck (1981) on nutrient inputs to the estuary; other data describe some of the inputs and transfers to the New York Bight (Mayer, 1982). Yet none completely describe all of the inputs and outputs of the estuary, and little information has been published on the upper river. Furthermore, the role of biota in trapping, mobilizing, or cycling matter in the Hudson ecosystem is far from well understood.

Mathematical models in impact assessment work are widespread and range from the simplest of calculations (e.g., the oxygen sag-curve model to measure BOD impacts) to extremely complex, total ecosystem models (e.g., PEST [Park, *et al.*, 1980]). Entrainment-impingement models, based on paradigms from fisheries science, have been routinely used (and abused, as in the case of the Hudson) to assess power plant impacts on fish populations (for more discussion, see Hall, 1977 and Barnthouse *et al.*, 1984). Other applications have included fate and transport of toxic substances (EXAMS, Burns *et al.*, 1981), hydrodynamic and physical/chemical models for evaluation of thermal plume, wasteload allocation, water diversion, and dredge-and-fill, and models that incorporate trophic aspects of the impacted system with physical and/or chemical phenomena (e.g., Kremer and Nixon, 1978).

Many reviews exist on the usefulness of mathematical models, of which Swartzman *et al.* (1977), Mitsch (1983), Turgeon (1983), Barnthouse *et al.* (1984), and Limburg *et al.* (1984) serve as useful references for estuarine impact assessment models. For all their promise as synthetic tools, models have been plagued by problems of data requirements, uncertainties (what *is* the proper formulation to describe a given impact?), and error due to limitations of the numerical computation procedures used. Thus far, models of fairly well-understood, purely physicochemical processes have progressed more successfully than biological ones, both on the Hudson and elsewhere, although we have seen (Chapter 4) the difficulties that can arise when using physical models to predict effects.

The state-of-the-art of biological modelling is such that much of what is developed for impact assessment is also a testing of theory, rather than straightforward application of reliable algorithms. There are many unresolved questions about the ecology of estuaries, and models must reflect those gaps in scientific understanding. This situation is unlikely to change in the near future; we must learn to live with this fact. For a decision-maker, it may be better to use cautiously the results from a model known to be imperfect, rather than to use nothing at all.

In general, ecosystems studies that have had the greatest success in elucidating environmental problems have used a variety of evaluative techniques, including: 1) field measurements that quantify flows and storages of energy, nutrients, and biomass, as well as physical controlling parameters; 2) experiments, especially meso- and microcosms, that isolate or mimic parts of the real system, but are simple enough to study a particular process; and 3) mathematical models that link together disparate information and can be used to test the consequences of various hypotheses put forth by the investigator. These approaches are more powerful when developed in parallel, so that results from one kind of investigation can help the researcher to clarify, modify, or suggest new hypotheses in concurrent endeavors. Thus, for instance, a project's modelling team can synthesize field-derived and experimentally derived information and suggest what sorts of further measurements would be most useful. Measurements, in turn, can be used to verify or invalidate a model.

One cannot say *a priori* that any of these methods for examining ecosystem structure and function will be the "best" to use in the Hudson or anywhere else. However, it is important to be sure that a general characterization of the ecosystem is on record as a baseline for comparison with subsequent alterations. Otherwise, a fairly complete survey should be included as a first level of an ecological assessment package; such a package could be included in any major impact assessment work. If adequate information already exists about the area under consideration, it may not be necessary to duplicate the work.

Institutional Changes

One way that planning and management authorities deal with the problem of scientific biases is to develop infrastructures that allow scientists to operate more independently than when under contract to parties required to produce the EIS. Then research monies are not contingent upon producing a "desired" result. An independent scientific team may have greater potential for dealing objectively with available scientific data. Such teams, reporting to an autonomous scientific panel, can remove at least those uncertainties that stem from the political arena rather than from scientific constraints, unless the autonomous board itself becomes politicized. For instance, the Hudson's PCB Settlement Advisory Committee, as an independent review body for directing and reviewing research pertinent to remedial action on the problem, can be said to have greatly stimulated the understanding of chemical and sediment movement in the river and estuary.

Other states and regions have taken up this institutional pattern for environmental management and have been fairly successful in bringing together regulators, regulated interests, scientists, decision-makers, and laypeople to work out development plans that everyone can at least live with (Limburg *et al.*, 1984). The State of Maryland's Power Plant Siting Program is a good example. Patterned after programs existing in several European countries, the Maryland program maintains an autonomous board of scientific and technological advisors. Funding comes through the state, but is collected from the utility companies. The program is an apparent success partly because of the general agreement among all parties that the unbiased scientific review process is in the best interest of all parties. Also, since 1972, coastal states have instituted Coastal Zone

Management offices in accordance with the Coastal Zone Management Act; many of those programs have had great influence on the allocation of estuarine resources (Limburg *et al.*, 1984).

As suggested by McDowell in Chapter 3, it might be prudent to restructure environmental management so that the need to place so much weight on scientific research interpretation in a litigative setting is decreased. There are other points in decision-making, particularly in the legal process, where scientific input is needed and welcomed. An opportunity occurs during the creation of laws, when scientists can provide technical information to assist lawmakers in structuring the intent and scope of environmental legislation. Scientists also assist in the formulation of language of proposed legislation and can aid lawmakers in debate of the legislation. Once environmental legislation is passed, scientific input is also necessary for writing rules and criteria for regulatory and enforcement action (Limburg *et al.*, 1984).

Mediation provides another avenue by which science can enter the environmental regulatory process outside of a litigative setting. Settlement of the 17-year Hudson River power plant dispute was brought about through mediation after many years of litigation failed. A critical point in the settlement negotiation was reached through a collaborative modelling effort by expert scientists on opposing sides of the cooling tower issue (Talbot, 1983; Barnthouse *et al.*, 1984). The necessity for shutting down plant operation during critical periods in the life history of Hudson River fish was agreed upon by the scientists as the only feasible alternative to cooling towers that would afford some protection to fish-spawning activities (Talbot, 1983). However, an attempt to mediate the Westway dispute was not as successful. Meetings between the numerous and varied parties interested in Westway failed to result in any compromise plan. Finally, a suggestion was made by the Hudson River Foundation in early 1984 to use an independent mediator to help resolve the PCB disputes.

Another institutional change that has received favorable response is the strategy known as adaptive environmental assessment and management—the precepts of which are developed in Holling (1978). The forcefulness of this approach lies in the underlying philosophy of developing assessment techniques to deal with uncertainty and risk. Adaptive management necessitates the constant collection of information (including baseline studies) to decrease uncertainty, prior to and over the course of the activity; at the same time, it sets up a framework whereby policymakers and/or managers can interact with the scientists who carry out the assessments. The approach integrates data collection, mathematical assessment and optimization techniques, and intense discussion to evaluate and modify options. This is probably the best posture to adopt for most environmental assessment work, given the absence of clear-cut answers to essential questions (Limburg *et al.*, 1984).

Cumulative Impact Assessment: The Way of the Future?

Throughout this book, we have dealt separately with each environmental impact. Yet, if the Hudson is to be managed as an ecosystem, it is important to understand cumulative as well as immediate effects. Based on what is known about the hydrodynamics, sewage-derived and natural nutrient and carbon loadings, PCB and other chemical transformations, and entrainment-impingement effects of power plants, is it possible even in a qualitative manner to say what the additional impact of Westway (filling in of 200 acres on the lower Hudson) would be? Or of an additional power plant in the mid-Hudson region? Or of decommissioning an operating plant?

The answer is, probably not at this point. Although large data bases exist, our review appears to be the only attempt to link together all of the myriad sources of biological, chemical, physical, and social information. However, there is certainly reason to believe that more synthesis might happen in the future, at least with respect to the fate of hazardous chemicals in the system. Coordination of research in a cooperative spirit has occurred in the past on the Hudson, and it recently was called for again in the January 1984 workshop on PCBs (Chapter 4). Also, in this age of rapid information transfer, the establishment of a computerized data storage and retrieval system, which could be generally accessed by remote computers, could prove extremely valuable.

No amount of good will can solve problems without money to pay for the research. Thus, a second, very important factor is the development of funding sources. The latter-day formation of the Hudson River Foundation has done much to refocus interest on the Hudson ecosystem. The Foundation's purpose is to support both basic and applied research on the Hudson River, with emphasis on potential human uses of the estuarine ecosystem (HRF, 1984). Perhaps the Hudson River Foundation, in stewarding the bulk of future research, can successfully orchestrate the necessary research efforts, including among other approaches ecosystem studies *in situ* and synthetic models.

In summary, future impact assessments on the Hudson River should be greatly aided first by learning from past experiences such as those we have tried to document here. Second, although several different regulatory agencies have jurisdiction over the various activities that affect the Hudson, some centralized "book-keeping" mechanism to keep track of cumulative activities is necessary. Third, that information should be organized and made available to researchers, so that constant review and evaluation of the "state-of-the-River" can be accomplished. As long as we continue to utilize the Hudson's resources to the point of scarcity, long-term monitoring programs are needed. These should provide information on the status of the ecosystem, as well as on economically important populations. Only in this way will the successful development of managerial models proceed. Finally, scientific assessments were seen both to suffer and gain from courtroom exposure; and so ways in which time spent in court can be minimized without losing the critical review of data may help scientists and decision-makers alike to get on with the business of assessing and managing the Hudson. More emphasis on scientific input to development of legislation and regulation is recommended. Along with a renewed commitment to integrated studies, integrated planning has been instituted in the form of New York's Coastal Management Program. This program has been set up in accordance with the Federal Coastal Zone Management Act of 1972 (U.S.C. sections 1451 *et seq.*), and it was recently (autumn 1982) approved for New York State. Among other benefits, a 1670-ha sanctuary will be set aside along the Hudson estuary. This will be used for study of the ecosystem and should be extremely useful for baseline work for impact assessments.

This extensive review has led us to conclude that some of the scientific evaluation studies were performed as well as they could have been, given the circumstances, while others fell disappointingly short of that mark. The Hudson River has been the proving ground for much of America's environmental impact assessment, and many of the mistakes made have already served as lessons to decision-makers elsewhere. The mechanisms for managing the estuary have been evolving toward a more holistic perspective; certainly, most environmental investigators dealing with the Hudson today have a broader understanding of potential consequences than they had 15 years ago.

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14 Fisheries of the Hudson River Estuary

Karin E. Limburg, Kathryn A. Hattala, Andrew W. Kahnle, and John R. Waldman

ABSTRACT Fisheries have been prosecuted in the Hudson since prehistoric times. Oysters, American shad, and sturgeon were important food fisheries into the twentieth century, although of these, only a dwindling commercial shad fishery persists. Striped bass, another formerly important commercial fishery, went into decline and subsequent recovery from management actions; today, it supports a major recreational fishery. Other important sport fishing includes largemouth and smallmouth bass, and American shad. Toxicants and power plants have been long-term threats to fisheries, and will continue to pose problems for the indefinite future.

Introduction

Of all the relationships humankind entertains with the Hudson River, perhaps none is so intimate as that of fishing. The harvest of fish and shellfish from the Hudson has endured for thousands of years, and connects us both with the river's productivity and with our cultural past.

Other chapters in this book describe the fish fauna and its use of various habitats within the system. Here, we concentrate on the fisheries themselves, focusing on key species within the commercial and sportfishing arenas. We also examine some of the factors that potentially have large effects on fisheries, namely, the impacts of power plants that withdraw water from the river, and the persistence of contaminants, especially PCBs.

Historical Importance of Hudson River Fisheries

FROM NATIVE TO COMMERCIAL FISHING

Before modern agriculture and globalization of products, the fisheries of the Hudson River were an important and diverse local source of protein. Native Americans harvested fish and shellfish long before the arrival of European settlers. Dating of the oyster middens at Croton Point Park show that humans fished there nearly six millennia ago (Anonymous, 2001). Middens at Tivoli Bays in the upper tidal Hudson bear evidence of the consumption of fish and even bland-tasting freshwater mussels (Funk, 1992). Adriean Van der Donck, one of the documenters of the first Dutch settlements, noted "this river is full of fishes" (Boyle, 1979). Settlers could feast on finfish, including American shad, sturgeons, and striped bass, as well as on blue crab, scallops, and the plentiful oysters that extended throughout New York Harbor, East and Harlem Rivers, and up the Hudson as far as Stony Point. Oysters from Gowanus Bay were the size of dinner plates and especially sought after (Waldman, 1999). The Hudson River beds produced well over 450,000 barrels (50,000 m^3) of oysters per annum in the early nineteenth century (Boyle, 1979).

Commercial fishers in the eighteenth and nineteenth centuries harvested a wide variety of finfish species from the Hudson, many of which were documented by Mitchill (1815) who made numerous observations in the public markets. Among the species most heavily exploited in the nineteenth century were American shad and the two sturgeons. Sturgeons were valued for both their roe and flesh. Harvests were so great in the tidal Hudson that sturgeon was popularly known as "Albany beef," because it was shipped upriver to a hungry market. Shad could be taken in great numbers in the spring spawning runs by stake-nets or drift-nets, then salted for later consumption. In 1895, it was the number one inland fish harvested in the United States (Cheney, 1896), valued at almost $185,000 – equivalent to over $3,900,000 today.

Both American shad and sturgeons were overharvested in the late nineteenth century. Because of its life history characteristics of late maturation and nonannual spawning, coastwide

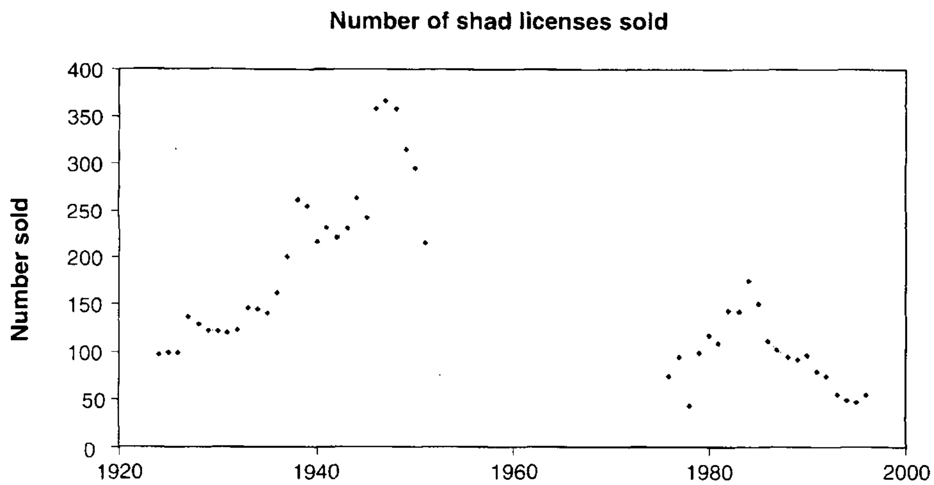


Figure 14.1. Numbers of shad licenses sold to Hudson River fishermen, 1924–96. Data from 1924–51 are from Talbot (1954) and from 1976–96, Hattala and Kahnle (1997). License records from intervening years were lost.

overharvesting of sturgeon was inevitable, given the level of effort. Overharvesting of shad peaked in the 1890s, with catches declining precipitously thereafter (Stevenson, 1899). Writing in 1916, Dr. C. M. Blackford declared,

> ... there is probably no fish on earth that surpasses the shad in all the qualities that go to make up an ideal food fish ... [*but it*] *is the one whose preservation has become a national problem.*

In the late 1800s, the U.S. Fish and Fisheries Commission took the radical step of artificial propagation, which was the state-of-the-art in U.S. fisheries management at the time. Indeed, in June 1871, Seth Green, then one of the top fish culturists in the country, steam-trained across the country with delicate shad fry held in milk cans, discharging them into the upper Sacramento River (recounted in Boyle, 1979). Shad became established on the Pacific coast, invading the Columbia River within 30 years (Ebbesmeyer and Hinrichsen, 1997) and constituting an important, if exotic, component of the ichthyofauna there today.

Concurrent with turn-of-the-century overharvesting problems, a growing and rapidly industrializing New York City created serious stress on New York Harbor, with dumping of soot and garbage and discharges of wastes an ever-increasing nuisance. The oyster fisheries were essentially gone by the 1920s (Franz, 1982), and the fouled water imparted an unpleasant flavor to most of the fishes (NYSCD, 1964). Nevertheless, fisheries continued to constitute a livelihood, at least in part, for many upriver communities throughout much of the twentieth century (Fig. 14.1). With the enactment of the National Environmental Policy Act in 1970 and amended Clean Water Act in 1972, conventional pollution declined and in many aspects, the river recovered (Limburg, Moran, and McDowell, 1986). However, as a result of widespread PCB contamination, several of the important commercial fisheries are closed, and today commercial effort is at an all-time low (see Shapley, 2001 for a journalistic account or Hattala and Kahnle, 1997).

ANGLING

The Hudson River Estuary figures prominently in the history of American angling. Due in part to the high quality of fishing in its waters and to the many books and articles written about it, Zeisel (1990) considered New York City to have become the capital of American angling by 1850. Among the important angling writers were Frank Forester and Genio Scott. In his classic work, *Fishing in American Waters*, (Scott, 1875) wrote about angling in the Hudson River estuary in the vicinity of New York City. Several sections were devoted to striped bass angling, including trolling for them from skiffs in the "seething and hissing" waters of Hell Gate in the East River, a riptide where currents reached ten knots. Scott also described fishing for striped bass from rowboats near the hedges (fish weirs made from brush) in the Kill Van Kull and from bridges in the Harlem River. The Harlem River, although dammed for tidal mill power for the first half of the nineteenth century, was a major resource which offered excellent angling for striped bass, bluefish, weakfish, porgy, and flounder (Zeisel, 1995).

These species, and others, were fished all over New York Harbor from shore and from vessels. Zeisel (1995) quoted *Harper's Weekly* of August 4, 1877, which stated that "On almost any day of the year except when the ice makes fishing impossible, hundreds of men and boys may be seen on the river front engaged in angling." Zeisel (1990, 1995) also reported that in the mid-1800s, skiffs could be rented from various liveries and that during summer, hundreds of boats filled with anglers could be seen on the harbor's best spots.

Angling in New York Harbor during Scott's time included species almost never seen today. Scott provided instructions on exactly where and how to catch sheepshead near Jamaica Bay, an area where they were so abundant that farmers would fish them with hand-lines to supplement their income. Black drum, another twentieth century absentee, also were commonly landed during the previous century in Upper and New York Bays and the East and Harlem Rivers (Zeisel, 1995).

A surprising category of fish that were caught in Upper New York Bay and along the docks of lower Manhattan from 1760 to 1895 was sharks (Zeisel, 1990). Although their species identities remain unknown, large sharks were abundant in these inshore waters during that period, possibly drawn by large amounts of food refuse being disposed of in New York Harbor. Accounts exist (ca. 1815) of shark fishers catching as many as seven sharks at lengths of up to 14 feet at Manhattan's Catherine Market (Zeisel, 1990).

Fish along the shores of Manhattan began to taste contaminated from petroleum by the late 1800s, pushing anglers to more distant waters such as the "fishing banks" in the New York Bight (Zeisel, 1995). But angling farther upriver in the Hudson River developed more slowly. According to Zeisel (1995), fishing activity centered on wharves and docks at major landings such as the mouth of Rondout Creek in Kingston, and at Newburgh, Poughkeepsie, and Hudson. Both shad and sturgeon roe were commonly used baits in the Hudson's freshwater reaches. Important species caught (mainly with hand-lines) included striped bass, white perch, American eel, and catfish. Tributaries of the Hudson River were also fished, particularly in spring for spawning runs of suckers and yellow perch. Many of these tributaries also supported trout, but this angling declined as they were fished out, with attention shifting to the black basses.

The endemicity in the Hudson River of one gamefish, Atlantic salmon, has been debated since Robert Juet – a member of Henry Hudson's exploratory expedition up the river – reported "many Salmons and Mullets and Rays very great." This notion was fueled by their occasional capture by net in the river throughout the nineteenth century. However, a number of scientists have concluded that the Hudson did not support a salmon population and that such appearances were probably strays from neighboring systems such as the Connecticut River. Nonetheless, Atlantic salmon eggs from Penobscot River specimens were stocked in the Hudson River in the 1880s (Zeisel, 1995). These stockings were sufficient to result in hundreds of commercial catches in the lower river and fewer via angling upriver, chiefly at Mechanicville (following collapse of a dam at Troy). However, there is no evidence that natural reproduction occurred and this fishery dwindled after stocking was halted. Given that Juet's observation was made in September in Lower New York Bay and because of its superficial salmonid resemblances, it is likely that he mistook weakfish for salmon.

Fishing clubs became numerous along the Hudson River beginning in the late 1800s (Zeisel, 1995). They led the fight against the Hudson fishing license, which was in effect from the 1930s to 1946. Inasmuch as it was instituted during the Depression and was costly, many people ignored it as they angled for sustenance. Game wardens were overwhelmed and judges dismissed cases against destitute offenders, which together with the fact that the river was not stocked by the state with fish, eventually led to its repeal.

Angling on the Hudson River estuary continued without fanfare during the early to mid-1900s. But because of its severe sewage and industrial contamination, the estuary appears to have reached a nadir in angling activity over that period.

The Current Regulatory Framework

Hudson River fisheries are managed by the New York State Department of Environmental Conservation (DEC). Regulatory capacity lies within the Division of Fish, Wildlife and Marine Resources. For anadromous fish species in the Hudson and in marine waters, state regulations for commercial and recreational fishing follow guidelines set by Interstate Fishery Management Plans developed through the Atlantic States Marine Fisheries Commission (ASMFC). The ASMFC is a Federal commission created to coordinate cooperative management of shared coastal resources for the fifteen coastal states from Maine to Florida, along with the two Federal resource agencies, the U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS). As set forth in its mission statement (ASMFC, 2002),

> With the recognition that fish do not adhere to political boundaries, the states formed an Interstate Compact, which was approved by the U.S. Congress. The states have found that their mutual interest in sustaining healthy coastal fishery resources is best achieved by working together cooperatively, in collaboration with the federal government. Through this approach, the states uphold their collective fisheries management responsibilities in a cost effective, timely, and responsive fashion.

A number of important laws underpin fishery management in the Hudson (see text box, "Milestones in Fisheries Legislation"). The Anadromous Fish Conservation Act provides authority and funding for preservation and restoration of anadromous fisheries, and was the impetus for much-needed research on biology, life history, population status, and characteristics of fisheries. The Fishery Conservation and Management Act of 1976, known as the Magnuson Act, created a 200-mile Exclusive Economic Zone (EEZ) along the U.S. coast, enabling controlled fishing in U.S. territorial waters. Fishing in the EEZ is regulated by regional management councils and NMFS. State jurisdiction is defined as zero to three miles, and is coordinated through the ASMFC. The Sustainable Fisheries Act and the Magnuson-Stevens Act of 1996 evolved from the Magnuson Act. In particular, Magnuson-Stevens changed emphasis to include protection of aquatic habitats, to focus on optimum sustained yield that took account of "relevant social, economic, or ecological factor[s]," and mechanisms to reduce the risk of decision making by vested interests (Ross, 1997).

Milestones in Fisheries Legislation

1965	Anadromous Fish Conservation Act
1976	Fishery Conservation and Management Act (Magnuson Act)
1979	Emergency Striped Bass Study (sub-set of AFCA)
1984	Atlantic Striped Bass Act
1993	Atlantic Coastal Fisheries Cooperative Management Act
1996	Sustainable Fisheries Act
1996	Magnuson-Stevens Fishery Conservation and Management Act

The Emergency Striped Bass Study (ESBS) of 1979 and the Atlantic Striped Bass Act (ASBA) of 1984 responded to dramatic declines in catches of striped bass, particularly in the Chesapeake Bay. The ESBS increased coastwide research and monitoring for striped bass stocks, and the ASBA, as a follow-on, required mandatory compliance with the Interstate Fishery Management Plan for striped bass. Finally, the Atlantic Coastal Fisheries Cooperative Management Act, modeled on the ASBA, provides a regulatory framework for all species managed through the ASFMC. A Fishery Management Plan (FMP) must be developed for each species, and fisheries must be monitored by each member state.

Profiles of Significant Hudson River Fisheries Stocks

In this section, we describe recent trends and status of the major commercial fishery species in the Hudson.

STRIPED BASS

***Striped bass* live approximately 25 to 30 years**

Sex	Age at Maturity	Size
Male	3 to 6 y	16 to 24 in (40 to 60 cm)
Female	6 to 8 y	27 to 32 in (68 to 80 cm)

Migratory range: Canada, New England, and mid-Atlantic coasts

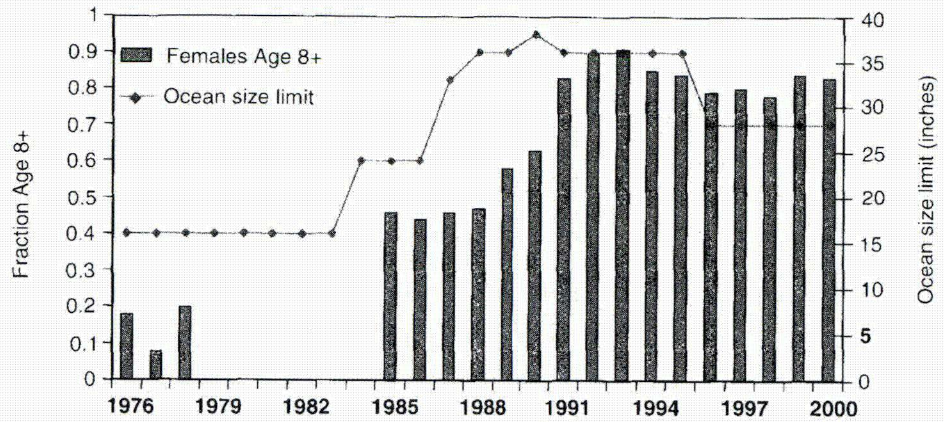


Figure 14.2. Changes in ocean size limits, and the proportion of female striped bass aged 8+ in the Hudson River spawning stock.

In the years prior to 1983, few restrictions governed the take of striped bass in state and coastal marine waters. Size limits were minimal. In New York waters, fish as small as 16 inches fork length (FL, equivalent to 40.6 cm enacted in 1939 by New York State) could be taken, there existed limited seasonal and gear restrictions, and there was no catch limit. The small size limits allowed few striped bass to reach maturity. Females begin to reach maturity at six years of age, with over 97 percent spawning by age eight. These fish are in the size range of 24 to 28 inches (61 to 71 cm; see text box).

In the Chesapeake Bay, the striped bass fishery focused on "pan rock" with fish as small as 12 to 14 inches (30.5 to 35.6 cm) making up most of the harvest. Over the course of roughly 15 years from the 1970s through the early 1980s, few adult spawners returned to the Bay. With the collapse of the Chesapeake stock in the mid 1970s, states realized that it would take a concerted, cooperative effort to restore the Chesapeake population. To achieve this goal, the Emergency Striped Bass Act (part of the Anadromous Fish Conservation Act) was passed by the U.S. Congress in 1979. This new Federal law required all coastal states that harvested striped bass to follow management regulations contained in the newly developed fishery management plan. Management would no longer be by voluntary agreement, but rather by enforced compliance. The enforcement for non-compliance is complete closure of an entire state's fishery for that species. The first striped bass fisheries management plan (FMP) was adopted by ASMFC in 1981.

Over the course of the next fifteen years, management regulations followed an adaptive process, and the FMP was amended six times. The most severe restrictions occurred in Maryland where a moratorium on striped bass fishing was implemented in Chesapeake Bay. Marine commercial fisheries were limited by severely reduced quotas to less than 20 percent of historical harvest levels, and season, size limits, and allowable gears were specified and enforced. Recreational fisheries were limited by size and bag limits, and by seasons. These regulations, especially size limits, were adjusted annually from 1984 until 1990, from 24 to up to 38 inches (61 to 96.5 cm), to protect the females from the 1982 year class (young fish produced) of the Chesapeake Bay until most of them spawned at age eight.

The effect of these regulations was startling, not only for the Chesapeake stock, but for other striped bass stocks along the coast. The coastal protective measures immediately protected immature fish of the Hudson spawning stock of striped bass. Hudson River striped bass may leave the estuary as early as age one to seasonally utilize the nearshore marine waters. Prior to adoption of the FMP, recreational and commercial fisheries alike exploited these immature bass. Once fish were no longer harvested at 16 inches, the increasing coastal size limits gave refuge to the Hudson's immature and mature population. The effect was the return of greater numbers of older, larger fish each year (Fig. 14.2), which in turn produced ever greater numbers of young.

By 1995, coastwide management targets were being met: striped bass were returning to the rivers to

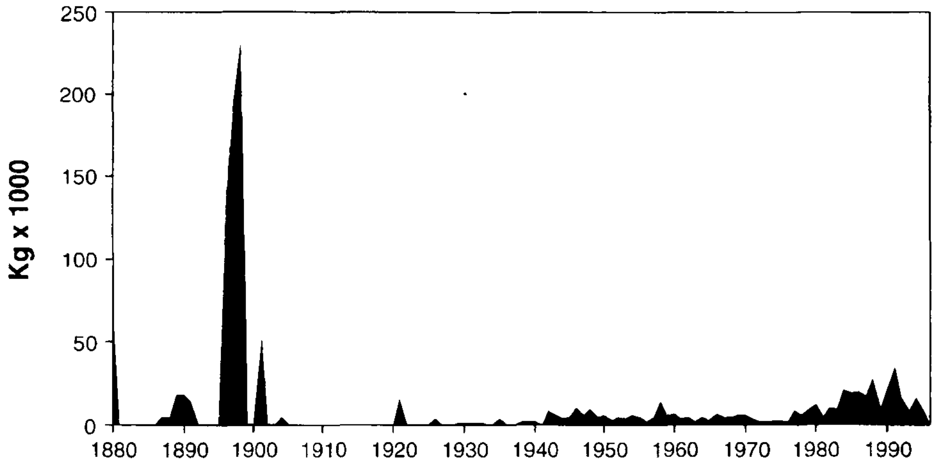


Figure 14.3. Historic commercial fishery landings of Atlantic sturgeon in the Hudson River Estuary, 1880–1995.

spawn, production estimates were up, and adult age structure was stabilized. It was then that the Chesapeake stock was declared restored. The state management agencies were not complacent about their success. Even with record numbers of fish, management restrictions were loosened slowly. Commercial harvest quotas were increased, and recreational size limits were lowered to 28 inches.

Annual tracking of mortality rate of the stock is still key. Harvest from all sources is compiled annually. Spawning stocks are monitored for age structure and survival. Young-of-year abundance estimates provide early warning of changes that may come.

ATLANTIC STURGEON

> ***Atlantic sturgeon*** live approximately 60 to 80 years. Males mature by age 8 to 12 and 15 to 20 years for females. Females spawn every three years.
>
> **Migratory range:** entire Atlantic coast, Canada to FL

Records of sturgeon harvest are available as far back as the 1880s, a time when harvest levels climbed to record highs. The high harvest level essentially clear-cut the once robust population. The Hudson's Atlantic sturgeon stock continued to remain severely depressed through the rest of the twentieth century (Fig. 14.3).

A vestigial fishery persisted in the river through the 1980s, made up of a small group of fishers taking a few fish each year for their caviar and meat. However, interest in this fishery began to change in the late 1980s. Elsewhere on the east coast, other Atlantic sturgeon stocks had already been overfished and harvest restricted or eliminated. The most important were those that targeted sturgeon produced in the rivers of North Carolina, South Carolina, and Georgia (Smith, 1985). These fisheries stimulated a market demand for smoked sturgeon products as the supply was eliminated through regulation of harvest. In ocean waters, interest rose in the late 1980s targeting the immature sturgeon for the smoked meat market, especially in New York and New Jersey (Waldman, Hart, and Wirgin, 1996).

This market shift occurred while the restrictions in striped bass management were taking hold along the Atlantic coast. Atlantic sturgeon was among the species that became fishing targets to make up for lost income. In addition, import restrictions from the Middle East (Iran was a source of much of the caviar available in the United States) greatly enhanced the value of any domestic source of caviar. Some of the Hudson's shad fishers began to experiment and eventually became very successful at capturing adult Atlantic sturgeon.

Based on the success of rebuilding the striped bass stocks, the Atlantic Coastal Fisheries Cooperative Management Act was passed in December

1993. This act gave the same stringent enforcement power to all FMPs developed under ASMFC. States, with New York in the lead, began to look with much scrutiny at the condition of the River's Atlantic sturgeon stock and the rate at which they were being fished.

With their long lifetime, older age at maturity, and irregular spawning schedules, Atlantic sturgeon are easily over-fished. Young individuals were being harvested in coastal waters as they left the Hudson at age three to seven to begin their long marine residence before they mature ten to fifteen years later. Few fish were surviving to return to the river, and even here a fishery targeted the spawning adults. In 1995, New York tried to implement controls in the fishery with season and area closures, followed in 1996 with the imposition of a quota system, limiting the total take. But by 1997, New York's stock assessment demonstrated that harvest and fishing rates were severely over the limit that the population could handle. A moratorium was put in place that year, and by 1998 the entire U.S. Atlantic coast was closed to harvest. The interstate management plan set a forty-year time limit for the coast-wide moratorium based on the life history of the animal. That is, within the next forty years, the current spawning population's young should be able to grow and mature to produce one more generation before examining the reopening of any fishery.

AMERICAN SHAD

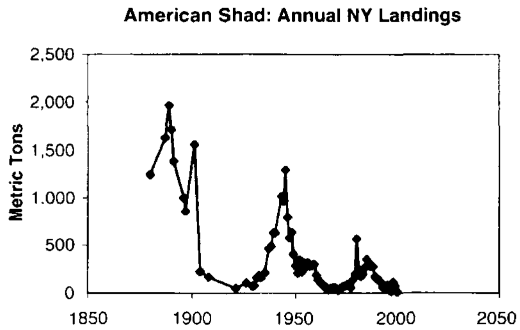
> ***American shad*** in the Hudson River live 13 to 15 years. Males begin to spawn by age 3 to 5, females by age 5 to 7.
>
> **Migratory range of Hudson shad**: Atlantic coast, Canada to NC

At the turn of the twentieth century, the new immigrant population continued to swell the growing Atlantic coast cities, including New York. It amazed them to find that every spring fish returned to the Hudson by the thousands, an easy food supply to feed the hungry. Unfortunately for shad, it earned recognition as the second highest harvested fish on the east coast following Atlantic cod. Atlantic sturgeon came in third. The seemingly unlimited harvest, however, wore down the stock, and before long shad suffered the same fate in the Hudson as in other Atlantic coast rivers.

The story of respite, rebuild, overharvest, and collapse occurred several times for the Hudson shad stock (Hattala and Kahnle, 1997). During periods of lowered fishing pressure, the stock rebuilt between collapses. However, the resiliency of this highly fecund species was slowly being eroded as the century wore on. The first collapse occurred prior to the known record. United States Fish Commission reports documented that in the 1870s the Hudson stock was "over-fished and in need of replenishment." Seth Green, then working for New York State, began a hatchery to stock shad in the spawning areas in the upper reaches of the tidal Hudson and even above the Troy Dam (Cheney, 1896). Fishing was not the only problem for the stock. Spawning areas were lost as the shallow bays behind the river's islands were slowly filled with dredge spoil from creation of a shipping channel to the Port of Albany. Nearly a third of the upper tidal Hudson was filled, almost all of it shad spawning habitat. Water quality in the spawning reach also suffered through much of the twentieth century (Faigenbaum, 1937; Burdick, 1954; Talbot, 1954; Boyle, 1979) until improvements to sewage treatment were made.

The gaps in the fishery landings records from the early 1900s (Fig. 14.4) are thought to be from lack of fishing activity. This lack of fishing would have allowed the shad stock to rebuild to a size necessary to produce the dramatically large harvest that occurred during the years leading up to World War II. Fishing this available food source became a valued trade during the war, so much so that fishing rules in the river were suspended. Each spring in the war period, hundreds of fishermen set their nets, and riverside communities took as many fish as the nets could bear.

In less than twelve years, the next stock collapse was underway: the greater the effort, the fewer the fish. In addition, water quality worsened. Sewage poured in and habitat suffered. In the summer, sections of the river, around Albany and the lower estuary, were completely devoid of oxygen. A few shad kept returning, but the overall stock size remained much reduced from its former status. This problem was not unique to the Hudson: for example, the Delaware River was so polluted between



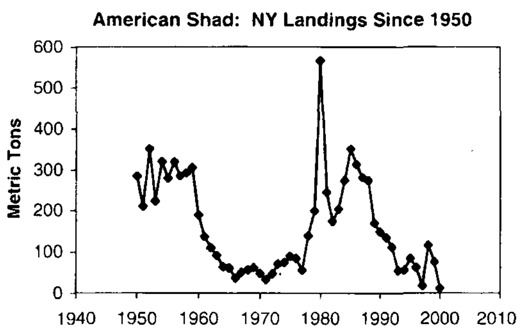


Figure 14.4. Catches of American shad in New York State. Most of the catches are from the Hudson. Top panel: trends since 1880. Bottom panel: trends since 1950. Note differences in scale. *Sources:* National Marine Fisheries Statistics, Walburg and Nichols (1967).

Trenton and Philadelphia that this entire segment went anoxic in the summer months, preventing any movement of fish, such as migrating shad (Chittenden, 1969).

Finally in the mid 1970s, the environmental movement gained momentum. With the passage of the much-strengthened amendments of the Clean Water Act in 1972, the sewage dumping eventually abated. The river slowly started to recover, along with its fisheries.

Humanity's influence again was felt, just as in the case of Atlantic sturgeon. During the recovery effort for striped bass, many near-shore ocean fishers shifted their focus to American shad. These "ocean intercept" fisheries directed their fishing pressure onto mixed assemblages of east coast shad stocks, including the Hudson's. Some stocks began to show declines, or no sign of recovery, despite restoration programs. Since 1991, the Hudson's shad stock began its latest decline, showing classic signs of overfishing. Individuals are smaller at any given age, and fewer older fish are returning to spawn.

A 40% reduction in effort of the directed ocean intercept fishery occurred in 2003 followed by a complete closure on December 31, 2004. How effective will this measure be? At this point, it is unclear how quickly the stocks will respond to the reduced harvest. Directed fishing may come to an end, but in some cases, shad picked up in other fisheries may become discarded bycatch. Continued monitoring of this bycatch will be a key element in managing the coastwide restoration. In the Hudson River, it is still unknown whether further cutbacks will be required, for example, closure of more spawning area, or lengthening the lift (no fishing) period.

The Contemporary Sport Fishery

With the general upgrading of sewage treatment during the twentieth century and, particularly since passage of a New York State Bond Act in 1965 and the federal Clean Water Act amendments of 1972, the Hudson River and New York Harbor have seen recoveries of many fish populations (Waldman, 1999). The increased availability of fish and a growing perception that the Hudson River system has become cleaner has led to a pronounced increase in angling activity. However, this increase has not been well quantified due to the rarity and limited scope of angling surveys conducted, and to potential knowledge lost through consideration of the mainstem tidal Hudson River as an extension of the sea for which fishing licenses are not required. Moreover, despite this angling revival, its enjoyment is hindered by the continuing presence of PCBs and other contaminants in the river's finfish and shellfish and in resultant governmental restrictions and health advisories.

Boyle (1979) contrasted the intense angling effort for striped bass in the mid 1900s along the ocean coast with the dearth of striped bass anglers in the Hudson River, despite the species' high abundance in the river. Boyle wrote: "... only a relative handful of anglers, perhaps fifty at best, regularly take advantage of the striper fishing that is to be had in the Hudson." He also described the Albany Pool as being "so awesomely foul as to be a source of wonder to sanitary engineers" from raw sewage releases and that this caused the river to be essentially devoid of oxygen in summer for twenty to thirty miles south of the Federal Dam at Troy.

But in the last two decades of the twentieth century, as the Hudson River reached levels of purity not seen for decades to a century or more and the striped bass population continued to increase, angling over the length of the tidal river grew in popularity, with the area below the Federal Dam becoming especially attractive as striped bass and other anadromous fish aggregated there in large numbers (Lake, 1985; Zeisel, 1995). A snapshot of this emergent striped bass fishery in 1997 between the George Washington Bridge and the federal dam was provided by Peterson (1998). Using a combination of 37 aerial flights and 2,700 angler interviews from April through June, he estimated the striped bass fishery supported 619,132 angler-hours distributed over 145,842 angler-trips. Of these, the boat fishery was responsible for 71 percent of effort and 84 percent of catch. Total catch was estimated at 112,757 striped bass, of which only 12.5 percent were harvested. This low harvest was attributed to concerns over PCB contamination and to restrictive bag limits (one fish 18 inches or larger north of George Washington Bridge; one fish 28 inches or larger south of George Washington Bridge). This fishery in the Hudson River and New York Harbor became so popular that several, mainly springtime charter boat operations were launched (Vargo, 1995; Waldman, 1999), and annual tournaments are now held. Accounts of urban angling for striped bass in New York Harbor may be found in Waldman (1998, 1999).

Another fishery that has grown from one enjoyed by relatively few local residents in the mid 1970s to one that supports charter boats and tournaments that garner national publicity is for the two black basses of the river: largemouth and smallmouth bass (Nack et al., 1993). These species occur in freshwater and low salinity reaches of the river. Recruitment in the Hudson River is low for black basses but growth is rapid (the fastest in New York State; Green, Nack, and Forney, 1988), resulting in a fishery that is attractive because it provides a high percentage of large specimens despite low densities of adults (<2 largemouth bass per hectare; Carlson, 1992). Moreover, these fisheries are primarily catch-and-release, with considerable effort spent in tournaments or practicing for tournaments; Green and Jackson (1991) estimated that as of 1990, there were fifty to sixty black bass tournaments held annually in the river. This tournament activity is centered in Catskill (Green et al., 1993).

There is concern over the effects of tournaments on the Hudson River black bass population. Green et al. (1993) estimated that during 1989–91 at least 10 percent of the river's largemouth bass were weighed in during summer. Increased handling, especially during warm conditions, may lead to greater mortality (Cooke et al., 2002). Although cause and effect was not demonstrated, the estimated population size of largemouth bass (>280 mm) declined from 22,000 in 1989 to 14,000 in 1991. On the other hand, more recent estimates of populations indicate that largemouth were back up to 22,000 by 2000 (LMS, 2001). Smallmouth bass abundance was estimated at 5,000–6,000 (LMS, 2001). Tournament intensity was lower in 1999 and 2000 compared to surveys conducted in the late 1980s, and the catch rate for largemouth bass in 2000 was the highest on record (LMS, 2001).

Ironically, a new sport fishery has developed for American shad in the Hudson River as they continue their long-term decline there. Anglers have learned that in addition to below the Federal Dam where shad aggregate, they may also be found by targeting particular types of habitat and tidal stages throughout much of the tidal freshwater portion of the river (NYSDEC, 1982).

Several angling surveys have occurred that stemmed from health concerns about fish consumption but that nonetheless provided ancillary information on the nature of the fishery. Belton, Roundy, and Weinstein (1986) surveyed anglers in the lower Hudson River, Upper New York Bay, and Newark Bay between 1983 and 1985. Young-of-the-year bluefish made up 85 percent of the observed finfish catch, with larger bluefish, striped bass, summer flounder, and winter flounder also prominent. Blue crab was heavily fished and was the most frequent species consumed. Two-thirds of respondents who admitted eating their catches considered them to be totally safe to eat and about one-fifth viewed them as slightly polluted but not harmful, despite a New York State Department of Health advisory aimed at limiting human consumption of cadmium.

Another factor that contributed to a recent increase in angling activity in the Hudson River is the development of shoreline access. Many communities have opened shorelines, piers, and bulkheads to fishing with the help of directed funding such as the Hudson River Improvement Fund. New

Table 14.1. Current power plants along the tidal Hudson River.

Name of facility	Initial year of operation	Original operator	Current operator	Location (km from Battery)	Total gross rated capacity (Mwe)	Total cooling water flow (1,000 m^3/d)	Fuel type
Albany Units 1–4	1952–1952	Niagara Mohawk		229	400	1,921	Fossil
Danskammer 1–4	1951–1967	Central Hudson	Dynegy	107	480	1,725	Fossil
Roseton 1 & 2	1974	Central Hudson	Dynegy	106	1,248	3,496	Fossil
Indian Point 2	1973	Con Edison	Entergy	69	906	4,746	Nuclear
Indian Point 3	1976	NY Power Auth.	Entergy	69	1,000	4,746	Nuclear
Lovett 1–5	1949–1969	Orange & Rockland	Mirant	68	496	1,725	Fossil
Bowline 1 & 2	1972–1974	Orange & Rockland	Mirant	60	1,244	4,189	Fossil
59th Street, NYC	1918	Con Edison	Entergy	8	132	917	Fossil

Data from Limburg et al. (1986) and updated.

York City has constructed piers for angling at several sites.

Conflicts with Fisheries

As seen throughout the pages of this book, the Hudson River is many things to many people. So far we have reviewed the conflict between the river as food production base and sewage recipient. We now discuss, briefly, two other anthropogenic activities potentially at odds with sustainable fisheries: power generation and toxicants. For more detail on background, see Limburg et al. (1986) and Chapter 25.

WATER WITHDRAWAL BY ELECTRIC POWER PLANTS

Until recently, a consortium of public utility companies (Consolidated Edison of New York, Orange and Rockland Utilities, Central Hudson Gas and Electric, New York Power Authority, and Niagara-Mohawk) owned and operated seven generating stations ranging from 59th Street on Manhattan to Albany (Table 14.1). The plants are under new ownership as a result of industry deregulation. All of the plants use Hudson River water as coolant, and recycle the water back to the river. These plants have a combined rating of 5,905 Mwe, but more relevant here, a combined total cooling water flow exceeding 23,465,000 m^3 per day. This flow is on par with freshwater discharges measured at Green Island, where the average annual discharge (1918–1980) is 44 percent higher, but where mean August flows are 42 percent lower (Limburg et al., 1986).

Initial concern about potential impacts of power plants was that the heated effluent would cause harm to the biota, but it was soon seen that the larger potential threat was direct mortality due to two factors: entrainment, or the passage of small organisms, particularly fish larvae, through the plants and across the heated turbines; and impingement, or the trapping of fish on intake screens designed to keep large particles out of the cooling water inlets. Gradually, attention focused mostly on the potential impacts of the power plants on a few "representative and important species," but primarily on striped bass.

Between 1974 and 1980, a protracted series of hearings and litigations by a group of plaintiffs consisting of government agencies and environmental organizations examined the utilities' environmental impact statements. During these hearings, increasingly complex mathematical models were developed to describe the potential losses of key species, especially striped bass, as a result of entrainment and impingement. At the same time, data were collected in several major programs, all funded by the utilities and continuing today. These are the Long River Survey, designed to assess egg and larval densities; the Fall Shoals Survey, to assess juvenile densities offshore; and the Beach Seine Survey, designed to assess onshore fish communities and abundance. It was determined through statistical analysis of the data sets that the level of variation in the data obscured any clear forecasting of the impacts of the plants, and that it might take as long as fifty years of data collection to observe any clear trends (Limburg et al., 1986). With no foreseeable scientific determination, all the parties to the litigation entered into a negotiated settlement, lasting from 1980–90, that prescribed outage (period of reduced water use) schedules to reduce larval mortality, modifications of intake screens, and the establishment of an institution (The Hudson River Foundation) to provide secure funding for future Hudson River studies.

During the fifteen years since the Hudson River Settlement Agreement expired, the utility companies continued to monitor fish communities and produce annual reports. In addition, they prepared a new draft environmental impact statement (DEIS, 1999). In the meantime, the Federal government deregulated the power industry, and over the past few years all the utilities have been purchased by private corporations (Table 14.1). Additionally, approval has been sought for another five new-generation power plants along the Hudson. The new plants will use only a fraction of the water and will be closed-cycle, i.e., will use cooling towers rather than returning thermal effluent to the river.

The socioeconomic climate for operating utilities along the Hudson appears to have changed; deregulation's intent was to produce more competition, and a potential side effect is that the companies operating the existing plants are less concerned with environmental effects than the previous owners. However, the new owners inherited the environmental issues of operating the old plants, and these are still in need of resolution. Among the issues that will likely be contested in future hearings are whether or not fish populations (particularly striped bass) have "compensatory mortality," or the ability to rebound at low densities, as when depleted by power plant mortality; whether bay anchovy, an important estuarine forage species that suffers up to 50 percent year class removal by the plants, truly constitutes a Hudson River population or is part of a larger, offshore stock; and whether the power plants affect species that experience other environmental stresses, for instance, Atlantic tomcod that has been stressed due to a long-term warming trend in the river (Daniels et al., in press), which could severely affect this cold-adapted species.

Table 14.2. FDA guidelines on maximum allowable levels of selected contaminants in fish

Substance	Level	Food type
Aldrin, Dieldrin	0.3 ppm	all fish
Chlordane	0.3 ppm	all fish
DDT, TDE, DDE	5.0 ppm	all fish
Heptachlor	0.3 ppm	all fish
Mirex	0.1 ppm	all fish
PCBs	2.0 ppm	all fish
2,4-D	1.0 ppm	all fish
Arsenic	76 ppm	crustaceans
	86 ppm	molluscan bivalves
Cadmium	3 ppm	crustaceans
	4 ppm	molluscan bivalves
Chromium	12 ppm	crustaceans
	13 ppm	molluscan bivalves
Lead	1.5 ppm	crustaceans
	1.7 ppm	molluscan bivalves
Methyl mercury	1 ppm	all fish
Nickel	70 ppm	crustaceans
	80 ppm	molluscan bivalves

Source: FDA 1999.

PCBs AND OTHER TOXICANTS

Toxic substance contamination is widespread in the Hudson and is covered in other chapters. It has had a fundamental impact on fisheries here, as well as throughout New York State. Fish commonly angled in the Upper and Lower Hudson contain ten-fold greater levels of PCBs than Great Lakes fish, and these levels are two orders of magnitude greater than found in Chesapeake Bay (Baker et al., 2001).

The Food and Drug Administration (FDA) prohibits the interstate sale of contaminated products. FDA guidelines on selected toxic substances are given in Table 14.2. Note that for PCBs, the action level of 2 ppm is now considered by many to be too high, and many states are adopting more stringent guidelines. This has translated into the closure of commercial fisheries for striped bass since 1976, some of which do remain for many years in the Hudson and build up elevated body burdens of PCBs (Zlokovitz and Secor, 1999). Other species for which smaller commercial fisheries existed include eels, bullhead, and carp, all of which currently contain high levels of PCBs and other contaminants. According to data from Skinner et al. (1996, 1997), striped bass also exceed the action limits on mercury and dioxin, eels do so on PCBs, DDT, dioxin, and chlordane, and white perch has concentrations above the action limit for chlordane.

Although crustaceans bioaccumulate high levels of metals and organochlorines in their hepatopancreas, their muscle tissue is very low in contaminants, and hence fisheries persist with the caveat that hepatopancreas, or "tomalley," should be discarded. The only other commercial fisheries that persist are for American shad and river herring which as adults only return to the Hudson to spawn, and therefore have low contaminant burdens. River herring are sold as bait to striped bass sport fishers. Ironically, the increase of striped bass that cannot be kept and sold commercially has driven some of the few remaining commercial fishers to give up, because the nets become full with striped bass and must be laboriously picked out without profit.

Since the awareness of widespread contamination in the 1970s, the New York State Health Department and the DEC both issue annual health advisories against eating certain fish from particular waters, including many specific areas within the Hudson drainage. Nevertheless, angler surveys indicate that the message does not always get through to the fishers. A survey by Barclay (1993) interviewed anglers in 1991 and 1992 at twenty shorefront locations from Fort Edward to New York Harbor. Survey respondents were predominantly male (92 percent) and 84 percent were between the ages of 15 and 59. Two-thirds of the anglers were Caucasian, 21 percent were African American, and 10 percent were Hispanic (others were 2 percent). Barclay found that almost one-fifth (18 percent) of the anglers who eat their catch were trying to catch blue crabs, whereas another 23 percent indicated they were not targeting any particular species. Of those who eat their catches, only 48 percent were aware of health advisories. Fish consumption varied by ethnicity; 94 percent of Hispanic, 77 percent of African American, and 47 percent of Caucasian anglers ate their catches. During 1995 in a New Jersey portion of New York Harbor, Burger et al. (1999) found there were ethnic differences in consumption rates, sources of information about fishing, knowledge about the safety of the fish, awareness of fishing advisories, and knowledge about health risks.

Most recently, in 1996, NYSDOH (2000) surveyed shoreline-based anglers on the Hudson River between Hudson Falls and Tarrytown, New York; the protocol of this survey was similar to that of Barclay (1993). Three regions were defined: Area 1, from Hudson Falls to the Federal Dam at Troy; Area 2, from the Federal Dam to Catskill; and Area 3, from Catskill to Tarrytown. Because of high levels of PCB contamination, angling in Area 1 during 1996 was catch-and-release only. In both the Barclay (1993) and NYSDOH (2000) surveys, more than 90 percent of anglers said they were fishing primarily for recreation or other similar reasons, and only 6–7 percent said they were fishing primarily for food. In 1996, about one-third of anglers surveyed had kept at least some of the fish they caught from the river.

The most numerous catches were of white perch and blue crab, with striped bass, white catfish, and American eel also frequent (NYSDOH, 2000). But species most commonly kept (by total weight and in order) were white perch, white catfish, striped bass, and carp. Together with the two black basses, bluefish, and American eel, these eight species accounted for 83 percent by weight of the fish observed to have been harvested in this survey. NYSDOH (2000) concluded that numerous anglers in Area 3 remained unaware of health advisories for consumption of fish from the Hudson River. This is likely because anglers fishing the lower Hudson are not required to purchase licenses, and the health advisories are included in the state's fishery regulations booklet given out with the license.

A landmark decision by the U.S. Environmental Protection Agency in 2000, upheld by Director Whitman in August 2001 (Johnson, 2001), enforces a dredging order that will require sediments from a 10-mile (16 km) stretch of the upper Hudson to be removed. These contaminated sediments have been shown to be the greatest continuing source of PCB contamination for fish in the River and Estuary. As Baker et al. (2001) point out, such a massive project will require careful execution and monitoring, but the resultant lowering of PCB concentrations in fish should be rapid following project completion. This will have the immediate effect of permitting consumption of many currently inedible species.

The Future of Fisheries in the Hudson

It is difficult enough to forecast catches from one year to the next for a single species, and virtually impossible to predict the future of Hudson River multispecies fisheries over the long term with any sort of accuracy. Nevertheless, we can comment on some trends.

Commercial fishing is in long-term decline, in the Hudson and many other east coast estuaries. If the status quo were to remain, the future would not look optimistic. However, the restoration of striped bass through a concerted, interstate management program demonstrates that overexploited species can be brought back, and restoration programs are under way for American shad, river herring, and sturgeon in many of the same systems. Fishery management programs in the Hudson use a combination of regulatory instruments (closures, seasons, and limits on minimum size, numbers caught, etc.), focusing on regeneration of a natural stock rather than through hatchery supplementation, although these last are ongoing in a number of east coast states. Further, a number of interagency programs are working to remove toxicants from the river and reduce the inputs. Beside the EPA's PCB removal project in the upper Hudson, programs such as the Contaminant Assessment and Remediation Project, part of the New York-New Jersey Harbor Estuary Program, are identifying the fate and transport of contaminants in order to remove them. Although serious problems still exist in the Harbor region, improvements have been noted (Steinberg et al., 2001).

Whereas commercial fisheries have diminished in the River, recreational fishing has increased to unprecedented levels. The restoration of striped bass stimulated a wave of angling interest, and sport fishers throng the Hudson during the stripers' spawning season. The projected toxicant cleanups will benefit all users of the resources, including users of striped bass. However, the conflict between sport and commercial resource users of striped bass may widen, unless both can come to an understanding on how management allows sharing of this common resource, as it occurs in marine waters along the entire mid-Atlantic coast. Recreational angling contributes to local economies, but so do commercial fisheries to a lesser, and some think, unimportant degree. But there are noneconomic impacts of cultural value in preserving the heritage of commercial fisheries, as well as in promoting stewardship of the resource by all users.

Overlain on the patterns of human alteration of fish stocks and their habitats is the prospect of fundamental climate change, resulting in a warmer Hudson River. Already we may be seeing evidence of this. Rainbow smelt and Atlantic tomcod, both northern boreal species at the southern extent of their range in the Hudson, are disappearing. Smelt have not appeared in utilities' or state fisheries' surveys since the mid 1990s, and tomcod have declined dramatically and appear to be cycling between moderately and very low abundances (DEIS, 1999). On the other hand, gizzard shad, a species known from the Mississippi and southeastern drainages, appears to be increasing dramatically in the Hudson, and is also appearing in estuaries as far north as Maine. Gizzard shad has the potential to become a strong ecological actor in the Hudson fish community, because it can compete for zooplankton effectively, rapidly outgrow its "window of vulnerability" to predation, and can then subsist on detritus and thus not be food limited. How these and other changes in the dynamic fish community will affect fisheries is a research question, but clearly they will have an impact.

The long-term patterns seen in fisheries statistics, and especially the more intensive monitoring studies of the past twenty to thirty years, have taught us much about the dynamics of Hudson River fish stocks, what is possible to know (e.g., spawning stock characteristics such as age and size distributions) and what may never be possible to know precisely (e.g., absolute stock abundances). In many respects, we now have the tools available for sustainable fisheries management. The critical element needed to carry through is strong public and political commitment of resources for continued adaptive assessment and management.

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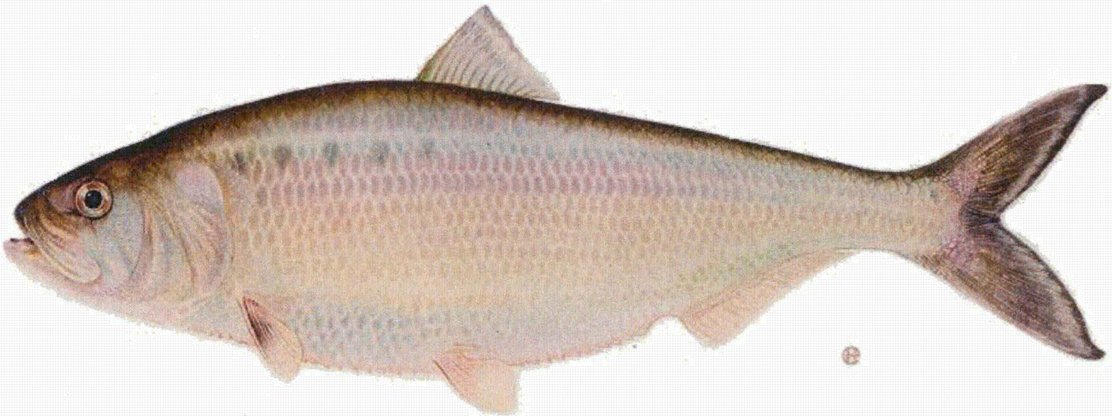

Hudson River American Shad
An Ecosystem-Based Plan for Recovery
Revised: January 2010

HUDSON RIVER AMERICAN SHAD
AN ECOSYSTEM-BASED PLAN FOR RECOVERY

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To meet the goals of the
Hudson River Estuary Action Plan

Results of a recent Atlantic States Marine Fisheries Commission analysis of coast-wide shad stocks indicated that Hudson River American shad are in serious trouble (ASMFC 2007a). Commercial landings of shad from the Hudson River Estuary are at their lowest level since 1880. Moreover, the spawning stock is experiencing excessive and unacceptably high mortality, and that mortality has seriously reduced the abundance of adults and the production of young in the estuary. Restoration of this signature species will require a broad-based ecosystem initiative that includes management actions in the estuary and in the Atlantic Ocean and focused ecological studies to understand American shad's role within the estuary. The following summarizes current causes of decline and outlines a detailed program of response.

Causes of Decline

American shad of the Hudson River Estuary are anadromous. They spawn in spring in the river, but spend most of their lives in the nearshore Atlantic Ocean from Virginia to Maine. The Hudson estuary extends 245 km from NY City to the Federal Dam at Troy. American shad spawn in freshwater from Kingston (km 145) through Troy. Juveniles use the upper 150 km of the estuary as a nursery area and emigrate from the river in fall. They return to the Hudson 3-7 years later for spawning.

American shad are caught by recreational and commercial fishermen while in the Hudson and by various commercial fisheries while in the ocean. It is not known if shad are taken by recreational fishing while in ocean waters, or if they are taken in combination with, or mistaken for, hickory shad. Commercial ocean fisheries that targeted American shad (directed fisheries) were closed in all Atlantic coastal states in 2005. Incidental take of shad in other ocean commercial fisheries (called bycatch) continues and can be legally sold in some states including New York.

The principal known cause of the decline in Hudson River American shad was overharvest by directed ocean commercial fisheries and in-river commercial and recreational fisheries (ASMFC 2007a). Directed ocean harvest of American shad has ended, but losses to in-river harvest continue. Losses of young and adult shad to ocean commercial bycatch (unintended catches) may have been a factor in the decline, but the magnitude of such losses is essentially unknown. Young American shad in the river are also lost to various cooling water intakes.

Habitat loss and alteration most likely affected historical abundance of American shad in the Hudson River Estuary. Substantial destruction of potential shad spawning and nursery habitat occurred from the late 1800s through the mid 1900s from dredge and fill in the upper third of estuary during development and maintenance of the navigation channel from New York City to Albany/Troy (Miller and Ladd 2004). This habitat alteration was probably a factor in shad decline in the late 1800s and early 1900s. However, major habitat alteration has not occurred over the last 50 years and it is unlikely that it has been a factor in the most recent stock decline. Such habitat loss however, may influence the rate of stock recovery.

Interactions among biota within the estuary may influence shad abundance, but supportive data are lacking. It has been suggested that changes in predator abundance in the river may have affected survival of young shad. Largemouth bass, smallmouth bass, white catfish, and channel catfish occur throughout the freshwater shad nursery area when early shad life stages are present. Bluefish, striped bass, and weakfish are present in the lower estuary in fall as young shad emigrate from the river. Diets of these potential predators in the river have been poorly studied and the effects of these predators on shad survival remain speculative. Competition with other biota may also influence young shad survival. The recent introduction and explosive growth of zebra mussels in the Hudson substantially reduced phytoplankton, along with subsequent_zooplankton production (Caraco 1997). Since young shad feed on zooplankton, it is possible that feeding by mussels reduced food available to young shad. Following the arrival of zebra mussels, the diet of blueback herring shifted from open water zooplankton and benthic drift to biota found in shallow water vegetation beds (personal communication, Dr. D. Strayer, CIES, Millbrook, NY). Presumably, this shift occurred because open water prey became less available. It is not known if a similar diet shift has occurred in American shad. However, Strayer et al. (2004) did find that growth of young of year American shad decreased after zebra mussels established themselves in the river. A decrease in growth has the potential to affect survival of age zero shad during their first winter.

Two hypotheses for causes of shad decline were discounted in the recent ASMFC (2007a) analyses. They were striped bass predation on mature shad and poor water quality. Crecco et al (2007) reported that adult striped bass preyed on small mature American shad in the Connecticut River. The authors speculated that the recent increase in striped bass abundance may have affected shad abundance in other Atlantic Coastal rivers. However, extensive analyses of Hudson River striped bass gut contents concluded that this was not an issue in the Hudson (ASMFC 2007a). Moreover, abundance data for adults from several East Coast Rivers suggested no relationship between striped bass abundance and shad abundance. Declines in water quality in shad spawning and nursery areas have been suggested as a cause of shad decline in some east coast estuaries. However, this is not so in the Hudson where water quality has improved over the last 30 years.

Recovery Goals

The Draft *2010-2014 Hudson River Estuary Action Agenda* of NYSDEC calls for the restoration of the Hudson River shad by 2050. This shad recovery plan defines short and long term objectives associated with this goal and describes activities needed to achieve the goal and objectives.

Several measures are available to define objectives and assess the status of the Hudson River American shad stock. These include:

- Annual index of relative abundance of age zero fish called the juvenile abundance index or JAI. This is obtained by annual NYSDEC sampling by beach seine in the upper two-thirds, freshwater portion of the Estuary.
- Spawning stock biomass, or SSB. This is a relative annual index of total weight of mature female shad in the river. It is calculated from egg abundance estimated by contractors to Hudson Valley electric generating companies and age structure and weight at age data collected by NYSDEC spawning stock sampling.
- Rates of total annual mortality (A) of mature females. This is defined as that fraction of females present at the start of the calendar year that die during the year. The rate is estimated from data obtained by NYSDEC spawning stock sampling.

We propose that recovery objectives consist of a matrix of these three indices. No single index is adequate because each index responds at a different rate to different influences on the stock. For example, the JAI usually responds first to changing early life survival while SSB responds most quickly to changing adult survival. A healthy sustainable fish stock needs good recruitment (relatively high JAI), adequate spawning stock size, and reasonable (low) adult mortality rates. The use of all three indices addresses all of these needs and is the most robust approach to setting benchmarks.

1. Long term objective:

    Restore American shad abundance to levels that occurred in the 1940s. Quantitative targets will include relative abundance of age zero American shad and SSB indices estimated for 1940-1950 from population modeling and calibrated to relative abundance indices obtained by NYSDEC beach seine sampling and recent SSB estimates. Restoration assumes a total mortality rate on the adult stock at or below 52% as specified in the 2007 ASMFC stock assessment.

    Progress toward the JAI benchmark will be measured by a five year running average which dampens the influence of wide inter-annual fluctuations in the measure. Progress toward SSB and total mortality benchmarks will be measured by three year running averages. These indices warrant a shorter multi-year mean because they do not vary as widely among years and both already encompass many year classes. Inter-annual variation is too high in all of these indices to allow use of a single year's value to measure restoration progress.

2. Short term objective:

    Restore American shad abundance to levels observed in the late 1980s. The quantitative targets will be the mean age zero abundance index from NYSDEC beach seine monitoring from 1985 through 1989, the mean SSB for 1985 through 1989, and a total mortality rate (A) on the adult stock at or below 52%.

Progress toward these benchmarks will be measured in the same manner as progress toward long term objectives. Specific quantitative targets for long and short term objectives will be defined in a separate report and updated as needed.

Recovery Plan

Recovery of Hudson River American shad will require continued stock monitoring, actions that we can implement relatively quickly and at relatively low cost, and longer term actions that will take planning and substantial funding. The following summarizes proposed recovery activities. It includes suggestions made at a Hudson River American shad workshop hosted by the Hudson River Foundation (HRF) in New York City on 31 July 2008. In November of 2008, the HRF published a special request for proposals for research in connection with the recovery of American shad in the Hudson River. Contracts funded in responses to this request are expected to improve our understanding of the ecological role of American shad in the Hudson. Status of recovery plan activities and estimated costs will be updated annually.

1. Maintain American shad monitoring programs

We need to continue current annual stock monitoring to track current condition and progress in response to management actions. Two separate, fishery independent shad monitoring efforts must be maintained.

A. NYSDEC programs.

Objective: Monitor annual status of juvenile and adult American shad in the Hudson River.
Actions:
1) Obtain an annual abundance index for juvenile shad in the estuary by 30.5 m beach seine; and
2) Characterize annual size and age structure and survival rates of spawning American shad.

B. Hudson Valley Generating Companies (HVGC)

Objective: Provide annual indices of egg and larval fish abundance.
Background: Data are used by NYSDEC in conjunction with NYSDEC spawning stock age data to calculate an annual index of adult shad biomass (SSB Index).
Action: Continue the Long River Ichthyoplankton Survey.

2. Reduce Mortality – Short Term

The most important and meaningful action that we can take right now for shad recovery is to reduce mortality on all life stages as quickly as possible.

A. In River Fisheries

Objective: Minimize or eliminate losses to commercial and recreational fisheries that target American shad within the Hudson River to levels that will allow the population to grow.
Action: Implement fishing restrictions for American shad fisheries in the Hudson River.

B. NY Ocean Fisheries

Objective: Eliminate legal sale of shad caught while fishing for other species in NY ocean waters.
Action: Implement new regulations for NY marine waters. Issue is complex because many fisheries are involved and data on shad landings are limited.

C. Water Intakes

Objective: Reduce or eliminate losses of all shad life stages to Hudson River power generating plants.
Action: Ensure that permits include provisions to reduce losses of shad to water intakes.

3. Reduce Mortality – Long Term: Characterize and Reduce Bycatch

American shad from the Hudson River estuary are taken in commercial fisheries from Maine to Virginia. Unintended loss of shad in fisheries targeting other species is called bycatch. Knowledge of bycatch characteristics (quantity, location, and time of year) allows us to evaluate the impact of bycatch and to reduce it where needed through regulation in New York state waters and through ASMFC action in waters of other states and in federal waters. Since shad from many stocks are taken as ocean bycatch, we will also need to develop a method to identify that part of the bycatch from the Hudson River. This will allow New York to focus regulatory protection on those fisheries most affecting Hudson shad.

A. Available National Marine Fisheries Service (NMFS) bottom trawl data

Objective: Identify locations and seasonal timing of American shad concentrations in ocean waters
Background: NMFS conducts bottom trawl surveys of ocean fish abundance and distribution from Maine through North Carolina. Trawling occurs in spring and fall. Although few American shad are taken in this survey, enough are taken to characterize seasonal concentration areas. This information will facilitate the search for shad bycatch in existing and future bycatch monitoring databases.
Action: NYSDEC staff will analyze NMFS data with the assistance of NMFS staff at the Northeast Fisheries Science Center at Woods Hole, MA. Analyses will summarize abundance of American shad catch by bottom trawl by season and location.

B. Available NMFS Sea-sampling Data

Objective: Characterize American shad bycatch recorded in existing National Marine Fisheries Service (NMFS) sea sampling data.

Background: Current NMFS data were obtained by onboard sampling of commercial fishing operations to document catches of endangered marine mammals, sea birds, and reptiles. Coverage of fishing operations is patchy because it is concentrated on times and locations where bycatch of endangered biota is expected. These data have not been analyzed for presence of American shad.
Action: NYSDEC staff will analyze NMFS data with the assistance of NMFS staff at the Northeast Fisheries Science Center at Woods Hole, MA. Analysis will, where possible:

- Identify and characterize fisheries with shad bycatch and identify, quantify, and characterize bycatch of these fisheries by time and location. Analysis is expected to follow procedures identified in ASMFC (2007b) and Wigley et al. (2007).
- Identify times and locations of inadequate fishery monitoring coverage that can be resolved through additional onboard monitoring.

C. NY Ocean Sea Sampling

Objective: Identify, quantify, and characterize the American shad bycatch in ocean commercial fishing operations based in New York State.
Background: American shad are rare in the existing NMFS sea sampling database. Thus, existing data may be inadequate to quantify and characterize shad bycatch and additional sea sampling may be needed.
Action: If needed, develop and conduct an at sea sample program of commercial vessels fishing in NY ocean waters. Since many fish species managed by NY are taken as bycatch in ocean fisheries and the cost to monitor additional species is insignificant, monitoring will cover all NY managed species. The result will be more useful and the program more defendable. Needed actions include:

- Develop sample design needed to achieve a given level of precision; contracted through the Pew Institute of Ocean Studies/SUNY Stonybrook.
- Execute a contract for onboard sampling of commercial vessels based on developed sample design; possible funding sources include the Hudson Estuary Program (HREP) and the Ocean and Great Lakes Ecosystem Conservation Council (OGLECC);
- If onboard monitoring identifies fisheries or specific times or locations of high shad bycatch, NYSDEC will take the necessary steps to reduce bycatch, including educational and regulatory or legal actions.

D. Port Sampling in the NY Bight

Objective: Obtain information on shad bycatch in commercial Atlantic herring and mackerel fisheries of the Atlantic Ocean in the NY Bight.
Background: American shad and river herring are taken in the Atlantic herring and mackerel fisheries that occur from the Gulf of Maine through Cape May. The fisheries operate in the Gulf of Maine in summer when juvenile river herring predominate the bycatch and from Cape Cod through Cape May in winter when American shad occur as bycatch. These are high volume fisheries where catch is vacuumed out of the nets and into the hold. Thus, onboard observers are ineffective. As an alternative, the state of

Maine samples harvest as it is unloaded in fish processing plants. Sampling has focused on ports north of Cape Cod because Maine is most concerned with bycatch of river herring.
Action: Expand port sampling of the Atlantic herring and mackerel fisheries to ports from Cape Cod, MA through Cape May, NJ in winter when American shad are more common in the bycatch.

E. Sea Sampling in Other Coastal States

Objective: Obtain information on shad bycatch in commercial fisheries of other coastal states and in Federal waters more than three miles from shore (EEZ).
Background: Will need support of other states and the federal government for a broad based bycatch monitoring program. Sampling will require funding from the federal government and private foundations.
Action: This will be best accomplished through the ASMFC Inter-State Fisheries Management Plan (ISFMP) program and Shad and river herring ISFMP Draft Amendment 3. This assures compatible sampling, data sharing and consistency with the Atlantic Coastal Cooperative Statistics Program (ACCSP). Possible funding sources include the Wildlife Conservation Society or the Pew Institute for Ocean Studies.

F. Ocean Harvest Stock Identification

Objective: Identify Hudson River American shad in ocean bycatch.
Background: Bycatch of American shad in ocean fisheries includes fish from many spawning stocks along the Atlantic coast. Researchers have developed several promising approaches to American shad stock identification including microchemistry of shad otoliths and various DNA based techniques.
Action: Support proposed studies with assistance in proposal development, letters of support, and biological samples as needed.

4. Characterize and restore critical spawning and nursery habitat.

Approximately 1,420 hectares of upriver shallow water habitat were lost through dredge and fill operations during construction of the federal navigation channel in the early and mid 1900s (Miller and Ladd 2004). Much of this area was potential shad spawning and nursery habitat. The identification, characterization, and restoration of lost habitat are important long-term components of Hudson River shad restoration.

A. Spawning Habitat

Objective: Identify and characterize current spawning habitat used by adult shad.
Background: Current knowledge of American shad spawning location in the Hudson River Estuary must be inferred from general location of shad eggs. These data are not adequate to pinpoint specific spawning location and thus do not allow characterization of that habitat. More precise spawning locations can be identified by sonic or radio tracking of spawning shad in conjunction with benthic maps and GPS location information. NYSDEC Hudson River Fisheries Unit (HRFU) has used this technology

on juvenile Atlantic sturgeon so equipment, vessels, and expertise reside within the Department.
Action: Implement a study of movement and habitat use of mature American shad in the Hudson River spring spawning migration.

B. Nursery Habitat

Objective: Identify and characterize shallow water habitat used by eggs, larvae, and juvenile American shad in the Hudson River Estuary.
Background: Early life stages of American shad are too small to tag and shallow vegetated areas are not sampled by existing sample programs in the Hudson River Estuary. However, larval push nets have been designed to sample early life stages of fish in shallow vegetated and unvegetated river habitat. This gear was very effective at collecting larval fish from vegetated shallows in the Kissimmee River in Florida (personal communication, Daniel Miller, NYSDEC, Staatsburg, NY).
Action: Sample existing vegetated shallow water habitat by larval push net mounted on the bow of a work boat. Although NYSDEC can develop sample apparatus, develop a sample design, and collect samples, sample identification would best be done by a contractor. Potential funding sources include HREP, SWG, HRF, or NRD.

C. Demonstration Restoration Project

Objective: Create a demonstration shad habitat restoration project.
Action: Craft experimental projects to increase the amount of spawning and nursery habitat similar to habitats identified in tasks A and B above. Experimental projects would cover a range of possible restoration approaches, include measurable objectives, and specify monitoring to verify results. Promising methodology could then be applied in conjunction with resource agencies such as the Army Corps of Engineers. Logistic challenges to this type of restoration have been identified and still need to be addressed. They include restoration dredge spoil disposal and regulatory and permitting issues (habitat trading).

5. Ecosystem Studies

During their first year of life, American shad are likely to be prey for a variety of predators and could compete with other species for critical food. Either interaction could be a factor in the recent decline in shad abundance. Studies of these interactions could clarify the role of juvenile American shad within the ecosystem, but most likely would not lead to effective restoration actions.

A. Predation.

Objective: Identify diets of estuarine predators of young of the year American shad that are abundant enough to affect the shad population.
Background: The most logical marine predator to evaluate is striped bass. This species has increased in abundance in the last 20 years and appears to congregate in the lower river in the fall when young shad emigrate. The most logical freshwater predators are

largemouth bass, smallmouth bass, white catfish, and channel catfish. These fish are relatively abundant in the middle and upper estuary in spring and summer when young shad are in shallow water nursery areas.

It should be noted that diet analyses of potential predators may be hampered at this time by the paucity of young shad in the river. Unless a predator focused on them, young shad would likely be a rare diet item. Moreover, diet studies of in-river predators ignore the potential impact of ocean predators, although diets of striped bass while in the ocean have been found to be focused on menhaden.

Action: Conduct a survey of available published and unpublished literature on diets of potential Hudson River Alosine predators. If available data are not conclusive, conduct diet studies of these predators when and where their presence overlaps that of juvenile American shad. Striped bass should be collected from the lower river in late summer and early fall. Freshwater predatory species should be collected in summer from shallow water nursery habitat in the mid and upper estuary. Sample size should be 200 to 300 stomachs for each species annually. Diet studies should continue for three consecutive years for each potential predator.

This work would best be done by contract. NYSDEC does not have the necessary expertise to efficiently identify food items. Contractors should work cooperatively with ongoing NYSDEC sampling programs to obtain all or a portion of the fish to be analyzed. Sample collection may require additional sampling by contractors. Potential researchers include Institute of Ecosystem Studies, SUNY Stonybrook, and SUNY Environmental Sciences and Forestry (ESF). The USGS-Columbia River Research Laboratory at Cook, WA is also exploring potential American shad predators and may partner with NYSDEC to conduct this work.

Potential funding sources include the HREP and the HRF.

B. Competition

Objective: Identify potential interactions between age zero American shad and other organisms within the estuary that may be competing for the same food source.

Background: The recent introduction and explosive growth of zebra mussels in the Hudson has substantially reduced phytoplankton, along with subsequent zooplankton production. Since young shad feed on zooplankton, it is likely that feeding by mussels has reduced food available to young shad. Preliminary analyses by Strayer et al. (2004) found decreased growth of juvenile shad following the introduction of zebra mussels. Moreover, the diet of blueback herring shifted from open water zooplankton and benthic drift to biota found in shallow water vegetation beds (personal communication, Dr. D. Strayer, CIES, Millbrook, NY). Presumably, this shift occurred because open water prey became less available. It is not known if a similar diet shift has occurred in American shad.

Effects of reduced zooplankton abundance on growth and survival of juvenile American shad would logically be exacerbated by any competition with other Alosines that use the same nursery areas. Both alewife and blueback herring utilize shad nursery areas and likely use the same zooplankton food resource. Diet work on Hudson River Alosines is limited and most occurred prior to the introduction of zebra mussels.

Action: Conduct a survey of available published and unpublished literature on diets of Hudson River Alosines. If data on post zebra mussel diets are inadequate, conduct diet analyses of early life stages of Alosines. This would involve annual collection for each species of 300 larvae and 300 young for three years. Early life stage samples can be obtained from the nursery habitat study described above in task 4B if studies are concurrent. NYSDEC can supply later stage juveniles from the annual beach seine survey. Coordination of sample collection and identification of gut contents should be done by a contractor. Potential researchers include Institute of Ecosystem Studies, SUNY ESF, and the USGS-Columbia River Research Laboratory. Possible sources of funding include the HREPand the HRF.

C. Ecosystem Modeling

Objective: Develop a bio-energetic model or models to assess the potential impacts of identified predators and competitors for food resources on Hudson River American shad.
Background: A description of predation or potential competitive interactions does not indicate that such interactions are significant. For example, the knowledge that striped bass prey on juvenile shad does not in itself prove that such predation has affected shad abundance. Potential impacts of predation can be evaluated by energetics-based population models. These models require substantial information about fish growth, consumption rates, diet, metabolic rates, survival, and abundance. Enough of these data are currently available for Hudson River fishes to warrant some exploratory model runs. Even if results are inconclusive, attempts at modeling will identify data needed to improve modeling and thus guide future research.
Action: Develop a proposal to collate the necessary data and to build a bio-energetic model. Potential researchers include CIES, SUNY-ESF, SUNY Stonybrook, and the USGS-Columbia River Research Laboratory. Possible funding sources include HREP and the HRF.

D. Climate Change

Objective: Evaluate the relationship between early life stage and adult abundance and various indices of ocean and river water temperatures.
Background: There is evidence that surface temperatures of the Atlantic Ocean have changed over the last 150 years (Kerr 2005, Sutton and Hodson 2005). Ocean temperatures have been relatively warm since about 1991. Moreover, Hudson River water temperatures have generally increased between 1920 and 1990 (Ashizawa and Cole 1994). Changes in ocean temperature could affect timing of shad ocean migration to spawning rivers as well as movement to summer feeding and overwintering locations. Changes in river temperatures could affect timing of spawning and early life stage growth relative to food supplies. Any of these changes could affect survival of Hudson River American shad and hinder recovery efforts.
Action: Develop a proposal for appropriate analyses using existing data. Potential researchers include CIES, SUNY-ESF, SUNY Stonybrook, and the University of Massachusetts. Possible funding sources include HREP and the HRF.

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Glossary

ACCSP- Atlantic Coastal Cooperative Statistics Program
ASMFC- Atlantic States Marine Fisheries Commission
CIES- Cary Institute of Ecosystem Studies
ESF- Environmental Science and Forestry
HREP- Hudson River Estuary Program
HRF- Hudson River Foundation
HRFU- Hudson River Fisheries Unit
NMFS- National Marine Fisheries Service
NRD- Natural Resources Damages [Unit- NYSDEC]
NYSDEC- New York State Department of Environmental Conservation
SUNY- State University of New York
SWG- State Wildlife Grants
USGS- United States Geological Survey

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Impacts of entrainment and impingement on fish populations: A review of the scientific evidence

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Review

Impacts of entrainment and impingement on fish populations: A review of the scientific evidence

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ABSTRACT

In 1972, the United States Congress enacted §316(b) the Clean Water Act, which mandates minimization of the adverse impacts of entrainment and impingement of fish and other aquatic life at cooling water intake structures. Since the Act was passed, there has been continuous controversy over the magnitude of any such impacts and over the need for mitigating measures to reduce these impacts. The objective of this paper is to examine the published scientific information relevant to this issue The review includes (1) peer-reviewed literature reporting results of studies of impacts of entrainment and impingement at power plants on fish populations, (2) peer-reviewed literature and "blue-ribbon" commission reports on aquatic resource degradation that evaluate causes of observed degradation of aquatic ecosystems, and (3) EPA's own assessments of causes of degradation in coastal environments. The clear conclusion from the review is that any impacts caused by impingement and entrainment are small compared to other impacts on fish populations and communities, including overfishing, habitat destruction, pollution, and invasive species. The available scientific evidence does not support a conclusion that reducing entrainment and impingement mortality via regulation of cooling water intakes will result in measurable improvements in recreational or commercial fish populations.

1. Introduction

In 1972, Congress passed the Federal Water Pollution Control Act Amendments, 33 U.S. C. §§ 1251 et seq., (popularly known as the Clean Water Act or CWA), which included a provision [§316(b)] authorizing the United States Environmental Protection Agency (EPA) to regulate cooling water intake structures. Specifically, §316(b) requires that "*the location, design, construction and capacity of cooling water intake structures shall reflect the best technology available for minimizing adverse environmental impact* [emphasis added]." The adverse impacts that were the subject of the amendment result from (1) the drawing of fish and shellfish eggs and larvae into and through the condenser cooling systems of power plants, where mechanical and thermal stresses can cause high levels of mortality, and (2) trapping of fish against the screens that prevent debris from being drawn into the cooling water intake. These processes are referred to, respectively, as "entrainment" and "impingement." In 1976, EPA issued a rule implementing §316(b); however, that rule was suspended on procedural grounds in 1977. For more than 20 years beginning in 1977, no rule was in place and permitting authorities made decisions implementing §316(b) on a case-by-case, site-specific basis. As a result of a lawsuit initiated by environmental groups, EPA agreed in 1995 to issue regulations implementing §316(b) in 1999. This deadline was later extended, and the rulemaking was subdivided into three phases. Phase I would cover new cooling

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water intake structures, Phase II would cover existing intake structures withdrawing more than 50 million gallons of cooling water per day, and Phase III would cover existing intake structures withdrawing between 2 and 50 million gallons per day. EPA issued the final Phase I rule in 2001 [FR 66(243):65255-65345]. EPA issued a final Phase II rule in 2004 [FR 69 (131):41575-41693]. This rule was suspended in 2007 after several key provisions were overturned by the U. S. 2nd Circuit Court of Appeals. EPA issued a final Phase III rule in 2006 [FR 71(116):35006-35046]. In 2011, EPA proposed a new rule that would be applicable to both Phase II and Phase III facilities [FR 76 (76):22174-22288].

All of these rules continue to be controversial because of the perception that valued aquatic resources are at risk, and because the costs of compliance, especially for existing facilities, can be extremely high. Interestingly, §316(b) does not define the term "adverse environmental impact." Throughout the 1970s, the term was understood by most scientists involved in environmental impact studies to refer to adverse changes in the abundance or productivity of populations of fish or shellfish susceptible to entrainment and impingement. Intensive field and laboratory investigations were conducted to address impacts of entrainment and impingement on fish populations in several major ecosystems, most notably the Connecticut River (Merriman and Thorpe, 1976) and the Hudson River (Barnthouse et al., 1988a).

Since 2001, EPA and many state agencies to whom authority to implement §316(b) has been delegated have issued rules in which adverse impacts have been implicitly or explicitly defined as entrainment and impingement per se, irrespective of whether any adverse changes in populations can be demonstrated or predicted.

EPA asserted in the preamble to its 2004 Phase II rule that "multiple types of undesirable and unacceptable impacts may be associated with Phase II existing facilities, depending on conditions at the individual site." The preamble cited a wide variety of potential adverse impacts on populations and ecosystems that could potentially result from entrainment and impingement. EPA used data obtained from power plant operators and other sources to estimate that annual mortality of fish and shellfish due to entrainment and impingement at large power plants was equivalent to a loss of 3.4 billion one-year-old organisms. However, the literature cited to document the occurrence of potential population and ecosystem-level effects resulting from these losses included only two peer-reviewed scientific paper (Boreman and Goodyear, 1988; Summers, 1989), neither of which involved measurements of actual population or ecosystem changes.

Yet, during the 40-year period over which rules have been developed, challenged, and revised, power plants with once-through cooling have been operating continuously throughout the U.S. and Europe, many with extensive monitoring programs. At the same time, scientists and resource management agencies concerned about degradation of freshwater and marine resources have conducted many studies intended to identify causes of observed population and ecosystem decline.

The purpose of this paper is to evaluate the scientific validity of arguments concerning adverse impacts of entrainment and impingement through a review of the peer-reviewed scientific literature on fish population depletion and on ecosystem services. The review includes (1) peer-reviewed literature reporting results of studies of impacts of entrainment and impingement at power plants on fish populations, (2) peer-reviewed literature and "blue-ribbon" commission reports on aquatic resource degradation that evaluate causes of observed degradation of aquatic ecosystems, and (3) EPA's own assessments of causes of degradation in coastal environments. There is extensive literature on impingement and entrainment, most prepared by or for power companies as part of regulatory compliance activities. Similar studies have also been performed by non-governmental environmental organizations (NGOs). This "gray" literature has rarely been independently peer-reviewed, is highly variable in quality, and is inevitably vulnerable to charges of lack of objectivity. For these reasons, this review is limited to literature that has been independently and professionally peer reviewed.

The issue is not whether entrainment and impingement could *potentially* have adverse environmental impacts, but on whether any such impacts have been shown to occur over the 40 years since the enactment of §316(b), either through direct study of power plant impacts or through studies identifying causes of observed population and ecosystem degradation.

2. Peer-reviewed studies of adverse impacts of entrainment and impingement

Even prior to the 1972 passage of the CWA, concerns had been raised by both government agencies and nongovernmental organizations about the potential impacts of entrainment and impingement on fish populations (Barnthouse et al., 1984). Despite these concerns, in the more than 40 years since they were originally raised relatively few studies of adverse impacts of entrainment and impingement on fish populations have been published in the peer-reviewed scientific literature. The best-known of these studies were published as American Fisheries Society Monographs.

2.1. *Connecticut River and Hudson River monographs*

The Connecticut River Ecological Study, which documented monitoring and assessment studies performed during construction and early operation of the Connecticut Yankee plant on the lower Connecticut River, was originally published in1976 (Merriman and Thorpe, 1976). An update reproducing the original monograph and documenting ecological studies performed in the river after the completion of the original study was published in 2004 (Jacobson et al., 2004). The Connecticut River study was designed in the mid-1960s, prior to the emergence of entrainment and impingement as a major regulatory issue, at a time when thermal discharges were expected to be the most important causes of adverse impacts on receiving water bodies. Hence, much of the study focused on impacts of Connecticut Yankee's thermal plume. Entrainment monitoring was conducted, however, and the study estimated that 4% of fish eggs and larvae passing by the plant could be entrained. The study authors drew no inferences concerning the impacts of entrainment on adult populations because of lack of information concerning: (1) the natural mortality rates of susceptible life stages and (2) the carrying capacity of the river system.

The updated study (Jacobson et al., 2004) documented results of 37 years of monitoring and research conducted following the completion of the original study, including the entire remaining period of operation of Connecticut Yankee, which ceased commercial operation in 1996. Major changes in the Connecticut River fish community documented in this monograph include decreased abundance of native alosids (alewife, blueback herring, and American shad), increased abundance of alosids native to mid-Atlantic and southern rivers (gizzard shad and hickory shad), and a shift in the relative abundance of different catfish species. None of these changes were attributed to the operation of Connecticut Yankee, and the authors concluded that there is no evidence that plant operations had any long-term impact on the ecology of the lower Connecticut River.

Environmental research and assessment studies addressing impacts of entrainment and impingement at multiple power plants located on the lower Hudson River, New York were documented in a 1988 monograph (Barnthouse et al., 1988a). In contrast to the Connecticut River study, the emphasis of the Hudson River studies was on quantifying the impacts of entrainment and impingement on populations of juvenile and adult fish. Species addressed included striped bass, white perch, Atlantic tomcod, bay anchovy, alewife, blueback herring, and American shad. Most of the data used in the quantitative assessments, however, was collected over a 3-year period (1974–1976) when the power plants (Indian Point Units 2 and 3, Bowline Point Units 1 and 2, and Roseton Units 1 and 2) that were the focus of the assessments had just begun operation. Hence, most of the papers in the monograph deal with either estimated impacts on individual year classes or potential long-term impacts on adult populations. The estimated reductions in individual year classes (Boreman and Goodyear, 1988; Barnthouse and Van Winkle, 1988) ranged approximately from 10% to 20%. These mortality rates, although by no means negligible, were judged by both agency and utility scientists to be substantially smaller than mortality rates routinely sustained by many harvested species (Barnthouse et al., 1988b). The settlement agreement that ended litigation between EPA, the State of New York, and the Hudson River utility companies required a variety of mitigation measures to reduce entrainment and impingement, but did not require closed-cycle cooling (Barnthouse et al., 1988b). The river-wide monitoring program that provided the data used in these studies has continued through the present, and subsets of the data have been used in several peer-reviewed publications (Barnthouse et al., 2003a; Strayer et al., 2004; Heimbuch, 2008; Barnthouse et al., 2009), however, no publications have used these data to address long-term impacts of entrainment and impingement at Hudson River power plants.

2.2. *Other studies using population models and site-specific data*

Jensen (1982) used conventional fishery assessment models to quantify the impact of entrainment and impingement at the Monroe power plant in southeastern Michigan on the yellow perch stock in the western basin of Lake Erie. He concluded that entrainment and impingement at Monroe would cause only a 2–3% impact on the equilibrium biomass of the yellow perch population. In contrast, fishing this population at the level associated with maximum sustainable yield (annual harvesting of 35% of the population) would reduce the equilibrium biomass of the population by 50%. In a related paper, Jensen et al. (1982) used the same types of models to quantify impacts of entrainment and impingement at 15 power plants on alewife, rainbow smelt, and yellow perch populations in Lake Michigan. The authors concluded that impacts of entrainment and impingement on the biomass of all three species were small: 0.28% for yellow perch, 0.76% for rainbow smelt, and 2.86% for alewife.

Lorda et al. (2000) used a model of the Niantic River, Connecticut winter flounder population to evaluate combined impacts of entrainment, impingement, and fishing on future trends in the abundance of this population. The model was parameterized using 25 years of data on entrainment and impingement of winter flounder at the Millstone Nuclear Power Station and a similar time series of data on the abundance and age structure of the population of winter flounder that spawns in the Niantic River. Lorda et al. (2000) found that the influence of fishing on the abundance of this population was much larger than the influence of entrainment and impingement. According to these authors, by 1995 fishing had reduced the biomass of the Niantic River winter flounder spawning stock by nearly 90%, from an un-fished level of 120,000 lbs to less than 15,000 lbs. Because of the high level of fishing mortality, reducing entrainment at Millstone by 50% would increase the spawning population by only about 9%. The conclusion of Lorda et al. (2000) concerning fishery impacts is consistent with the findings of the National Marine Fisheries Service (NEFSC, 2011), which has concluded that the Southern New England-Mid Atlantic winter flounder stock, of which the Niantic River population is a component, has been severely depleted by overfishing.

Barnthouse et al. (2003b) used a combination of long-term monitoring data and population-level assessment models to address impacts of 25 years of operation of the Salem Generating Station in New Jersey on fish populations and communities in the Delaware Estuary. Trends analyses found no evidence that entrainment and impingement at Salem had caused reduction in either the diversity of the Delaware Estuary fish community or the abundance of key fish populations. To the contrary, statistically significant increases in one of the two community metrics evaluated and in the abundances of susceptible fish species such as weakfish, striped bass, and American shad were observed. Model analyses showed that the impacts of entrainment and impingement on weakfish and other harvested fish populations was small compared to the impacts of fishing. Although finding no evidence for impacts caused by Salem's operations, Barnthouse et al. (2003b) found strong evidence that many Delaware Estuary fish populations had increased in abundance following improvements in water quality and reductions in harvests that occurred between 1975 and 1998.

Henderson et al. (1984) used 11 years of data on impingement of sand smelt at the Fawley Power Station, Hampshire, UK to assess impacts of age-selective impingement on the age distribution of local sand smelt population. These authors found that impingement had no measurable effect, and concluded that the operation of Fawley Power Station had no significant effect on the long-term stability of this population.

Perry et al. (2003) used population models to evaluate impacts of entrainment and impingement at six Ohio River power plants on local populations of bluegill, freshwater drum, emerald shiner, gizzard shad, sauger, and white bass. The models were parameterized using annual estimates of (1) entrainment and impingement from each power plant and (2) the abundance of the target populations in the navigational pools on which the plants are sited. Given available data concerning year-to-year variability in the abundance of these populations, the model was used to determine whether, if there had been no entrainment and impingement, a measurable increase in the abundance of each population could have occurred. Results indicated that the abundance of 6 of the 22 local populations examined might have been measurably higher, if there had been no entrainment and impingement. However, the authors noted that these predicted increases were small compared to changes caused by habitat modification, water quality, floods, droughts, and temperature extremes.

Heimbuch et al. (2007a) used population models to assess impacts of entrainment and impingement at the Poletti Power Project on winter flounder and Atlantic menhaden populations in the New York/New Jersey Harbor Estuary and Long Island Sound. These authors found reductions in abundance due to entrainment and impingement of only 0.09% for winter flounder and 0.01% for Atlantic menhaden as a result of entrainment and impingement at Poletti.

Nisbet et al. (1996) modeled the potential impact of entrainment of fish larvae by the San Onofre Nuclear Generating Station (SONGS) on fish populations in the Southern California Bight. They concluded that, depending on assumptions made concerning the strength of density-dependence, the standing stock of local queenfish and white croaker populations could be reduced by about 13% and 6%, respectively. No estimates of impacts of fishing on these populations were available, and no data on abundance trends were available for determining whether any reductions in abundance had occurred.

Ehler et al. (2003) used predictive models and population trends data to evaluate impacts of entrainment at the Diablo Canyon Power Plant on the central California coast on rockfish and kelpfish populations in the vicinity of the plant. Based on relatively high station-related mortality predicted by the model and a decline in abundance following start-up of the plant, the authors concluded that entrainment could have had an adverse impact on local clinid kelpfish populations. Ehler et al. (2003) had no information concerning other influences on clinid kelpfish, because these fish are not harvested and little is known about their life history.

It should be noted, however, that White et al. (2010) recently challenged the assumptions underlying the assessment approach used by Ehler et al. (2003) and others to addressed impacts of entrainment at California coastal power plants. White et al. (2010) explicitly simulated the dispersal and settlement processes of larvae spawned by bottom-dwelling fish in the vicinity of cooling water intake structures. These authors found that because of density-dependent post-settlement mortality, entrainment of larvae generally had only minor effects on adult population density. Compared to the spatially explicit model used by these authors, the approach used by Ehler et al. (2003) and others consistently overstated entrainment impacts. White et al. (2010) found that entrainment of larvae could only threaten the persistence of a local population if adult densities were already reduced to low levels by other stressors.

2.3. *Studies comparing equivalent adult losses to commercial landings*

The "equivalent adult" model is an assessment approach that uses estimates of rates of mortality of fish at different ages to express losses of early life stages of fish in terms of the number of fish entrained or impinged that would otherwise have survived to adulthood (EPRI, 2004). Some authors have addressed adverse impacts of entrainment and impingement by comparing estimates of impingement and entrainment losses, expressed as equivalent adults, to commercial fishery landings. As discussed in EPRI (2004), equivalent adult estimates are often highly uncertain, because of the difficulty of accurately estimating mortality rates of early life stages of fish. Moreover, equivalent adult estimates are usually conservative, because they do not account for density-dependence of early life stage mortality (Rose et al., 2001). In addition, this simple comparative approach involves neither long-term trends analysis of population-specific data nor explicit modeling of population dynamics. For this reason, the equivalent adult approach is best viewed as a screening approach suitable for identifying situations in which an adverse impact might occur. Without other supporting information, it cannot demonstrate whether or not an adverse impact due to entrainment and impingement is occurring or has occurred.

Saila et al. (1997) used equivalent adult models to address impacts of entrainment and impingement on pollock, red hake, and winter flounder entrained and impinged at the Seabrook Station, New Hampshire. These authors found that for the years 1990–1995 the maximum number of equivalent adult pollock entrained and impinged at Seabrook in any year was 136 fish, and the maximum number of equivalent adult red hake impinged and entrained in any year was 801 fish. Estimated numbers of equivalent adult winter flounder were higher, up to 4401 fish in 1991. According to the authors, this total, representing less than 2 metric tons of biomass, was equivalent to 3 days of average catch by a typical class 2 trawler in the Gulf of Maine.

Turnpenny (1988), Turnpenny and Taylor (2000), and Greenwood (2008) used a similar approach to quantify impacts of impingement at power plants in the United Kingdom. All three of these studies found that impingement at power plants was equivalent only a few percent of commercial harvests.

2.4. *Studies of cumulative impacts of entrainment and impingement*

At least in principle, impacts of entrainment and impingement on marine fish populations with coastwide distributions should be assessed on a cumulative basis, accounting for all water withdrawals that could affect each species.

To address the issue of cumulative impacts, the Atlantic States Marine Fisheries Commission (ASMFC) established a "Power Plant Committee" to investigate the feasibility of coastwide assessments, using Atlantic menhaden as a test case. As reported by Heimbuch et al. (2007b), the committee found that insufficient entrainment and impingement data were available to perform a scientifically credible assessment, and concluded that it would not be scientifically defensible to extrapolate entrainment and impingement estimates between power plants. The committee developed a model that could be used to link entrainment and impingement mortality to the Atlantic menhaden stock assessment model used by the ASMFC, but could only demonstrate the use of the model with hypothetical entrainment and impingement data.

Using admittedly incomplete data, Newbold and Iovanna (2007) modeled the cumulative impacts of entrainment and impingement mortality at all U.S. coastal power plants on 15 harvested marine fish populations. These authors utilized entrainment and impingement loss estimates developed by EPA (2002, 2004) to support the 316(b) Phase II rulemaking, together with harvest data obtained from the National Oceanic and Atmospheric Administration (NOAA) and life history information obtained from EPA and other sources. Density-dependent population models developed using this information were used to estimate the increase in population abundance that could occur if all entrainment and impingement were eliminated. According to the models, eliminating entrainment and impingement of California American shad, California anchovy, Atlantic cod, Atlantic herring, Atlantic mackerel, pollock, scup, silver hake, summer flounder, and winter flounder would increase the abundance of these species by less than 1%. Eliminating entrainment and impingement of Atlantic American shad and Atlantic menhaden would increase the abundance of these species by 1–3%. Eliminating entrainment and impingement of California striped bass, Atlantic striped bass, and Atlantic croaker would increase the abundance of these species by 20–80%. These results appear questionable because, in contrast to most of the species included in Newbold and Iovanna's (2007) study, populations of Atlantic striped bass and Atlantic croaker have grown substantially since 1980 (Richards and Rago, 1999; ASMFC, 2010) in spite of ongoing entrainment and impingement.

Since entrainment and impingement mortality rates in the model used by Newbold and Iovanna (2007) are estimated through model calibration, there is no simple way to determine the source of these very high values. However, it should be noted that the entrainment and impingement loss rates estimated by USEPA (2002, 2004) and used by Newbold and Iovanna (2007) were obtained by extrapolating entrainment and impingement estimates from power plants with available data to plants with no available data based on relative intake flows. This procedure was acknowledged by the authors to have introduced potentially large and unknown uncertainties. Newbold and Iovanna (2007) characterized their analysis as a "screening" analysis and did not claim to have accurately estimated the impacts of entrainment and impingement on any of the modeled populations.

3. Causes of adverse impacts documented in peer-reviewed literature and "Blue Ribbon" commission reports

The status of fishery resources, especially marine resources, has been a matter of great national concern for many years. In contrast to the paucity of papers documenting adverse impacts of power plants on fish populations and on aquatic ecosystems in general, the peer-reviewed scientific literature documents many cases of large, often catastrophic changes in fish populations and communities resulting from eutrophication, invasive species introductions, and overfishing. Over the past 20 years, this literature has been reviewed and synthesized by a variety of expert committees. Despite the regulatory attention paid to §316(b) issues during this period, none of these committees identified entrainment and impingement as major environmental threats. Reports prepared by two especially prestigious organizations, the Pew Oceans Commission and the National Research Council, are highlighted here.

3.1. *Pew Oceans Commission*

In 2003, the Pew Oceans Commission evaluated scientific information and policy options for dealing with nine major threats to marine resources: nonpoint source pollution, point source pollution, invasive species, aquaculture, coastal development, overfishing, habitat alteration, bycatch, and climate change. Most of these same threats were also discussed in a report by the U.S. Commission on Ocean Policy (2004).

The Pew Oceans Commission report was accompanied by supporting reports documenting adverse effects of overfishing, pollution, urban sprawl, invasive species, and aquaculture on marine ecosystems (Dayton et al., 2002; Beach, 2003; Boesch et al., 2003; Carlton, 2003; Goldburg et al., 2003). The Pew Commission report and supporting documents contain many policy recommendations intended to address all of the above impacts, but made no mention of or recommendations with respect to cooling water withdrawals at power plants or other industrial facilities.

3.2. *National Research Council reports*

The U.S. National Research Council (NRC) has published studies relevant to most of the causes of impact discussed in the Pew Commission report. Such reports are typically commissioned by federal agencies to address scientifically complex and politically contentious issues that are believed to be of national importance. For example, a 1995 NRC (NRC, 1995) identified five threats to the biodiversity of marine ecosystems: overfishing, chemical pollution and eutrophication, physical habitat alteration, invasions of exotic species, and global climate change. Three studies addressed adverse impacts of overfishing (NRC, 1998, 1999, 2006). Two studies addressed impacts of invasive species (NRC, 1996, 2008a). Two studies addressed inputs of nutrients and hazardous chemical pollutants to coastal marine waters (NRC, 2009, 1993). One study (NRC, 2008b) addressed impacts of habitat disturbance caused by marine debris. No agency has ever asked the NRC to review impacts of entrainment and impingement on aquatic populations or ecosystems.

4. EPA National Coastal Conditions Reports

The conclusions reached in the reviews discussed above are largely supported by the EPA's own review of coastal environmental conditions, contained in a series of National Coastal Conditions reports. The third and most recent of these reports, termed "NCCR III," was published in 2008 (USEPA, 2008). This report which assesses the condition of all U.S. coastal waters, is a collaborative effort involving EPA, NOAA, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, and other agencies representing states and tribes. It is intended to provide a snapshot of coastal conditions in 2001 and 2002. An update, including data collected through 2006, is currently in review.

NCCR III, like the two earlier reports, uses five indices to evaluate the quality of coastal conditions: water quality, sediment quality, benthic community composition, coastal habitat condition, and fish tissue contamination. In addition to the five coastal condition indices, NCCR III summarizes information on overharvesting of fish species in waters bordering the U.S. coastline. Entrainment and impingement are not discussed as potential influences on coastal conditions. Chapter 9 of NCCR III provides a detailed evaluation of a particular site, Narragansett Bay, Rhode Island, with respect to human uses and specific sources of environmental degradation. This is the only chapter that mentions electric power production. The impact of the thermal discharge from the Brayton Point station on the local winter flounder fishery is discussed, but entrainment and impingement are not mentioned.

5. Discussion

The diverse literature on the condition of aquatic resources, including studies of both marine and freshwater ecosystems throughout North America, consistently identifies overfishing, habitat destruction, pollution, and invasive species as being the predominant causes of past and present impairment of fish populations and the ecosystems that support them. In those few cases where impacts of entrainment and impingement have been specifically investigated, such impacts have rarely been found. Some model-based studies (Nisbet et al., 1996; Perry et al., 2003) have suggested that potentially significant impacts might occur, but in only one study, of clinid kelpfish entrained at the Diablo Canyon Power Plant (Ehler et al., 2003), have authors cited empirical data to support a conclusion that a significant impact of entrainment and impingement on a local population may be occurring. Even in this case other authors (White et al., 2010) have found that the method used to reach this conclusion is flawed and overstates impacts.

It is difficult to compare entrainment and impingement to most of the stressors identified as significant causes of fish population decline. Entrainment and impingement do not impair the ability of habitat to support fish, due to either physical or chemical alteration. Entrainment and impingement are, however, comparable to fishing in that both processes act through removal of fish from populations. Although entrainment and impingement generally remove fish at an earlier age than does fishing, impacts of both can be expressed in terms of annual mortality rates, which then can be compared.

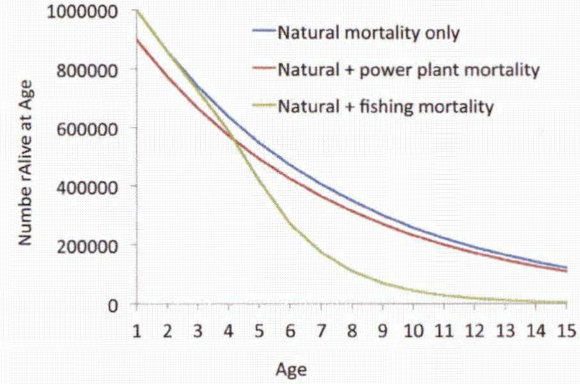

Fig. 1 – Comparative effects of natural mortality, power-plant related mortality and fishing mortality on the abundance of a cohort of striped bass, from age 1 through age 15. The abundance of one-year-old striped bass is assumed to be reduced by 10% due to entrainment and impingement occurring during the first year of life. Declines in abundance during subsequent years occur due to natural mortality and fishing mortality (ASMFC, 1998).

A simple example serves to illustrate why fishing is such a powerful influence on fish populations, as compared to entrainment and impingement. Boreman and Goodyear (1988) estimated that entrainment mortality of striped bass due to all Hudson River power plants in 1974 and 1975 ranged from 0.068 to 0.13, equivalent to reducing the sizes of the 1974 and 1975 year classes by 6.8% to 13%. No estimates of fishing mortality for striped bass during this period are available, however, the current target fishing mortality rate established by the ASMFC is 0.3 (ASMFC, 2003). Hudson River striped bass are susceptible to entrainment for only a few months, and to impingement primarily during their first year of life. In contrast, striped bass first become susceptible to fishing at an age of 2 years and become fully recruited to the fishery at age 5 (ASMFC, 1998). They continue to be susceptible to fishermen for the remainder of their lifespan of up to 30 years. The consequences of this pattern of mortality are illustrated in Fig. 1 Natural mortality in age 1 and older striped bass is believed to be approximately 15% per year (ASMFC, 1998). Given this mortality rate, out of every 1 million 1-year-old fish, 122,000 would still be alive after 15 years. If power plants reduced the initial number of one-year-old fish by 10% to 900,000, 110,000 fish would still be alive after 15 years. If, instead of entrainment and impingement, the fish are subject to fishing mortality according to the vulnerability schedule and target fishing rate established by the ASMFC, then only 4800 fish would still be alive after 15 years.

It is often said that it is impossible to prove a negative. Although adverse impacts due to entrainment and impingement have not been conclusively documented in published studies, this absence does not prove that adverse impacts are not occurring or could never occur. It can always be argued that the statistical power of tests used in environmental impact studies is simply too low to detect reductions in abundance, even reductions that are large enough to warrant regulatory action. However, the rarity of documentation of such impacts, after 40 years of operation of large power plants, some of which have been conducting extensive monitoring programs for several decades, provides substantial evidence that impacts related to entrainment and impingement are generally small compared to impacts identified by the Pew Oceans Commission (2003) and other sources as being major threats to aquatic ecosystem integrity. Most importantly, there is no scientific evidence to support a conclusion that reducing entrainment and impingement via aggressive regulation of cooling water intakes will result in measurable improvements in recreational or commercial fish populations. A more nuanced regulatory approach involving site-specific evaluations of costs and benefits of reducing entrainment and impingement would be more consistent with the available facts.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.envsci.2013.03.001.

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Analysis of Impingement Impacts on Hudson River Fish Populations

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Abstract.—Impacts of impingement, expressed as reductions in year-class abundance, were calculated for six Hudson River fish populations. Estimates were made for the 1974 and 1975 year classes of white perch, striped bass, Atlantic tomcod, and American shad, and the 1974 year classes of alewife and blueback herring. The maximum estimated reductions in year-class abundance were less than 5% for all year classes except the 1974 and 1975 white perch year classes and the 1974 striped bass year class. Only for white perch were the estimates greater than 10% per year. For striped bass, the 146,000 fish from the 1974 year class that were killed by impingement could have produced 12,000–16,000 5-year-old fish or 270–300 10-year-olds. We also estimated the reductions in mortality that could have been achieved had closed-cycle cooling systems been installed at one or more of three power plants (Bowline Point, Indian Point, and Roseton) and had the screen-wash systems at Bowline Point and Indian Point been modified to improve the survival of impinged fish. Closed-cycle cooling at all three plants would have reduced impingement impacts on white perch, striped bass, and Atlantic tomcod by 75% or more; installation of closed-cycle cooling at Indian Point alone would have reduced impingement impacts on white perch and Atlantic tomcod by 50%–80%. Modified traveling screens would have been less effective than closed-cycle cooling, but still would have reduced impingement impacts on white perch by roughly 20%.

This paper presents quantitative estimates of the impacts of impingement at Hudson River power plants on populations of white perch, striped bass, Atlantic tomcod, American shad, alewife, and blueback herring. These analyses, performed for the U.S. Environmental Protection Agency (EPA), include estimation of the impacts actually imposed on the 1974 or 1975 year classes (or both) of each population, and calculation of the reductions in impact that could have been achieved had cooling towers or modified traveling screens been installed at one or more power plants.

Our measure is the conditional impingement mortality rate (Vaughan 1988, this volume). This measure is equivalent to the fractional reduction in year-class abundance due to impingement, provided that density-dependent mortality is low during the period in which impingement occurs. Conditional impingement mortality rates were calculated for the 1974 year classes of all six populations and for the 1975 year classes of all except alewife and blueback herring. Similar analyses could not be performed for the vulnerable and ecologically important bay anchovy because available data on the distribution, abundance, and mortality of this species were insufficient.

The model used for these analyses and the derivation of constituent equations have been described in detail by Barnthouse et al. (1979) and by Barnthouse and Van Winkle (1981). Like the model used by Texas Instruments (TI) (Englert and Boreman 1988, this volume), it is derived from Ricker's type-II fishery model (Ricker 1975). The conditional impingement mortality rate, computed for an arbitrary time interval, is

$$m = 1 - (1 - A)\exp(u/A); \qquad (1)$$

m = conditional impingement mortality rate;
u = impingement exploitation rate;
A = fraction of the initial population dying from all causes during the time interval.

In applying equation (1) to our impact assessment, we (a) decomposed A into components due to impingement mortality and natural mortality and (b) set the time interval for calculation at 1 month rather than 1 year. Separating natural mortality (n) from impingement mortality (m) involved substituting $[1 - (1 - m)(1 - n) = m + n - mn]$ for A in equation (1) and then solving the equation iteratively. This procedure enabled us to assess the potential effectiveness of mitigating measures that would reduce the numbers of fish impinged or increase the survival of impinged fish but would not affect natural mortality rates. The monthly time interval was employed to allow for seasonal variations in natural and impingement mortality.

Data Source and Uncertainties

Impingement

The impingement estimates used in these analyses were obtained from sampling programs conducted at the Bowline Point, Lovett, Indian Point, Roseton, Danskammer, and Albany generating stations. During 1973–1977, impinged fish were collected and enumerated regularly at all six power plants. At Indian Point, all screen washes were monitored and attempts were made to collect, identify, and count all impinged fish. At the other plants, screen washes were monitored for 24 h one or more days per week. At all plants, length-frequency data were obtained, making it possible to calculate approximate age distributions of impinged fish.

Barnthouse (1982) identified two important sources of bias that affect estimates of numbers of fish impinged and killed at power plants: low collection efficiency and high (at least for some species at some plants) survival of impinged fish. For reasons that are not completely understood, not all fish that are impinged and killed are collected and counted during screen-wash monitoring. Experiments with marked fish showed that collection efficiencies at the major plants range from less than 20% at Indian Point unit 2 to nearly 80% at Indian Point unit 3 and Bowline Point. For some species at some plants, the bias due to low collection efficiency appears to be partly or completely offset by the survival of fish impinged, washed off the screens, and returned to the river on days when screen washes are not monitored (Muessig et al. 1988, this volume). Barnthouse (1982) developed a table of adjustment factors to account for the likely biases in impingement estimates for each species at each plant. The impingement estimates employed in the assessments presented here were adjusted by these factors.

Abundance and Mortality

Estimates of the abundance of the 1974 and 1975 year classes of the species of interest, at the time they first became large enough to be impinged, were obtained from the TI field sampling programs (Young et al. 1988, this volume). For white perch, mark–recapture population estimates were available. For the other species, abundance estimates had to be extrapolated from catch–effort data. The uncertainties associated with all of these estimates were large. To account for these uncertainties, upper and lower bounds on the abundance of each year class were estimated. For white perch, these were taken to be the upper and lower 95% confidence limits around the mark–recapture population estimates. For the other species, bounds were calculated from maximum and minimum estimates of sampling gear efficiency, assumed to be 100% (lower population bound) or 20% (upper bound). Estimates of the efficiency of TI's 30-m beach seine (TI 1978) and of other similar gear (Kjelson 1977) are substantially above 20%.

Estimates of mortality rates for impingeable juvenile fish were calculated from TI's weekly (longitudinal river survey) or biweekly (fall shoals survey) abundance estimates for the years 1974 and 1975. The time series for each year class was fitted, by least squares regression, to the equation

$$\log_e P_t = \log_e P_0 - Dt; \tag{2}$$

P_t = population size on day t;
P_0 = population size on day 0 (the first day of the period of vulnerability to impingement);
D = daily instantaneous mortality rate.

Gear selectivity and migration in and out of the study area bias estimates of D obtained from equation (2). Time-dependent increases in gear avoidance and emigration of fall juveniles would cause equation (2) to overestimate the true mortality rate. Therefore, the values obtained from the regressions were assumed to be upper limits on the rate of natural mortality. There was no straightforward way to calculate lower bounds on D. It seemed reasonable, however, to assume that mortality among young-of-the-year fish of all species should be at least as high as the observed mortality of yearling and older white perch. Data presented by Wallace (1971) had indicated that mortality among yearling and older white perch is probably about 50% per year.

Table 64 shows that the abundances of the populations examined varied over approximately a factor of 50, the Atlantic tomcod being by far the most abundant and the striped bass and alewife the least abundant. Table 64 also shows a rough correspondence between abundance and numbers impinged; however, both the 1974 and 1975 year classes of white perch were impinged in high numbers relative to their estimated abundance. Mortality rates for most of the species were similar, with the notable exception of Atlantic tomcod (Table 64). The very high natural mortality rate estimated for this species is consistent with the observation that the Atlantic tomcod

TABLE 64.—Impingement, abundance, and natural mortality estimates used in impingement impact assessments (from Barnthouse and Van Winkle 1982).

Species	Year class	Total impingement (10^6 fish)[a]	Initial abundance (10^6 fish)[b]	Natural mortality rate	
				Age-0 fish[c]	Age-1+ fish[d]
White perch	1974	2.8–2.9	14–55	0.5–0.8	0.5
White perch	1975	2.4	24–63	0.5–0.8	0.5
Striped bass	1974	0.15	4–20	0.5–0.8	0.5
Striped bass	1975	0.08	5–28	0.5–0.8	0.5
Atlantic tomcod	1974	2.5	200–999	0.98	
Atlantic tomcod	1975	0.5	87–434	0.98	
American shad	1974	0.04	16–78	0.9	0.5
American shad	1975	0.06	16–80	0.9	0.5
Alewife	1974	0.16	4–20	0.5–0.9	0.5
Blueback herring	1975	0.46	29–145	0.5–0.9	0.5

[a]Total number of fish over all years during which members of that year class were impinged.
[b]Estimated abundance of year class at the beginning of its period of vulnerability to impingement.
[c]Expressed as annual mortality, except for Atlantic tomcod. For Atlantic tomcod, the estimate presented is for a 9-month period of vulnerability.
[d]Expressed as annual mortality.

population in the Hudson is composed almost exclusively of young of the year (McLaren et al. 1988, this volume).

Estimates of Impingement Mortality

Equation (1) calculates the magnitude of impingement mortality required to account for the observed number of impinged fish, given the number of fish initially available for impingement, the prevailing rate of natural mortality, and the age of the fish (in months) at the time they are impinged. Clearly, the impact of impinging a given number of fish is inversely related to the size of the year class from which they are removed. More counterintuitively, the impact of impinging a given number of fish of a given age is directly related to the prevailing rate of natural mortality. This is true because natural mortality and impingement "compete" for fish, in the sense that any particular fish can die only once and from only one cause. For any initial population size, a higher impingement mortality rate is required to account for the observed number of impinged fish if natural mortality is high than if it is low. For related reasons, the impact of impinging any particular fish increases with its age because the year class from which it is removed is continuously decreasing in abundance.

To set probable upper and lower bounds on the impact of impingement on the species of interest, we estimated ranges of conditional impingement mortality rates for each species from all possible combinations of initial abundance and natural mortality for the 1974 and 1975 year classes (Table 65). We also estimated conditional impingement mortality rates for white perch under alternative assumptions of 2- and 3-year vulnerability (Barnthouse and Van Winkle 1981). The two assumptions about the age distribution of impinged white perch constitute a third source of uncertainty affecting impact estimates for this species. Consequently, Table 65 presents two ranges for white perch: a "maximum range" (the highest and lowest conditional impingement mortality rates computed from the eight possible combinations of assumptions) and a "probable range" obtained by excluding the highest and lowest values. Because more and better field data were available for white perch and striped bass than for the other species, impact estimates for these two are more certain than are those for the other four species considered. The least adequate data, and consequently the least certain impact estimates, pertain to alewife and blueback herring.

Conditional impingement mortality rates calculated by McFadden and Lawler (1977) for the utility companies fell within our ranges for striped bass and Atlantic tomcod, but fell outside our ranges for American shad and white perch.

Several unique aspects of the life history of white perch in the Hudson River are responsible for the comparatively high impact of impingement on this species. During the winter, a major fraction of the population resides in the lower and middle estuary, in the vicinity of the Bowline Point, Lovett, and Indian Point plants. Although substantial winter impingement of white perch occurs at all three plants, the numbers impinged at Indian Point exceed by far the combined totals for all other Hudson River power plants (Barnthouse and Van Winkle 1981). This phenomenon appears to be related to the concentration of fish in deep

TABLE 65.—Ranges of estimates of conditional impingement mortality rates for six Hudson River fish species.

Species (year class)	Oak Ridge estimates: Low estimate	Oak Ridge estimates: High estimate	Utilities' estimate (McFadden and Lawler 1977)
White perch (1974)			
Maximum range	0.095	0.588	
Probable range	0.119	0.446	0.113
White perch (1975)			
Maximum range	0.077	0.245	
Probable range	0.115	0.245	
Striped bass (1974)	0.011	0.092	0.042
Striped bass (1975)	0.004	0.035	0.023
Alewife (1974)	0.014	0.043	
Blueback herring (1974)	0.005	0.025	
American shad (1974)	0.001	0.005	0.012
American shad (1975)	0.002	0.011	
Atlantic tomcod (1974)	0.010	0.049	0.015
Atlantic tomcod (1975)	0.006	0.030	

areas of the Hudson River channel near the Indian Point intakes, and in the vicinity of the salt front, which fluctuates above and below Indian Point during the winter (TI 1974, 1975). The mobility of these overwintering fish is greatly reduced by near-freezing water temperatures, increasing their vulnerability to impingement.

The vulnerability of yearling and older white perch contributes significantly to the impact of impingement. Yearling and older fish account for roughly 10% of the number of white perch impinged. In computing conditional mortality rates, a yearling white perch is "worth" 2–5 young of the year (depending on the mortality rate assumed), and a 2-year-old white perch is worth 4–10 young of the year. A major reason for the discrepancy between our conditional mortality rates for the 1974 white perch year class and the corresponding rate (Table 65) calculated by McFadden and Lawler (1977) is that the latter quantified the impact on young of the year only.

Although striped bass, like white perch, are most vulnerable to impingement during the winter, their distribution is centered well downriver from Indian Point (McFadden 1977). Consequently, the impacts of winter impingement on the 1974 and 1975 year classes of striped bass were much lower than the impacts on white perch. Bowline Point, rather than Indian Point, was the primary source of impact.

The extremely low impingement impacts on alewife, blueback herring, and American shad are related to the brief period that these species are concentrated in the vicinity of major power plants during their emigration from the estuary in autumn.

Evaluation of Mitigating Measures

In addition to estimating the impacts actually imposed on the 1974 and 1975 year classes of Hudson River fish populations, we estimated the reductions in impact that could have occurred had mitigation been attempted. The purpose of these analyses was to provide guidance to the EPA as to the biological effectiveness of mitigating technologies being proposed in the hearings and in the settlement negotiations. Two types of mitigation were investigated: installation of closed-cycle cooling systems (cooling towers) to reduce the numbers of fish impinged, and installation of modified traveling screens to increase the survival of impinged fish.

Closed-Cycle Cooling

We considered three closed-cycle cooling configurations: (1) cooling towers at the Roseton, Bowline Point, and Indian Point plants; (2) cooling towers at Bowline Point and Indian Point; and (3) cooling towers at Indian Point only. To calculate the numbers of white perch, striped bass, and

TABLE 66.—Estimates of conditional impingement mortality rates for the 1974 and 1975 Hudson River year classes of white perch, striped bass, and Atlantic tomcod, for three alternative closed-cycle cooling configurations.

	Closed-cycle cooling assumed at					
	Indian Point, Bowline Point, and Roseton		Indian Point and Bowline Point[a]		Indian Point only[a]	
Species (year class)	Low estimate	High estimate	Low estimate	High estimate	Low estimate	High estimate
White perch (1974)						
Maximum range	0.027	0.150	0.030	0.177	0.042	0.237
Probable range	0.031	0.128	0.036	0.143	0.049	0.195
White perch (1975)						
Maximum range	0.013	0.042	0.019	0.061	0.024	0.078
Probable range	0.020	0.042	0.029	0.061	0.036	0.078
Striped bass (1974)	0.003	0.023	0.003	0.024	0.010	0.081
Striped bass (1975)	0.001	0.013	0.001	0.013	0.003	0.024
Atlantic tomcod (1974)	0.004	0.018	0.004	0.019	0.004	0.019
Atlantic tomcod (1975)	0.001	0.003	0.001	0.004	0.001	0.004

[a]Once-through cooling assumed elsewhere.

Atlantic tomcod that would have been impinged had closed-cycle cooling systems been in operation during the years 1974–1977, we assumed that the number of fish impinged at a particular plant is directly proportional to the volume of water withdrawn by that plant. Thus, the reduction in impingement at each generating unit assumed to have a cooling tower was calculated from the estimated reduction in cooling water withdrawal for that unit (see Barnthouse and Van Winkle 1982 for detailed methods). Under this assumption, the numbers of fish impinged at the three plants would be reduced by 89% (Indian Point Unit 3, winter) to 98% (Bowline Point, all seasons).

Impacts associated with this reduced impingement (Table 66) are based on the same estimates of abundance and mortality used to generate the values in Table 65. Comparison of these two tables shows that the installation of closed-cycle cooling would have greatly reduced the impacts of impingement on all three species. If cooling towers had been built at all three plants, the maximum conditional impingement mortality rates for white perch would have been reduced by about 75% for the 1974 year class and by about 80% for the 1975 year class. Similar reductions could have been achieved for striped bass and Atlantic tomcod. Nearly equal mitigation could have been achieved by closed-cycle cooling at Bowline Point and Indian Point only, the 1975 white perch year class being the only appreciable exception. Closed-cycle cooling at Indian Point units 2 and 3 alone would have reduced the impact of impingement on white perch and Atlantic tomcod by 50%–80%.

Modified Traveling Screens

During the settlement negotiations, the utilities suggested that impingement impacts could be reduced by installing traveling screens equipped with fish buckets and special screen-wash systems (sometimes called "Ristroph" screens) at Bowline Point and Indian Point. It was claimed that 60% survival of impinged white perch and striped bass could be obtained by use of these screens.

We assisted EPA in evaluating this proposal by estimating the reduction in impact on the 1975 year class of white perch that would have occurred had these screens been in place during 1975–1977. Two cases were examined. In case 1, it was assumed that 60% survival of white perch could be achieved at both Bowline Point and Indian Point. Evidence available at the time suggested that 60% survival was overly optimistic. Cannon et al. (1979) had found no evidence that fish-bucket-type traveling screens were more effective at reducing impingement mortality than were the continuously rotating conventional traveling screens already employed at Bowline Point and Roseton. Therefore, in case 2, it was assumed that impingement survival with the modified traveling screens would be equal to that observed for the existing screens at Bowline Point and Roseton. We had previously estimated (Barnthouse 1982) impingement survival at these two plants to be about 40% for white perch for the screen-wash

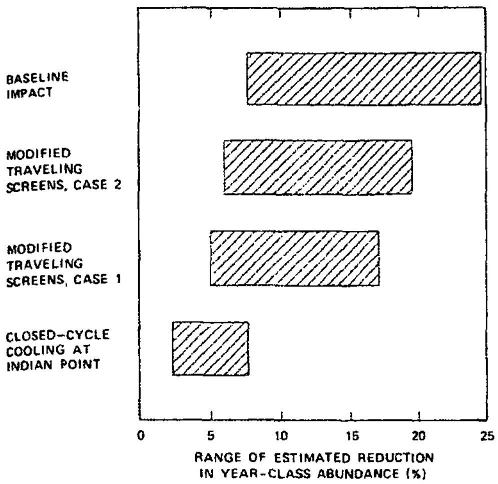

FIGURE 68.—Evaluation of modified traveling screens as a means of reducing the impact of impingement on the Hudson River white perch population, with the 1975 year class as a reference. It is assumed that that continuously rotating traveling screens with fish buckets are installed at all generating units at Bowline Point, Indian Point, and Roseton. In case 1, 60% of the white perch impinged on these screens are assumed to return to the river alive. In case 2, only 40% survive. The top bar shows the range of baseline impact estimates for the 1975 year class (from Table 65). The other bars show corresponding ranges for modified traveling screens (cases 1 and 2) and for closed-cycle cooling at Indian Point units 1 and 2 (from Table 66).

systems and operating modes employed during 1974–1979.

Our results suggested that modified traveling screens would be much less effective than closed-cycle cooling (Figure 68). However, a moderate degree of mitigation could be achieved. Regulations then in force required that all fish impinged at Indian Point be collected and counted (Mattson et al. 1988, this volume). If these regulations were relaxed then, even if the modified screens were no more effective than continuously rotating conventional screens, a 20% reduction in impact could be achieved by increasing survival at Indian Point from 0% to 40%.

Discussion

The maximum reductions in year-class abundance due to impingement at Hudson River power plants were estimated to be less than 5% for all year classes except the 1974 and 1975 white perch year classes and the 1974 striped bass year class. Thus, our results suggest that, for most of the species examined, impingement is probably not a biologically important source of mortality except, perhaps, when added to other, more serious stresses.

Only for white perch are impingement losses high enough to be a major source of mortality. Our conditional impingement mortality rates are equivalent to reductions in year-class abundance on the order of 10–60%. When combined with entrainment losses, estimated at roughly 10% per year (Boreman and Goodyear 1988, this volume), the total impact of once-through cooling water withdrawal on this population appeared to be in excess of 20% per year class for the years examined. Our understanding of the white perch population and its interactions with other components of the Hudson River ecosystem is insufficient for predicting the long-term effects of these losses.

The estimated reductions in striped bass year-class abundance (up to 10% per year) probably do not, by themselves, constitute a threat to the population as a whole. However, the loss of these fish may have socioeconomic importance. About 146,000 striped bass of the 1974 year class and 80,000 of the 1975 year class were killed by impingement at Hudson River power plants (Table 64). We used the theory of conditional mortality rates to estimate the number of these fish that could have survived to enter the sport or commercial fisheries. Barnthouse and Van Winkle (1982) presented initial population sizes, population sizes at age 2, and conditional impingement mortality rates for the 1974 and 1975 striped bass year classes. These values were used to calculate the number of "equivalent 2-year-olds" impinged from each year class: 42,000–57,000 for the 1974 year class and 23,000–30,000 for the 1975 year class (Appendix).

We used the life table for striped bass developed by Dew (1981) to extrapolate these estimates to numbers of 5- and 10-year-olds. The results of this exercise indicate that the impinged members of the 1974 year class could have produced 12,000–16,000 5-year-old striped bass (the median age for commercially caught striped bass in the Hudson) or 270–370 10-year-old sport fish. Impingement losses from the 1975 year class were equivalent to 6,400–8,400 5-year-olds or 150–190 10-year-olds. Hoff et al. (1988, this volume) developed estimates of annual survival of 5- to 10-year-old striped bass (0.45 for males and 0.60 for females) that are somewhat higher than Dew's estimate (0.47 for both sexes). Using the values from Hoff et al. roughly doubles our estimates of the numbers of equivalent 10-year-olds impinged.

Whether or not the biological impact of white perch impingement or the socioeconomic impact of striped bass impingement is important enough to warrant mitigation is, in our opinion, a sociopolitical question rather than a scientific one. The parties to the settlement negotiations did consider impingement of these species to be important. Mitigation of impingement at Indian Point was explicitly included in all of the settlement proposals considered.

Although our analysis (Table 66) showed the potential effectiveness of closed-cycle cooling at Indian Point, this solution was considered too costly by the utilities. Due to lack of applicable data, we could not evaluate the potential effectiveness of the angled intake screens that were ultimately agreed on as a mitigating measure. However, our evaluation of the fish-bucket-type traveling screens may have been a factor in the subsequent abandonment of these devices by the negotiators.

There is still considerable doubt as to the feasibility of angled screens as a mitigating measure for large power plants such as Indian Point. However, other means of reducing impingement mortality have been developed and implemented at Hudson River power plants since the period covered in this paper. Impingement of all species at Bowline Point has been substantially reduced following the installation of a barrier net (Hutchison and Matousek 1988, this volume). Experiments at Bowline Point and Danskammer, completed subsequent to our analyses, have shown that the survival of impinged white perch can exceed 60% when traveling screens are operated in the continuous mode (Muessig et al. 1988). Although routine operation in continuous mode is not feasible for existing traveling screen designs, continuous rotation is possible for short periods when impingement is high. The intake structure at Bowline Point was rebuilt in 1979–1980, in part to permit extended operation of the traveling screens in continuous mode. Thus, it appears that relatively simple devices and operational changes may have succeeded where expensive technologies proved impractical.

In conclusion, we note that, given the expense of collecting the data necessary for performing assessments of the kind described here, it is desirable to identify in advance the circumstances that may lead to large (10% or greater) reductions in year-class abundance. Two such circumstances can be identified from the Hudson River studies:

(1) the presence of a major fraction of the population in close proximity to power plants at a time when the fish are stressed and susceptible to being impinged, and
(2) the vulnerability of fish through a major portion of their life-cycle.

When population-level assessment is necessary, information concerning the abundance and life history of the species involved is essential if biological or socioeconomic importance is to be inferred. It is not currently possible to estimate a level of impingement mortality above which population collapse or other clearly adverse long-term impacts may occur. It is possible, however, to use the measure of impact employed in this paper (i.e., the conditional impingement mortality rate) to distinguish between losses that may be important and losses that are clearly trivial. It is also possible to estimate the socioeconomic importance of impinging a given number of fish and to evaluate the reduction in impact that might result from implementing mitigating measures designed to reduce impingement or to increase the survival of impinged fish. We believe it is more fruitful to focus assessment studies on these achievable objectives than on the appealing, but unattainable, objective of long-term impact assessment.

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Appendix

If impingement mortality and natural mortality are independent, the number of striped bass surviving to age 2 can be estimated from

$$N_2 = N_0 S_2(1 - m); \qquad (A1)$$

N_2 = number of surviving 2-year-olds;
N_0 = number of young of the year (age 0);
S_2 = natural survival rate from age 0 to age 2;
m = conditional impingement mortality rate.

If there had been no impingement, the number of surviving 2-year-olds would have been

$$N_2' = N_0 S_2 = N_2/(1 - m). \qquad (A2)$$

The number of age-0 fish that would have survived to age 2 had they not been impinged (i.e., the number of "equivalent 2-year-olds" killed by impingement) is

$$N_{E2} = N_2' - N_2 = mN_2'. \qquad (A3)$$

Combination of equations (A2) and (A3) gives

$$N_{E2} = mN_2/(1 - m). \qquad (A4)$$

The ranges of equivalent 2-year-olds presented in the Discussion were obtained by applying equation (A4) to the values of N_2 and m presented in Table 16 of Barnthouse and Van Winkle (1982). These values were then extrapolated to equivalent 5- and 10-year-olds by means of the age-specific survival rates in Table 1 of Dew (1981).

Record 10/18

UNITED STATES DEPARTMENT OF COMMERCE
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OCT 12 2010

Mr. David J. Wrona, Chief
Projects Branch 2
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Washington, D.C. 20555-0001

Re: Indian Point Generating Unit Nos. 2 & 3 License Renewal; Docket Nos. 50-247 and 50-268; Essential Fish Habitat Consultation

Dear Messrs. Holian and Wrona:

The National Marine Fisheries Service [NMFS] has reviewed the essential fish habitat [EFH] assessment and supplemental information provided within the United States Nuclear Regulatory Commission's [NRC] 'Generic Environmental Impacts Statement for License Renewal of Nuclear Plants, Supplement 38, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3' [dGEIS], and its attendant appendices. These documents evaluate the proposed renewal of the operating licenses for Indian Point Energy Center's Units 2 [IP2] and 3 [IP3] for a period of twenty years. The documents include a brief description and analysis of adverse effects to a variety of diadromous and estuary-dependent fishes, crustaceans and other invertebrates, as well as EFH that is designated in the immediate project vicinity. We will elaborate on the affected resources and our concerns regarding continued operations at IP2 and IP3 under present conditions in subsequent sections of this letter. However, upon our review of the available information, NMFS does not reach all of the same conclusions as the NRC with respect to adverse effects that relicensing IP2 and IP3 would have on fishery resources and their habitats. We appreciate the opportunity to provide comments at this time in accordance with Mr. Wrona's letter of 21 September 2010.

The current licenses for the two Indian Point nuclear generation facilities are due to expire in 2013 and 2015, respectively. Because IP2 and IP3 withdraw and discharge water into the Hudson River, a navigable surface water body, their operations are subject to Clean Water Act oversight. In New York, this oversight is administered by the New York State Department of Environmental Conservation, which issues Clean Water Act §401 Water Quality Certificate [WQC] decisions under its State Pollutant Discharge and Elimination System [SPDES] program. The New York State Department of State also has a bearing on these proceedings in that it is responsible for any decisions relating to the consistency of the proposed action with the state's Coastal Management Program. Entergy Corporation [Entergy], the current owner-operator of the Indian Point Energy Center [Indian Point] generating units, has made application for the necessary state and federal authorizations and has requested that they are issued to run concurrently. Since these state actions may effect EFH, the NMFS is invoking its option to share our comments and recommendations to the involved state agencies on their activities as provided by the EFH implementing regulations. We do so here by including them in the service list for this correspondence.

The dGEIS and EFH assessment prepared by the NRC evaluate the proposed action of the license renewal for IP2 and IP3 and form the base documentation for consultation between NRC and the National Marine Fisheries Service [NMFS]. The authorities under which we engage in consultation include the

NRC's environmental protection regulations in Title 10, Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions", of the Code of Federal Regulations (10 CFR Part 51), which implement the National Environmental Policy Act of 1969, as amended (NEPA); the Fish and Wildlife Coordination Act (FWCA) , the Endangered Species Act (ESA), and the requirements of our EFH regulation at 50 CFR 600.905 of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), which mandates the preparation of EFH assessments and generally outlines each agency's obligations in this consultation procedure. The comments provided in this letter pertain to the FWCA and MSFCMA coordination issues that are part of your NEPA and relicensing processes.[1] To summarize briefly, these documents acknowledge that operating once-through cooling systems at Indian Point has resulted in adverse environmental impacts, yet both documents nonetheless conclude with NRC's preliminary determination that the adverse effects associated with license renewal would have only minimal impacts on both living aquatic resources themselves and on EFH designated for federally managed species in the immediate Indian Point area. NRC's analysis of impacts relies upon comparing near field impacts that would occur in the immediate project vicinity versus all EFH designated for a particular species. We frame the issue differently, and instead consider both the adverse effects to the local fishery stocks emanating from the Hudson and the unusually high potential capacity of the mid-Hudson for recruitment of estuary-dependent fishes and production of forage species as important defining issues that lead us to a different conclusion.

Project Background:

The Indian Point Energy Center [Indian Point] is a three-unit power station located on the east shore of the Hudson River in the Village of Buchannan, Town of Cortlandt, Westchester County, New York. Only two of the generating units are operating. Indian Point Unit 1 was permanently shut down in 1974 because the emergency core cooling system did not meet regulatory requirements and therefore posed an unacceptable public risk; IP2 and IP3 continue to operate and are the subjects of upcoming license renewals requested by Entergy. Indian Point has a long presence in the Hudson and is one of the facilities included in the 'Hudson River Settlement Agreement' [HRSA] agreed among the U.S. Environmental Protection Agency and five New York electric utility companies in a controversy regarding coastal habitat and water uses, fish kills and ecological damage in the Mid-Hudson region.

Under the HRSA, the power plant owners and operators made several concessions to stakeholders representing various environmental interests in exchange for them agreeing to withhold imminent pursuit of forced installation of closed-cycle cooling at Indian Point and several other once-through cooled power plants in the mid-Hudson region. In particular, Consolidated Edison abandoned its plans for developing a major pumped storage [hydroelectric] facility at Storm King Mountain, and the various plant operators agreed to collect data and analyze impacts their facilities were having on living aquatic resources for a period of ten years. Subsequent modifications to the HRSA extended the study period by another decade and have allowed these plants to continue withdrawing about a trillion gallons of river water or more per year. Total river water consumption is dependent upon how many days each plant is operating annually and at what output level. Scheduled outages at Indian Point and more sporadic operation of the fossil fueled plants are all determining factors in terms of the actual water consumption levels at any given time. The biological and ecological effects of these withdrawals are somewhat seasonal in that they reflect the biomass and species assemblage present at the time that the water withdrawals are taking place. The extended study period included implementing a variety of measures that partially mitigated for impingement and entrainment impacts, but these individually and cumulatively did not achieve the level of impact reduction that would result from installing closed cycle cooling at Indian Point.

The Indian Point generating units alone consume about 2.5 billion gallons of water *per day* for their pressurized-water reactors. To meet this need, Indian Point relies upon the Hudson River as a cooling water source and heat sink. Water is withdrawn directly from the river through batteries of seven intake

[1] ESA issues have been coordinated in consultation with our counterparts in the Northeast Regional Office's Protected Resources Division and we do not address them here.

bays into each generating unit and distributed to once-through condensers and auxiliary cooling systems. Cooling water is drawn into the plants by variable- or dual-speed pumps. As it first enters, the withdrawn water is skimmed of floating debris and subsequently passed over modified, vertical Ristroph traveling screens designed to protect aquatic life by retaining water and minimizing vortex stress. These modified screens attempt to reduce, but do not eliminate, impingement mortality. A high pressure spray-wash system removes debris from the front of the traveling screen mechanism and a low pressure spray-wash system flushes impinged fishes off the screen and into a sluice system that returns them to the Hudson River.

Under the HRSA, the former owners of Indian Point conducted impingement monitoring between 1975 and 1990 using a variety of techniques; however, neither the previous nor the current owner-operators have performed validation studies to evaluate the actual performance of the modified traveling screens. The EFH assessment Table 6 contains impingement data for IP2 and IP3 collected between 1981 and 1990. Revised data populating this table were provided to the NRC in December, 2009. Upon NMFS' request, these data were provided for our use on October 01, 2010 and were used in our review. Entrained organisms are not removed from the cooling water stream and instead are carried into and through the plants' cooling systems, as they are first collected by the circulating pumps, and subsequently passed through the plant intakes into the condenser tubes used to cool the turbine exhaust steam. Within the condensers, the organisms are subjected to mechanical damage and shear stress, thermal shock, and exposure to chlorine, industrial chemicals and biocide residues. Both the entrained organisms and heated effluent streams then exit the generating plant and are returned to the Hudson River through a shared discharge channel. According to the dGEIS, the prior Indian Point owner-operators periodically conducted entrainment loss studies for IP2 and IP3 since the early 1970s. The most recent data of this nature reported in the dGEIS are from 1990.

Environmental Setting:

The Hudson River Estuary supports an unusually large and diverse assemblage of fish and shellfish, and has long been recognized as a valuable national and regional resource. That is in part because the Hudson makes large contributions not only to local aquatic resource communities, but also to coastal and offshore fisheries that are supported by prey and other nutrients emanating from the estuary. Some of these fishery resources are managed by on an inter-state basis by the Atlantic States Marine Fisheries Commission [ASMFC] and others are managed federally pursuant to the Magnuson-Stevens Fishery Conservation and Management Act [MSFCMA] or the Endangered Species Act [ESA]. All of these aquatic organisms as well as non-managed species such as forage species and other lower trophic level organisms receive consideration under the federal Fish and Wildlife Coordination Act [FWCA] as NOAA trust resources.

More than 200 fish species have been recorded from within the entire Hudson watershed, and approximately two thirds of these occur in the estuary itself for all or part of their life cycles. More specifically, the Buchanan reach of the Hudson River is a tidally-dominated habitat that serves as a migratory corridor, spawning habitat, and nursery area for an unusually diverse species assemblage of resident or diadromous fishes, crustaceans, shellfish, and many lower trophic level prey items (Smith and Lake 1990). Ambient salinity conditions vary seasonally, and generally tend to lie in the mesohaline or oligohaline ranges. The immediate project reach is within the EFH designations for the Hudson-Raritan estuary and is significant with respect to the resources under the stewardship of the agencies mentioned above. As is true of other estuarine habitats, local temperature and salinity regimes, water depth, bottom type, sediment load and current velocities all influence the distribution and function of aquatic communities.

Evidence suggests that northeast coast estuaries have lost much of their rich former fishery productivity because of habitat degradation or loss, but lack of absolute species abundance data for early historical periods prior to significant human disturbances makes this conclusion somewhat inferential. Yet the linkage is supported by strong evidence, particularly that stock sizes for most estuarine dependent fishery resources under the jurisdiction of the Atlantic States Marine Fisheries Commission, New England or Mid-

Atlantic Management Councils, or the states of New York and New Jersey fishery management agencies, are not currently over fished, but fall below historic levels (NEFMC 1998; ASMFC 2005). This observation suggests that the Hudson River's ability to support and produce living aquatic organisms has been compromised over the years by lost habitat quality and quantity as humans have dredged, filled, and withdrawn river water for a myriad of uses, resulting in conflicts of use with fishery resources.[2]

As described above in the Project Background section of this letter, water withdrawals for once-through cooling systems that serve the mid-Hudson power plants has been a major conflict of use that has gone unresolved for decades. A total of five units remain in operation in the mid-Hudson: IP2, IP3, Bowline Point, Danskammer, and Roseton Generating Stations. All of these plants use one-through cooling systems. In the interim since the most recent relicensing was completed for the Indian Point plants, most fish species have experienced declines, and essential fish habitat [EFH] has been designated in order to better manage adverse anthropogenic effects on fisheries. For the immediate Indian Point area, designated EFH includes acreage that produces organisms that are under direct federal stewardship as well as prey items for species further downriver and offshore. The Hudson River is an important regional source for both harvested stocks and prey, so reductions in its productivity are of great significance to fishery ecology and fishery management.

Given the immense natural productive potential of the Hudson River Estuary, and taking into consideration the staggering numbers of organisms that are lost directly, indirectly and cumulatively through continued operation of electric generating stations that continue to use once-through cooling technology in the Mid-Hudson reach,[3] the National Marine Fisheries Service [NMFS] suggests that the current Indian Point relicensing process is an appropriate and opportune time to apply the Clean Water Act § 316(a) and 316 (b) provisions regarding large power generation facilities. We note that the Indian Point generating units comfortably fit under the criteria for being required to ensure that the location, design, construction, and capacity for cooling water intake structures reflect the best technology available [BAT] to protect aquatic organisms from being killed or injured by impingement or entrainment. We provide further rationale for this conclusion in the following sections of this letter.

General Comments on NRCs Exposition of Environmental Impacts of Operation in the dGEIS:

Nuclear power plant system operation may create a number of habitat disturbances that range from minor to major risk to aquatic resources. The evaluation of these impacts would have been enhanced by a more expanded discussion rather than being distilled to a series of summaries on pp. 4-3 to 4-6. These bullets address topics related to a variety of predominantly physical impacts that the NRC dismisses based upon prior experience at other nuclear plants or on the basis of information presented elsewhere in the EIS. We suggest that the NRC reconsider their evaluation before the GEIS and supplement is finalized. Several of these bullets mention subjects which have a potential bearing on EFH and other aquatic resources of concern, and some modifications would demonstrate adequate support for its conclusions. For instance, on page 4-3, the NRC considers altered currents at intake and discharge structures and finds:

> "Altered current patterns have not been found to be a problem at operating nuclear power plants and are not expected to be a problem during the license renewal term".

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[2] We note that the U.S. EPA generally has determined that operation of industrial scale cooling water intakes results in a wide spectrum of undesirable and unacceptable adverse effects on aquatic resources including entrainment and impingement; disrupting the food chain; and losses to aquatic populations that may result in reductions in biological diversity or other undesirable effects on ecosystem structure or function. See 66 Federal Register 65,256, 65,292 (December 18, 2001), 69 Federal Register 41,576, 41,586 (July 9, 2004). In addition,

[3] Described in NYSDEC's April 2, 2010 denial of Entergy's water quality certificate and also in the NRC's Supplement 38 to the generic Environmental Impact Statement for the proposed re-licenseing of IP2 and IP3

Given the large volumes of water consumed at Indian Point each day and the relatively narrow configuration of the Hudson River at the project reach, it seems plausible that under full operation, the plant *could* induce noticeable changes in the current regime or perhaps induce changes in the local erosion and accretion rates that have unintended adverse effects such as losses of submerged aquatic vegetation, chronic disturbances that discourage settlement of tiny prey items, and similar effects. Although NRC regulations do not compel the project proponents to provide plume modeling or field studies, our EFH regulations compel us to assume the worst case scenario that the effluent is creating a barrier to migrating fishes and other unacceptable environmental conditions that would adversely affect the amount and quality of available EFH. We understand that the plant operators have been using various measures to partially mitigate for these effects, but the lack of a detailed study that 1) evaluates the impacts of once-through cooling at Indian Point and the three other generating units ***and*** 2) clearly demonstrates that the measures they have been implementing are functionally equivalent to the installation of closed-cycle cooling leaves their position on the Clean Water Act § 316(a) and 316 (b) provisions as unsupported assertions. After several extensions of the HRSA, the situation remains fundamentally unchanged with regard to fish stocks and the plants are potential triggers for lost EFH in the form of direct habitat loss compounded by lost productivity in designated EFH.

There is similar concern in the statements for many of the other bullets in this section of the dGEIS, notably as regards the potential release of chemical or thermal pollution [and attendant adverse impacts to fishery resource movements, etc.]; entrainment of phytoplankton and zooplankton; induction of low dissolved oxygen; and other line items that would reduce the quality and quantity of designated EFH as described in the implementing regulations for the MSFCMA. As such, it is difficult for us to dismiss these topics so easily as problems that could be thoroughly assessed in our overall FWCA and EFH coordination. Along these same lines, existing entrainment study results from IP2 and IP3 collected from 1981-1987 do not seem to include hard data or discussion of the entrainment implications for fish eggs and larvae, copepods and other invertebrate prey items that are described clearly as prey in the EFH vignettes included for red hake, winter flounder, windowpane, bluefish and Atlantic butterfish. While Section H.1.2 of the dGEIS and its corresponding subsections do provide a short discussion of entrainment, and even casually observe that a wide variety of phytoplankton, zooplankton, and early life stages of fish and shellfish are vulnerable to becoming drawn into the generating plants via the cooling water stream, the review documents do not provide a thorough analysis of impacts to EFH with respect to their operations. Losses of this nature would have at least indirect and cumulative adverse effects on EFH not just in the mid-Hudson region, but extending into the marine portions of the coastal zone.

Coincidentally, the discussion noted in the foregoing paragraph touches upon the controversial nature of how different stakeholders view entrainment survival, which has a bearing on how a disagreement like the Hudson River power plant example can take deep root, intensify and perpetuate. For entrainment, the NRC documents note a wide range of perceptions on how different stakeholders view the potential for entrainment survival. As these documents suggest, the most conservative estimates consider entrainment 100% fatal, while some of the power companies suggest that some species or life stages could fare considerably better based upon 96-hour survival studies. The NRC correctly acknowledges in the dGEIS that the latter studies do not take into account indirect losses that arise to organisms becoming injured, disoriented or less able to forage in the event that they are fortunate enough to survive entrainment initially, and conclude for the purposes of their assessment that such losses are unknown. Consequently, NMFS does not see justification in the gDEIS to support a conclusion that impingement effects are not significant, or that any mitigation attempted to date has been as effective as the BAT for industrial scale operations, namely, closed-cycle cooling. This calls into question any progress claimed to have been made in implementing the HRSA in part because it gives the appearance that the various Indian Point operators did not follow through completely on their commitments under the HRSA. Moreover, it appears the operators are content to continue under the *status quo* without demonstrating that their mitigation to date has been functionally equivalent to best available technology as required under CWA §316(b).

NRCs Evaluation of Impacts on Aquatic Resources from Operation of the Cooling Water Intake:

The *intake* impacts for once-through cooling systems largely surround physical habitat loss associated with construction of the intakes themselves as well as the inability of aquatic species from being successfully able to use habitat within the volumes of water withdrawn from the source supply. These impacts may include changing particular ecological features such as local hydrological patterns as suggested in the foregoing section, but the preponderance of the impacts usually are associated with organism impingement and entrainment.

Impingement impacts tend to accrue to larger species and life stages that cannot pass through the impingement screens nor avoid the intake current, but become trapped on cooling water screens and sometimes cannot escape before suffering exhaustion, injury or even mortality. For the subject re-licensing proposal, we note that the most recent study results reported in the dGEIS and EFH assessment are decades old, with the most recent information collected in 1990. This fact concerns us on two counts: 1) the data may not accurately depict contemporary habitat usage of the mid-Hudson region by fishes, invertebrates, and other aquatic life, and 2) the project proponents have not evaluated the effectiveness of adaptive measures that have been implemented since the original HRSA was put into place. For instance, installation of the modified Ristroph traveling screens as a means of addressing some of the impacts associated with impingement injury and mortality was predicated on assumptions made in a limited pilot study. The review materials suggest that the actual performance of this gear has not been demonstrated *in situ*. This is an important consideration because gear does not always perform the same in the field as it does in a laboratory setting and its effectiveness can vary based upon the living aquatic resource assemblages it encounters in different geographic settings. Thus, we are left without empirical data to estimate the effectiveness of installing the modified screens and other mitigation measures against closed-cycle cooling. While the new gear may or may not have improved a less than ideal situation, neither NRC nor Entergy can definitively state how effectively the new screen designs are performing as a means of justifying an additional license renewal that permits continued use of once-through cooling in a potential license renewal.

Unlike impingement impacts, which tend to exhibit some selective characteristics in that they largely accrue to larger taxa or more mature life stages, entrainment of organisms into the cooling water source stream are relatively indiscriminate and may adversely affect *any* organism that fits through the screens and cannot counter the suction force of the intake. While the review material indicate that the IP2 and IP3 cooling systems have been retrofitted with dual-speed and variable-flow pumps in order that intake flows can be regulated to some degree to provide some level of mitigation or protection, we note that the dGEIS also indicates that using planned seasonal outages or maximum pump speeds does not eliminate the losses of fishes and other organisms to entrainment.

Regarding these collective intake impact matters, NMFS disagrees with the NRCs approach to presenting and analyzing the impingement and entrainment data. We particularly dispute the NRCs decision to attempt correlating overall *population level* trends with operation of the Indian Point nuclear generating facilities. First of all, analyzing the data over the entire range of a species instead of a more meaningful population segment does not follow the spirit of the National Environmental Policy Act nor the implementing regulations for EFH in the MSA because it ignores real and obvious impacts that could adversely affect a local stock. It is rare for the preponderance of a particular species be extirpated unless it already is endangered or threatened, but it certainly is quite plausible that a more local segment of an otherwise healthy population could be effectively decimated in an acute event or after years of suffering chronic or cumulative impacts. Thus, when considering the impacts of cooling water withdrawal on more local stock contributions emanating from the Hudson River and potentially recruiting to a greatly dispersed coastal fishery, the effects of cooling withdrawal even from a limited portion of the total available habitat (as it is construed in the dGEIS) could be quite profound. Finally, we are critical of this type of data transformation because it also has great potential for creating undesirable artifacts because it assumes all fishery habitats, regardless of their geographic location, size, and ecological condition, are equally valuable to the living resources that they support. The scientific literature is replete with studies that organisms do not use habitats uniformly over their ranges, and this observation is borne out in our own status and trends data that have been used to select closed areas or to make similar resource management decisions for certain federally managed fishery resources.

In concluding Section 4.1.5 of the dGEIS, upon which the NRC relies to support its overall EFH conclusions, the NRC posits that "impingement and entrainment from the operation of IP2 and IP3 are likely to have an adverse effect on aquatic ecosystems in the lower Hudson River during the period of extended operation", and goes so far as to name several potential mitigation options, but neither arrives at the specific conclusions that the units should be retrofitted with closed-cycle cooling systems, nor selects particular alternatives that they would recommend in lieu of closed-cycle cooling.

NRCs Evaluation of Impacts on Aquatic Resources from Operation of the Cooling Water Discharge:

As disclosed in the dGEIS, the *discharge* of heated water into the Hudson River can manifest a variety of lethal and sublethal effects on aquatic life, influence local ecological conditions, and create barriers to fish migrations. Direct effects tend to be thought of as mortalities that occur when an individual is exposed to conditions beyond their upper thermal tolerance limits. Indirect effects can result in changes to reproductive behaviors, changes in growth rate or survival of young, blocking migratory movements, altered predator-prey relationships, and similar community level disruptions. Oversight of these matters is regulated under a SPDES permit, which imposes effluent limitations, monitoring requirements, and other conditions to ensure that all discharges are in compliance with New York state code and the CWA. The most recent SPDES permit sets a maximum discharge temperature of 110^{0}F, and limits daily average discharge temperatures not to exceed 93.2^{0}F for a set number of days from mid-April through June. These terms have changed over a series of four consent orders since the original SPDES was let.

The NRC bases its evaluation of thermal effects on the status of the SPDES permits for Indian Point. According to the applicant's assessment, IP2 and IP3 are in compliance with terms of a SPDES permit issued by the State of New York as well as further mitigation required under the fourth HRSA consent order. The New York State Department of Environmental Conservation (NYSDEC), which maintains regulatory oversight over this arrangement, concludes that under certain circumstances, modeling demonstrates that discharges from the operating units at Indian Point allow greater than the four degree (F.) over ambient temperature limit, or a maximum of 83^{0}F, whichever is less, in certain estuary cross sections specified under New York State regulations. These matters have been, and remain, in dispute among the plant operators and the NYSDEC, culminating in the state denying a water quality certificate in April, 2010. An ongoing proceeding with the DEC has not resolved the problem, and the NRC notes in the dGEIS that the matter may not be concluded before the NRC issues its final SEIS.

The lack of a thermal study proposed by the NYSDEC or an alternative proposed by the applicant leaves the NRC in the position of having to use existing information to determine the appropriate thermal impact. This resulted in their finding that continued operations with once-through cooling and various mitigation measures would have a small to moderate effect, depending on the extent or magnitude of the plume, the sensitivity of aquatic life stages that were present, and related criteria. In addition to thermal discharges, the NRC considered the potential for plant operations resulting in other impacts to aquatic resources, and concluded that impingement and entrainment are likely to have adverse effects. The significance and extent of these impacts remain in dispute among the involved parties. The project proponents hold that existing operations adequately mitigate impingement and entrainment effects because dual- and variable-speed pumps as well as modified Ristroph were installed at IP2 and IP3, but the efficacy of these and related measures has not been verified by studies. The NYSDEC disagrees with their position, and has concluded that closed cycle cooling is the BAT to address the Hudson River utilities' impacts to aquatic resources. The NRC considered several additional mitigation options and determined that wedgewire screening systems are not feasible; and marine life exclusion systems and/or behavioral deterrents potentially would require further study.

We realize that the ongoing dispute between the plant operator and the State have hampered the NRC's ability to present a full analysis of additional mitigation options available for the existing cooling system, and its potential utility for conserving or protecting EFH functions and values. Nevertheless, we maintain that our analysis of the severity of the project impacts on NOAA trust resources is compelling, and that our conservation recommendations are necessary and appropriate to address the project impacts.

Essential Fish Habitat Comments:

Eight federally managed species with EFH designations within the mixing zone of the Hudson River estuary were identified in the NRCs EFH assessment. Of these, according to NRCs assessment, "there may be adverse individual or cumulative impacts on EFH in the project area for red hake larvae, winter flounder larvae, windowpane juveniles and adults, bluefish juveniles, and Atlantic butterfish juveniles and adults". However, the NRC went on to say in its preliminary EFH determination that they were of the opinion that none of these impacts would rise to a level of concern because "the proportion of EFH affected by IP2 and IP3 is small compared to EFH for the total managed stock". The NRC also proposed that continued operations of the open-cycle cooling systems for these units could continue in a renewed license scenario provided that appropriate mitigation measures were implemented to reduce thermal effluent as well as entrainment and impingement effects.

While the review materials include examples of measures that have been (or could be) implemented to reduce mortalities, it neither advocates a *particular* approach nor evaluates the effectiveness of those measures for protecting and conserving designated EFH or other fishery resource uses. We also note that because the EFH evaluation relies on comparing the immediate project waterfront against the total EFH designated coastally for selected species and life stages, it does not give adequate consideration to the fact that occupation and use of EFH is not uniform. The EFH designations are made on the basis of habitat that is supporting particular species and generic life stages, but does not currently discriminate more finely as to how that habitat is used within a designation. As an example, early juvenile life stages tend to focus on occupation of inshore nurseries and later [but still juvenile] fishes may be using coastal and offshore EFH that better meet their needs. Thus, we do not consider it appropriate to suggest that EFH for a one or two year old juvenile fish is equally suitable for supporting current young of the year juveniles.

Constraining the analysis of impacts to the immediate Indian Point reach and comparing that information against the habitat available to support the entire population and not the stocks originating from the Hudson River, erroneously creates the setting for not being able to find any impacts to EFH. A more appropriate analysis extends the view of entrainment, impingement and thermal discharge impacts to include the mortalities and reduced productivity of forage species, diadromous species, and resident fishes; to assess their impacts on coastal fisheries including species for which EFH is designated downstream; and to discuss how the lost productivity out of the mid-Hudson represents a net reduction in forage opportunities for offshore and downstream resources. This latter class of impacts is quite relevant in this situation and is not analyzed by the NRCs review materials. Nonetheless, the NRCs EFH assessment concluded that there may be adverse individual or cumulative effects of the proposed action on red hake larvae, winter flounder larvae, windowpane juveniles and adults, bluefish juveniles, and Atlantic butterfish juveniles and adults. However, in making this judgment, the NRC did not specify particular impacts of concern in the EFH assessment itself. Extrapolating from the dGEIS, NMFS notes that the primary impacts of concern regarding fishery resources and their habitat generally, and for EFH in particular, that would be associated with continued operations using an open-ended cooling system would be organism loss and habitat degradation. We could not enumerate these impacts based upon the materials provided for our review, but note that at over 2 billion gallons of water consumed per day, the amount of prey available to fishes in particular would be significantly diminished through entrainment alone.

While we recognize the impediments associated with lack of newer studies and related information, NMFS does not agree with some of the methods that the NRC used or assumptions that it made in performing its fish impact evaluations. According to the review materials provided, operating IP2 and IP3 as they currently are leads to direct impacts to EFH species and their prey in the mid-Hudson region. We also note that the EFH assessment and associated analyses were configured too narrowly to capture the breadth and implications that continued operations would have on living aquatic resources and their habitats both in the mid-Hudson and to coastal fisheries. As noted above, we are particularly concerned with the potential for Indian Point operations leading to reduced production or availability of prey, which constitutes an indirect or cumulative adverse effect that diminishes the quality of designated EFH as defined in the MSFCMA. Similarly, it is our opinion that a proper cumulative effects analysis for this situation should have included the adverse effects associated with operations at all of the mid-Hudson power plants that rely on Hudson River water to feed once-through cooling systems. We are not alone in this conviction. According to the NYDECs Final Draft Fact Sheet NY-0004472, dated November, 2003, regarding Indian Point's Surface Water Renewal Permit Action, "Pursuant to Section 316(b) of the CWA, and 6 NYCRR Section 704.5, the Department has determined that the site-specific best technology available (BTA) to minimize adverse environmental impact of the Indian Point Units 1, 2 and 3 cooling water intake structures is closed-cycle cooling." NMFS agrees with New York that a closed-cycle cooling system would significantly limit the amount of intake flow and thereby reduce impacts associated with especially impingement and entrainment. It is our opinion that implementing this measure is in the best interest of fishery resources and also is the most appropriate option for meeting our mutual EFH mandates while allowing continued electric generation at IP2 and IP3 in an otherwise sensitive ecological area.

Essential Fish Habitat Recommendations:

To minimize the impacts on EFH, pursuant to Section 305(b)(4)(A) of the MDFCMA, NMFS recommends that the following conservation recommendations be adopted in conjunction with the proposed federal action:

Implement the best available practicable technology to mitigate impingement, entrainment, and thermal impacts. The BAT for Indian Point would be reconfiguring the facilities by replacing the once-through cooling system with a state-of-the-art, closed-cycle design. A closed cycle cooling system would minimize water intake rates and return little to no heated water back into the Hudson River. The reduced water withdrawals and greatly diminished, perhaps even non-existent, plume associated with a closed-cycle cooling system would avoid and minimize what NMFS considers to be highly significant mortalities of billions of aquatic organisms and their attendant impacts to coastal fisheries.

Please note that Secton 305(b)(4)(B) of the MSFCMA requires that the NRC provide NMFS with a detailed written response to the EFH conservation recommendation, including a description of the measures adopted by the NRC for avoiding, mitigating, or offsetting the impact of the project on EFH. In the case of a response that is inconsistent with NMFS' recommendation(s), Section 305(b)(4)(B) o the MSFCMA also indicates that the NRC must explain its reasons for not following the recommendation(s). Included in such reasoning would be the scientific justification for any disagreements with NMFS over the anticipated effect of the proposed action and the measures needed to avoid, minimize, mitigate, or offset such effects pursuant to 50 CFR 600.920(k).

Please note that a distinct and further EFH consultation must be re-initiated pursuant to 50 CFR 600.920(1), if new information becomes available or the project is revised in such a manner that it affects the basis for the above EFH conservation recommendation.

Endangered Species Act:

The federally listed, endangered SNS and the candidate species for listing Atlantic sturgeon may be present in the project area. The NRC is currently in consultation with NMFS NEROs Protected Resources Division pursuant to Section 7 of the ESA and the NRC will conclude the ESA consultation with our colleagues in this Division of NMFS. The contents of the above EFH and FWCA coordination does not replace or supersede any negotiations that you may have conducted or will conduct with our PR division, and only pertains to our mutual obligations under the FWCA and MSFCMA.

Should you have any question regarding these comments or need additional information, please contact Diane Rusanowsky at diane.rusanowsky@noaa.gov; 203-882-6504

Sincerely,

Peter Colosi

Peter D. Colosi, Jr.
Assistant Regional Administrator
For Habitat Conservation

References:

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