ISSUE—10 CFR Part 51, Subpart A, Appendix B, Table B-1	Category	GEIS Sections	Comment
Impingement of fish and shellfish	1	4.2.2.1.3, 4.4.3	This issue is related to heat-dissipation systems that are not installed at IP2 and IP3.
Heat shock	1	4.2.2.1.4, 4.4.4	This issue is related to heat-dissipation systems that are not installed at IP2 and IP3.
GROUND WATER USE AND QUALITY			
Ground water use conflicts (potable and service water, and dewatering; plants that use <100 gpm)	1	4.8.1.1, 4.8.1.2	IP2 and IP3 do not use ground water for any purpose.
Ground water use conflicts (potable and service water, and dewatering; plants that use >100 gpm)	2	4.8.1.1, 4.8.1.2	IP2 and IP3 do not use ground water for any purpose.
Ground water use conflicts (plants using cooling towers withdrawing makeup water from a small river)	2	4.8.1.3	This issue is related to heat-dissipation systems that are not installed at IP2 and IP3.
Ground water use conflicts (Ranney wells)	2	4.8.1.4	IP2 and IP3 do not have or use Ranney wells.
Ground water quality degradation (Ranney wells)	1	4.8.2.2	IP2 and IP3 do not have or use Ranney wells.
Ground water quality degradation (saltwater intrusion)	1	4.8.2.1	IP2 and IP3 do not use for any purpose.
Ground water quality degradation (cooling ponds in salt marshes)	1	4.8.3	IP2 and IP3 do not use cooling ponds.
Ground water quality degradation (cooling ponds at inland sites)	2	4.8.3	IP2 and IP3 do not use cooling ponds.

ISSUE—10 CFR Part 51, Subpart A, Appendix B, Table B-1	Category	GEIS Sections	Comment
HUMAN HEALTH			
Microbial organisms (occupational Health)	1	4.3.6	This issue is related to a heat-dissipation system that is not installed at IP2 and IP3.
Microbiological organisms (public health; plants lakes or canals, cooling towers, or cooling ponds that discharge to a small river)	2	4.3.6	This issue is related to a heat-dissipation system that is not installed at IP2 and IP3.
TERRESTRIAL RESOURCES			
Cooling tower impacts on crops and ornamental vegetation	1	4.3.4	This issue is related to a heat-dissipation system that is not installed at IP2 and IP3.
Cooling tower impacts on native plants	1	4.3.5.1	This issue is related to a heat-dissipation system that is not installed at IP2 and IP3.
Bird collisions with cooling towers	1	4.3.5.2	This issue is related to a heat-dissipation system that is not installed at IP2 and IP3.
Cooling pond impacts on terrestrial resources	1	4.4.4	This issue is related to a heat-dissipation system that is not installed at IP2 and IP3.

References

Code of Federal Regulations, Title 10, “Energy,” Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.”

U.S. Nuclear Regulatory Commission, NUREG-1437, “Generic Environmental Impact Statement for License Renewal of Nuclear Plants,” Volumes 1 and 2, May 1996.

U.S. Nuclear Regulatory Commission, NUREG-1437, “Generic Environmental Impact Statement for License Renewal of Nuclear Plants: Main Report,” Section 6.3, “Transportation,” Table 9.1, “Summary of Findings on NEPA Issues for License Renewal of Nuclear Power Plants,” Final Report, Volume 1, Addendum 1, August 1999.

Appendix G

U.S. Nuclear Regulatory Commission Staff Evaluation of Severe Accident Mitigation Alternatives for Indian Point Nuclear Generating Unit Nos. 2 and 3 in Support of License Renewal Application Review

Appendix G

U.S. Nuclear Regulatory Commission Staff Evaluation of Severe Accident Mitigation Alternatives for Indian Point Nuclear Generating Unit Nos. 2 and 3 in Support of License Renewal Application Review

G.1 Introduction

Entergy Nuclear Operations, Inc. (Entergy) submitted an assessment of severe accident mitigation alternatives (SAMAs) for Indian Point Nuclear Generating Unit Nos. 2 and 3 (IP2 and IP3) as part of the environmental report (ER) (Entergy 2007). Entergy based its assessment on the most recent probabilistic safety assessment (PSA) for IP2 and IP3 (a site-specific offsite consequence analysis performed using the MELCOR Accident Consequence Code System 2 (MACCS2) computer code), and on insights from the Individual Plant Examination (IPE) (Con Ed 1992 and NYPA 1994) and the Individual Plant Examination of External Events (IPEEE) (Con Ed 1995 and NYPA 1997) for each unit. In identifying and evaluating potential SAMAs, Entergy considered SAMAs that addressed the major contributors to core damage frequency (CDF) and large early release frequency (LERF) at IP2 and IP3, as well as SAMA candidates for other operating plants that have submitted license renewal applications. Entergy identified 231 candidate SAMAs for IP2 and 237 SAMAs for IP3. This list was reduced to 68 (IP2) and 62 (IP3) unique SAMAs by eliminating SAMAs that are not applicable at IP2 and IP3 because they have design differences, they have already been implemented at IP2 and IP3, or they are similar in nature and could be combined with another SAMA candidate. Entergy assessed the costs and benefits associated with each of the potential SAMAs and concluded in the ER that several of these were potentially cost beneficial.

Based on a review of the SAMA assessment, the U.S. Nuclear Regulatory Commission (NRC) issued requests for additional information (RAIs) to Entergy by letters dated December 7, 2007 (NRC 2007), and April 2, 2008 (NRC 2008). Key questions concerned major changes to the internal flood model in each of the PSA updates; PSA peer review comments and their resolution; MACCS2 input data and assumptions (including core inventory, evacuation modeling, and offsite economic costs); assumptions used to quantify the benefits for certain SAMAs; reasons for unit-to-unit differences for certain risk contributors and estimated SAMA benefits; and further information on several specific candidate SAMAs and low-cost alternatives, including SAMAs related to steam generator tube rupture (SGTR) events. Entergy submitted additional information by letters dated February 5, 2008 (Entergy 2008a), and May 22, 2008 (Entergy 2008b). In response to the RAIs, Entergy provided clarification of the internal flooding analysis changes in each PSA model version; additional information regarding the peer review process and comment resolution; details regarding the MACCS2 input data, including results of a sensitivity analysis addressing loss of tourism and business; additional explanation and justification for the assumptions in each analysis case; descriptions of plant-specific features

that account for differences in risk and SAMA benefits between units; and additional information regarding several specific SAMAs, including SGTR-related SAMAs. Entergy's responses addressed the NRC staff's concerns and resulted in the identification of several additional potentially cost-beneficial SAMAs and the elimination of one previously identified cost-beneficial SAMA.

An assessment of SAMAs for IP2 and IP3 is presented below.

G.2 Estimate of Risk for IP2 and IP3

Entergy's estimates of offsite risk at IP2 and IP3 are summarized in Section G.2.1. The summary is followed by the NRC staff's review of Entergy's risk estimates in Section G.2.2.

G.2.1. Entergy's Risk Estimates

The two distinct analyses that are combined to form the basis for the risk estimates used in the SAMA analysis are (1) the IP2 and IP3 Level 1 and Level 2 PSA models, which are updated versions of the IPE (Con Ed 1992 and NYPA 1994) and IPEEE (Con Ed 1995 and NYPA 1997) for each unit, and (2) supplemental analyses of offsite consequences and economic impacts (essentially a Level 3 PSA model) developed specifically for the SAMA analysis. The SAMA analysis is based on the most recent IP2 and IP3 Level 1 and Level 2 PSA models available at the time of the ER, referred to as the IP2 Revision 1 PSA model (April 2007) for IP2 and the IP3 Revision 2 PSA model (April 2007) for IP3. The scope of the PSA models does not include external events.

The baseline CDF for the purpose of the SAMA evaluation is approximately 1.79×10^{-5} per year for IP2 and 1.15×10^{-5} per year for IP3. The CDF is based on the risk assessment for internally initiated events, including internal flooding. Entergy did not include the contributions from external events within the IP2 and IP3 risk estimates; however, it did perform separate assessments of the CDF from external events and did account for the potential risk reduction benefits associated with external events by multiplying the estimated benefits for internal events by a factor of approximately 3.8 for IP2 and 5.5 for IP3. This is discussed further in Sections G.2.2 and G.6.2.

The breakdown of CDF by initiating event is provided in Table G-1 for IP2 and IP3. For IP2, loss of offsite power sequences, including station blackout (SBO) events, and internal flooding initiators are the dominant contributors to CDF. For IP3, internal flooding initiators, loss-of-coolant accidents (LOCAs), SGTR events, and anticipated transient without scram (ATWS) events are the dominant contributors to CDF.

There are several significant differences between the two Indian Point units that account for differences in the risk contributions shown in Table G-1. These differences include:

The pressurizer PORV block valves are normally closed in Unit 2, and normally open in Unit 3. Thus, the ability to use the PORVs for feed and bleed cooling in LOOP and partial power loss events is greater at Unit 3, resulting in a lower CDF for LOOP events in Unit 3.

There are differences in the internal flooding sources and building configurations (e.g., ingress and egress paths). These physical differences together with differences in the method for calculating failure frequencies result in higher flood CDF frequencies in Unit 2.

In Unit 2, DC control power for EDGs and other loads on emergency 480 VAC busses is supplied from either normal or emergency backup supplies, with automatic switching between supplies. Unit 3 does not have this backup capability. This results in a lower CDF contribution from loss of DC power events in Unit 2.

Table G-1. IP2 and IP3 Core Damage Frequency

Initiating Event	IP2		IP3	
	CDF (Per Year)	% Contribution to CDF	CDF (Per Year)	% Contribution to CDF
loss of offsite power [1]	6.7×10^{-6}	38	1.2×10^{-7}	1
internal flooding	4.7×10^{-6}	26	2.2×10^{-6}	20
LOCA	1.5×10^{-6}	8	2.2×10^{-6}	19
transients [1]	1.2×10^{-6}	7	8.5×10^{-7}	7
ATWS	9.9×10^{-7}	6	1.5×10^{-6}	13
SBO				
SGTR	8.5×10^{-7}	5	7.2×10^{-7}	6
loss of component cooling water (CCW)	7.2×10^{-7}	4	1.6×10^{-6}	14
loss of nonessential service water	5.8×10^{-7}	3	1.1×10^{-7}	<1
interfacing systems LOCA (ISLOCA)	3.0×10^{-7}	2	2.8×10^{-7}	2
reactor vessel rupture				
loss of 125 volts (V) direct current (dc) power	1.5×10^{-7}	<1	1.5×10^{-7}	1
total loss of service water system	1.0×10^{-7}	<1	1.0×10^{-7}	<1
loss of essential service water	5.8×10^{-8}	<1	1.0×10^{-6}	9
	4.4×10^{-8}	<1	5.4×10^{-7}	5
	1.9×10^{-10}	<1	1.9×10^{-8}	<1
Total CDF (internal events)	**1.79×10^{-5}**	**100**	**1.15×10^{-5}**	**100**

[1] Contributions from SBO and ATWS events are noted separately and are not included in the reported values for loss of offsite power or transients.

The current Level 2 PSA models are based on the IPE models, with updates to reflect changes to the plant and modeling techniques, including a 3.3 percent and 4.8 percent power uprate for IP2 and IP3, respectively; inclusion of additional plant damage states (PDSs) to improve the Level 1–Level 2 PSA interface; and updated accident progression and source term analyses using a later version of the Modular Accident Analysis Program (MAAP) computer code. The Level 1 core damage sequences are placed into one of 57 PDS bins that provide the interface between the Level 1 and Level 2 analyses. The Level 2 models use a single containment event tree (CET) with functional nodes representing both systemic and phenomenological events. CET nodes are evaluated using supporting fault trees and logic rules.

The result of the Level 2 PSA is a set of nine release categories with their respective frequency and release characteristics. The results of this analysis for IP2 and IP3 are provided in Tables

E.1-9 (IP2) and E.3-9 (IP3) of the ER. The frequency of each release category was obtained by summing the frequency of the individual accident progression CET endpoints binned into the release category. Source terms were developed for each of the nine release categories using the results of MAAP 4.04 computer code calculations. The release characteristics for each release category were obtained by frequency-weighting the release characteristics for each CET endpoint contributing to the release category (Entergy 2007).

The offsite consequences and economic impact analyses use the MACCS2 code to determine the offsite risk impacts on the surrounding environment and public. Inputs for these analyses include plant-specific and site-specific input values for core radionuclide inventory, source term and release characteristics, site meteorological data, projected population distribution (within an 80-kilometer (50-mile) radius) for the year 2035, emergency response evacuation modeling, and economic data. The magnitude of the onsite impacts (in terms of cleanup and decontamination costs and occupational dose) is based on information provided in NUREG/BR-0184 (NRC 1997a).

In the ER, Entergy estimated the dose to the population within 80 kilometers (50 miles) of the IP2 and IP3 site to be approximately 0.22 person-sievert (Sv; 22 person-rem) per year for IP2, and 0.24 Sv (24 person-rem) per year for IP3. The breakdown of the total population dose by containment failure mode is summarized in Table G-2, based on information provided in response to an RAI (Entergy 2008a). SGTR events and late containment failures caused by gradual overpressurization by steam and noncondensable gases dominate the population dose risk at both units.

Table G-2. Breakdown of Population Dose by Containment Failure Mode

Containment Failure Mode	IP2		IP3	
	Population Dose (Person-Rem[1] Per Year)	**Percent Contribution**	**Population Dose (Person Rem[1] Per Year)**	**Percent Contribution**
intact containment	<0.1	<1	<0.1	<1
basemat meltthrough	1.1	5	0.6	3
gradual overpressure	7.4	34	4.4	18
late hydrogen burns	0.9	4	0.6	2
early hydrogen burns	2.1	10	0.8	3
invessel steam explosion	0.1	1	0.1	0
reactor vessel rupture	1.0	5	0.4	2
ISLOCA	1.6	7	1.1	4
SGTR	7.7	35	16.6	68
Total	**22.0**	**100**	**24.3**	**100**

[1]One person-rem = 0.01 Sv.

Review of Entergy's Risk Estimates

Entergy's determination of offsite risk at IP2 and IP3 is based on the following four major elements of analysis:

(1) the Level 1 and Level 2 risk models that form the bases for the IPE submittals (Con Ed 1992 and NYPA 1994) and the IPEEE submittals (Con Ed 1995 and NYPA 1997)

(2) the major modifications to the IPE models that have been incorporated in the IP2 and IP3 2007 PSA updates

(3) adjustments to the IPEEE seismic and fire risk results to represent recent plant changes, updated failure probabilities, and more realistic assumptions

(4) the MACCS2 analyses performed to translate fission product source terms and release frequencies from the Level 2 PSA model into offsite consequence measures

Each of these analyses was reviewed to determine the acceptability of Entergy's risk estimates for the SAMA analysis, as summarized below.

The NRC staff's reviews of the IP2 and IP3 IPE submittals are described in the NRC reports dated August 14, 1996 (NRC 1996) and October 20, 1995 (NRC 1995), for IP2 and IP3, respectively. Based on its review of the IPE submittals and responses to RAIs, the NRC staff concluded that the IPE submittals met the intent of Generic Letter (GL) 88-20; that is, the licensee's IPE process is capable of identifying the most likely severe accidents and severe accident vulnerabilities. Although no vulnerabilities were identified in the IPE, several plant improvements were identified. These improvements have either been implemented at the site or addressed by a SAMA in the current evaluation (Entergy 2007). These improvements are discussed in Section G.3.2.

There have been three revisions to the IP2 PSA model and two revisions to the IP3 PSA model since the respective IPE submittals. A comparison of the internal events CDF between the IPE submittals and the current PSA models indicates a decrease of approximately 45 and 75 percent for IP2 and IP3, respectively (from 3.13×10^{-5} per year to 1.79×10^{-5} per year for IP2 and from 4.40×10^{-5} per year to 1.15×10^{-5} per year for IP3). A description of those changes that resulted in the greatest impact on the internal-event CDF is provided in Sections E.1.4 and E.3.4 of the ER (Entergy 2007) and in response to a staff RAI (Entergy 2008a) and is summarized in Tables G-3a and G-3b for IP2 and IP3, respectively.

Table G-3a. IP2 PSA Historical Summary

PSA Version	Summary of Changes from Prior Model	CDF (per year)
1992	IPE submittal (excluding internal flooding) (RISKMAN)	3.13×10^{-5}
Update	5/2003 PSA Update (RISKMAN) - credited recovery of feedwater and condensate - added treatment of cross-header common-cause failure (CCF) for essential and nonessential service water headers - updated equipment performance and unavailability data - revised human error probabilities based on thermal-hydraulic calculations - updated reactor coolant pump (RCP) seal LOCA model - added treatment of internal flooding events	2.19×10^{-5}
Rev. 0	3/2005 PSA update (Computer-Aided Fault-Tree Analysis code (CAFTA)) - updated initiating event, component failure, and unavailability databases - updated offsite power recovery data per EPRI 1009889 - revised internal flooding analysis, including pipe-break frequencies and human error probabilities - changed CCF model from multiple Greek letter to Alpha method - updated human reliability analysis (HRA) method to the EPRI HRA method - updated RCP seal LOCA model to WCAP-16141 (WOG2000) - updated ISLOCA model to address ISLOCAs inside containment, to credit mitigation only for small LOCAs outside containment, and to remove credit for makeup to the refueling water storage tank (RWST)	1.71×10^{-5}
Rev. 1	2/2007 PSA update - updated selected initiating event frequencies - updated offsite power recovery model per NUREG/CR-6890 - included CCF for plugging service water pump strainers - revised model to reflect that normal offsite power feeds to the 480-V ac safeguards buses do not trip on a safety injection (SI) signal without a concurrent loss of offsite power - added credit for Indian Point Unit 1 (IP1) station air compressors for scenarios that do not involve loss of offsite power - revised auxiliary feedwater (AFW) success criterion to require flow to two (rather than one) steam generators for normal (non-ATWS) response	1.79×10^{-5}

Table G-3b IP3 PSA Historical Summary

PSA Version	Summary of Changes from Prior Model	CDF (per year)
1994	IPE submittal (including internal flooding CDF of 6.5×10^{-6})	4.40×10^{-5}
Rev. 1	6/2001 PSA Update - updated initiating event, component failure, and unavailability databases - updated offsite power recovery model per NUREG/CR-5496 - revised and added CCF component groups consistent with the most recent probabilistic risk assessment (PRA) practices, and updated CCF data - revised HRA to reflect EOP changes - updated RCP seal LOCA model per Brookhaven model, including credit for qualified high-temperature RCP seals	1.35×10^{-5}
	- incorporated major plant design changes, including: • replacement of power-operated relief valves (PORVs) to eliminate leakage and allow operation with the block valve open • reassignment of power supplies to emergency diesel generator (EDG) room exhaust fans to eliminate dependencies • modification of backup battery charger 35 to be able to be powered from 480-V MCC 36C, 36D, or 36E • installation of a diesel-driven station air compressor. • installation of temperature detectors to provide control room alarm if high temperature on the 15 and 33 feet (ft) elevation of the control building • installation of a waterproof door to the deluge valve station	
Rev. 2	2/2007 PSA Update - added a total loss of service water initiating event - updated offsite power recovery model per NUREG/CR-6890 - changed CCF model from modified Beta method to Alpha method - updated RCP seal LOCA model to WCAP-16141 (WOG2000) - revised AFW success criterion to require flow to two (rather than one) steam generators for normal (non-ATWS) response - modified success criteria for cooling of internal recirculation pumps to remove credit for cooling by redundant systems - removed the credit for an offsite gas turbine (which is no longer maintained)	1.15×10^{-5}

The CDF values from the IP2 and IP3 IPE submittals (3.13×10^{-5} per year and 4.40×10^{-5} per year, respectively) are near the average of the CDF values reported in the IPEs for pressurized-water reactors (PWRs) with dry containments. Figure 11.2 of NUREG-1560 shows that the IPE-based total internal events for these plants range from 9×10^{-8} to 8×10^{-5} per year, with an average CDF for the group of 2×10^{-5} per year (NRC 1997b). The NRC staff recognizes that other plants have updated the values for CDF subsequent to the IPE submittals to reflect modeling and hardware changes. The current internal event CDF results for IP2 and IP3 (1.79×10^{-5} per year and 1.15×10^{-5} per year, respectively) are comparable to those for other plants of similar vintage and characteristics.

The NRC staff considered the peer reviews performed for the IP2 and IP3 PSAs and the potential impact of the review findings on the SAMA evaluation in order to reach a conclusion regarding adequacy of the PRA to support SAMA evaluation. In the ER, Entergy described the peer review by the (former) Westinghouse Owner's Group (WOG) of the IP2 PSA model, conducted in May 2002, and of the IP3 PSA model, conducted in January 2001. The IP2 model reviewed was an updated version of the IPE that predated the May 2003 version described in Table G-3a. Similarly, the IP3 model reviewed was an updated version of the IPE that predated the June 2001 version described in Table G-3b.

For both IP2 and IP3, the ER states that all of the technical elements were graded as sufficient to support applications requiring the capabilities defined for grade 2 (e.g., risk-ranking applications). In addition, most of the elements were further graded as sufficient to support applications requiring the capabilities defined for grade 3 (e.g., risk-informed applications supported by deterministic insights).

For IP2, the ER states that there were no Level A findings (for which immediate model changes would have been appropriate) from the peer review. Although a number of minor model corrections were made following the peer review, no significant changes were made to the model structure or underlying assumptions in the May 2003 PSA update. The IP2 model was subsequently converted from the support-state RISKMAN model to a linked-fault-tree CAFTA model. Entergy indicates that the conversion effort included a number of modeling changes for consistency with other Entergy models and addressed the remaining findings and observations (F&Os) from the IP2 Peer Review (i.e., Level B, C, and D F&Os), where appropriate. In addition, the issues raised during the peer review of the IP3 model were also examined for applicability to IP2; all applicable issues were addressed consistent with the treatment used for IP3. For IP3, the ER states that all Level A and B F&Os from the IP3 peer review were addressed in the final version of the Revision 1 PSA model for IP3, which was issued in June 2001, and that less significant (Level C & D) F&Os were addressed, where appropriate.

Entergy indicates that the model changes incorporated in the IP2 Revision 1 and the IP3 Revision 2 PSA models also underwent an internal independent review by Entergy PSA staff and plant personnel and were subjected to a focused self-assessment to demonstrate technical quality in preparation for the NRC Mitigating Systems Performance Indicator (MSPI) program in 2006. In addition, the IP2 model was also subjected to a weeklong review by a team of industry peers from outside the Entergy staff in July 2005. Finally, the ER indicates that the model changes in the IP2 Revision 1 and the IP3 Revision 2 PSA models were peer reviewed for accuracy and consistency by members of the Entergy Nuclear Systems Analysis Group not directly involved in their implementation (Entergy 2007).

Given that the IP2 and IP3 internal events PSA models have been peer reviewed and the peer review findings were either addressed or judged to have no adverse impact on the SAMA evaluation, and that Entergy has satisfactorily addressed the NRC questions regarding the PSA (NRC 2007, NRC 2008, Entergy 2008a, Entergy 2008b), the NRC staff concludes that the internal events Level 1 PSA model for the plants is of sufficient quality to support the SAMA evaluation.

Section E.1.4 of the ER states that, for IP2, internal flooding was examined as part of the IPEEE, while Section E.3.4 indicates that internal flooding was included in the IP3 IPE. Internal flooding was later incorporated into the IP2 May 2003 PSA update, resulting in the consistent treatment of internal flooding for the two units.

The IP2 IPEEE analysis of internal flooding yielded a CDF of 6.6×10^{-6} per year while the IP3 IPE internal flooding analysis yielded a CDF of 6.5×10^{-6} per year. For each plant, three scenarios accounted for more than 80 percent of the flood CDF. All these scenarios result in a reactor trip and the nonrecoverable loss of safety-related switchgear from flooding sources located in or adjacent to the each unit's 480-V switchgear room.

The internal flooding analysis was included in the WOG peer review. In response to an RAI, Entergy provided a detailed discussion on the incorporation of peer review comments for IP2 and IP3. For IP2, the licensee indicated that there were only two WOG peer review findings associated with the internal flooding analysis.

The first finding related to use of a flooding event screening criterion of 1×10^{-6} per year in the analysis. That criterion, however, was only applied to a scenario involving the potential for intercompartmental flooding from the EDG building to the electrical tunnel and involved leakage that could be accommodated by existing plant drains rather than catastrophic failure. Therefore, it was determined that screening of this scenario was appropriate and a model change was not needed.

The second finding was a general concern that the flooding study had not been updated since 1993. The IP2 internal flooding analysis was subsequently updated in 2005 (Entergy 2008a). For IP3, the licensee indicated that the IP3 WOG peer review concluded that the internal flooding analysis demonstrated a superior combination of industry data and models to obtain plant-specific piping rupture frequencies. The peer review identified four F&Os related to the internal flooding analysis. One F&O was a strength that warranted no change to the model. The other findings related to incorporation of historical data, assembly of walkdown records, and consideration of applicable draft American Society of Mechanical Engineers (ASME) standards to enhance the flooding analysis. The findings related to the incorporation of historical data and to the assembly of walkdown records were resolved during preparation of the final version of Revision 1 of the IP3 PSA model. The draft ASME standards identified by the review team were reviewed, and no modeling changes were warranted. Therefore, all internal flooding review comments that affect the model were addressed in the model used for the SAMA analysis (Entergy 2008a).

As indicated above, the current IP2 and IP3 PSA models do not include external events. In the absence of such an analysis, Entergy used the IP2 and IP3 IPEEEs, in conjunction with minor adjustments in fire and seismic scenarios, to identify the highest risk accident sequences and the potential means of reducing the risk posed by those sequences, as discussed below.

The IP2 and IP3 IPEEEs were submitted in December 1995 (Con Ed 1995) and September 1997 (NYPA 1997), in response to Supplement 4 of GL 88-20 (NRC 1991). These submittals included a seismic PRA analysis, a fire PRA, a high-wind risk model, and a screening analysis for other external events. While no fundamental weaknesses or vulnerabilities to severe accident risk in regard to the external events were identified, several opportunities for risk reduction were identified and implemented, as discussed below. In letters dated August 13, 1999, and February 15, 2001, the NRC staff concluded that the submittals for IP2 and IP3 generally met the intent of Supplement 4 to GL 88-20, and that the licensee's IPEEE process is capable of identifying the most likely severe accidents and severe accident vulnerabilities (NRC 1999 and 2001). For IP3, the NRC staff identified an issue related to misdirection of manual fire suppression, which can fail equipment, but decided to resolve that issue separately from the IPEEE.

The IPEEE seismic analyses employed a seismic PSA following the guidance of NUREG-1407. The IPEEE estimated a seismic CDF of 1.46×10^{-5} and 4.4×10^{-5} per year for IP2 and IP3, respectively. Components related to decay heat removal were modeled in the seismic PSA for both units. No unique decay-heat removal vulnerabilities were found for either unit based on the quantitative risk results. Seismic-induced flooding and fires were examined as part of the IPEEE process for both units. Specific seismic-fire interactions were identified by Entergy, as listed in Table 2.12 of NUREG-1742 (NRC 2002). However, upon further consideration, the NRC staff concluded that the contribution to the CDF is small because the conditional probability of a fire, given an earthquake, is small (NRC 2001). For IP2 and IP3, the IPEEEs also addressed the issue of relay chattering through a detailed examination of the relays used in IP2 against the low-capacity relay list found in Appendix D of Electric Power Research Institute (EPRI) NP-7148-SL. A list of the dominant contributors to the seismic CDF for IP2 and IP3 is provided in Tables G-4a and G-4b, based on the information provided in response to an RAI (Entergy 2008a).

In Section 4.21.5.4 of the ER, Entergy noted that conservative assumptions were used in the seismic analyses, including the use of a single, conservative surrogate element to model the most seismically rugged components, the assumption that redundant components are completely correlated in determining the probability of seismic-induced failure, and the assumption that seismic-induced ATWS events are not recoverable. For purposes of the SAMA evaluation, Entergy performed a reevaluation of the seismic CDF, as discussed below. For IP2, as a result of an IPEEE recommendation, the CCW surge tank hold-down bolts were upgraded. This effectively eliminated the contribution from the failure of the CCW surge tank, reducing the seismic CDF for IP2 from 1.46×10^{-5} per year to approximately 1.06×10^{-5} per year. For IP3, no seismic improvements were recommended. However, Entergy reevaluated the seismic PSA to reflect updated random component failure probabilities and to model recovery of onsite power and local operation of the turbine-driven AFW pump. This reduced the seismic CDF for IP3 from 4.4×10^{-5} per year to 2.65×10^{-5} per year. These reduced CDF values were used in developing the external events multipliers in the SAMA benefit analysis, as discussed later.

1 **Table G-4a. IP2 Seismic Scenarios and Their Contribution to Seismic CDF**

Seismic Scenario Description	CDF (per year)	
	Frequency	Percent Contribution
failure of CCW, primarily caused by failure of surge tank hold-down bolts	4.2×10^{-6}	29
failure of the turbine building frame and consequential failure of control building	3.5×10^{-6}	24
collapse of IP1 super heater stack onto control building	3.0×10^{-6}	21
loss of 480 V emergency power	1.3×10^{-6}	9
loss of service water (seismic failure of service water pumps)	1.3×10^{-6}	9
seismic-induced loss of offsite power	4.4×10^{-7}	3
Other	7.4×10^{-7}	5
Total Seismic CDF from Dominant Scenarios	**1.46×10^{-5}**	**100**

2 **Table G-4b IP3 Seismic Scenarios and Their Contribution to Seismic CDF**

Seismic Scenario Description	CDF (per year)	
	Frequency	Percent Contribution
loss of 480-V ac electric power with consequential RCP seal LOCA	1.9×10^{-5}	43
loss of CCW with consequential RCP seal LOCA	1.0×10^{-5}	23
loss of offsite power with seismic failures of the RHR heat exchangers, the condensate stage tank, containment instrument racks, and AFW	9.2×10^{-6}	21
surrogate element (represents screened out, rugged components and structures, where failure leads to core damage)	3.5×10^{-6}	8
seismic-induced ATWS	2.2×10^{-6}	5
Total Seismic CDF from Dominant Scenarios	**4.4×10^{-5}**	**100**

The IPEEE fire analyses employed a combination of PRA with the EPRI's fire-induced vulnerability evaluation methodology. The evaluation was performed in four phases:

(1) qualitative screening

(2) quantitative screening

(3) fire damage evaluation screening

(4) fire scenario evaluation and quantification

Each phase focused on those fire areas that did not screen out in the prior phases. The final phase involved using the IPE model for internal events to quantify the CDF resulting from a fire-initiating event. Each fire area that remained after screening was then treated as a separate initiating event and was propagated through the model with the appropriate model modifications, as necessary. The CDF for each area was obtained by accounting for the frequency of a fire in a given fire area; the conditional core damage probability associated with that fire scenario in the fire area, including, where appropriate, the impact of fire suppression; and fire propagation. The potential impact on containment performance and isolation was evaluated following the core damage evaluation. The total fire CDF from the IPEEE was estimated to be 1.8×10^{-5} per year for IP2 (Con Ed 1995) and 5.6×10^{-5} per year for IP3 (NYPA 1997).

In Section 4.21.5.4 of the ER, Entergy noted that conservative assumptions were used in the IPEEE fire analyses, including overestimation of the frequency and severity of fires; conservative treatment of open, hot short, and short-to-ground circuits; and assumption of a plant trip for all fires. For purposes of the SAMA evaluation, Entergy performed a reevaluation of the fire CDF, as discussed below.

- For IP2, Section E.1.3.2 of the ER notes that the IP2 IPEEE fire model had the following known conservatisms:
- The main feedwater and condensate systems were assumed to be unavailable in all scenarios, even when their power source was not affected by the fire scenario.
- The pressurizer PORV block valves were assumed to be in the limiting position (open or closed) to maximize the impact of the fire.
- All sequences involving RCP seal LOCAs were assumed to lead to complete seal failure.

For the purpose of the SAMA evaluation, Entergy reevaluated the dominant IPEEE fire sequences (sequences with CDF contributions greater than 1×10^{-7} per year) to reduce the conservatisms associated with main feedwater and condensate unavailability and PORV block valve assumptions and to reflect updated modeling associated with RCP-seal LOCAs. In response to a RAI, Entergy explained that other portions of the fire analysis methodology and modeling were not revised as part of the SAMA update. Entergy also noted that preliminary fire analysis results were inadvertently included in the ER and provided a corrected, revised IP2 fire CDF value of 8.4×10^{-6} per reactor year (Entergy 2008a). These revised results are included in Table G-5a and were used in developing the external events multiplier in the SAMA benefit analysis.

Similarly, for IP3, Section E.3.3.2 of the ER notes that the IP3 IPEEE fire model had known conservatisms in estimating the fire ignition frequency (e.g., an air compressor ignition

frequency did not take into account that the compressor would operate only for a total of about 5 days per year). Also, at the time of IPEEE, the automatic suppression systems in some plant areas were placed in “manual” mode because of concerns with seismic interactions. Subsequently, some fire suppression systems were extensively modified so that the suppression mode could have been returned to “automatic.” As part of the update for the purpose of SAMA evaluations, Entergy performed a reanalysis of the fire CDF and provided a revised IP3 fire CDF value of $2.55\text{x}10^{-5}$ per year (Entergy 2007). These revised results are included in Table G-5b and were used to develop the external events multiplier in the SAMA benefit analysis.

Table G-5a. IP2 Fire Areas and Their Contribution to Fire CDF

Fire Area	Area Description	CDF (per year) IPEEE	CDF (per year) Fire Reanalysis
1A	electrical tunnel/pipe penetration area	$9.2\text{x}10^{-7}$	$6.6\text{x}10^{-7}$
2A	primary water makeup area	$1.1\text{x}10^{-6}$	$5.1\text{x}10^{-7}$
11	cable spreading room	$4.3\text{x}10^{-6}$	$2.0\text{x}10^{-6}$
14	switchgear room	$3.8\text{x}10^{-6}$	$1.4\text{x}10^{-6}$
15	Control room	$7.1\text{x}10^{-6}$	$3.0\text{x}10^{-6}$
74A	electrical penetration area	$1.1\text{x}10^{-6}$	$7.3\text{x}10^{-7}$
6A	Drumming and storage station	$1.5\text{x}10^{-9}$	$1.5\text{x}10^{-9}$
32A	cable tunnel	$9.6\text{x}10^{-8}$	$9.6\text{x}10^{-8}$
1	CCW pump room	$2.2\text{x}10^{-9}$	$2.2\text{x}10^{-9}$
22/63A	Service water intake	$7.5\text{x}10^{-9}$	$7.5\text{x}10^{-9}$
23	AFW pump room	$6.2\text{x}10^{-9}$	$6.2\text{x}10^{-9}$
Total Fire CDF from Major Fire Areas		**$1.8\text{x}10^{-5}$**	**$8.4\text{x}10^{-6}$**

Table G-5b. IP3 Fire Areas and Their Contribution to Fire CDF

Fire Area	Area Description	CDF (per year) IPEEE	CDF (per year) Fire Reanalysis
14	480-V switchgear room	$3.5\text{x}10^{-5}$	$1.3\text{x}10^{-5}$
11	cable spreading room	$6.8\text{x}10^{-6}$	$5.3\text{x}10^{-6}$
15	Control room	$3.7\text{x}10^{-6}$	$3.7\text{x}10^{-6}$
14/37A	480-V switchgear room/south turbine building	$4.5\text{x}10^{-6}$	$1.8\text{x}10^{-7}$
10	diesel generator 31	$2.1\text{x}10^{-6}$	$2.0\text{x}10^{-6}$
102A	diesel generator 33	$1.9\text{x}10^{-6}$	$4.7\text{x}10^{-9}$
60A	upper electrical tunnel	$7.1\text{x}10^{-7}$	$7.1\text{x}10^{-7}$
101A	diesel generator 32	$3.4\text{x}10^{-7}$	$5.2\text{x}10^{-9}$
7A	lower electrical tunnel	$2.8\text{x}10^{-7}$	$2.8\text{x}10^{-7}$

Table G-5b (continued)

Fire Area	Area Description	CDF (per year)	
		IPEEE	**Fire Reanalysis**
23	AFW pump room	2.3×10^{-7}	2.3×10^{-7}
37A	south turbine building elevation 15 ft	3.8×10^{-8}	3.8×10^{-8}
17A	primary auxiliary building (PAB) corridor	3.2×10^{-8}	3.2×10^{-8}
Total Fire CDF from Major Fire Areas		$\mathbf{5.6\times10^{-5}}$	$\mathbf{2.6\times10^{-5}}$

For high-wind and tornado events, the ER noted that IP2 structures and systems predate the 1975 Standard Review Plan (SRP) criteria. Therefore, a detailed PRA was developed as part of the IPEEE analysis to address the impact of high-wind events at IP2. The equipment of concern includes that located within sheet metal clad structures (e.g., the gas turbine and AFW components) and equipment in the yard, including the condensate storage tank (CST) and service water pumps. The CDF for high-wind events was estimated in the IPEEE to be 3.03×10^{-5} per year. In Section E.1.3.3.1 and E.1.4.3 of the ER, Entergy noted that its planned removal of the gas turbines from service would reduce the probability of recovering power from the offsite gas turbine location (as modeled in the PRA), but as shown by a sensitivity analysis this impact would be offset by the increased reliability and ruggedness of the new IP2 SBO/Appendix R diesel generator relative to that of the gas turbines. Accordingly, Entergy used the IPEEE high-wind CDF of 3.03×10^{-5} per year in determining the external event multiplier for IP2, as discussed later.

The IP3 structures and systems also predate the SRP criteria, but the IPEEE found the estimated CDF for high-wind events to be below the 10^{-6} per year screening criterion (from NUREG-1407). This conclusion is based in part on the assumption that high water levels are maintained in the condensate storage and city water storage tank, thus preventing significant wind load and pressure differential damage to the tanks that provide water to the AFW system (NYPA 1997). Because of the low CDF value, the IP3 external-event multiplier does not explicitly account for risks associated with high-wind and tornado events.

The IP2 and IP3 IPEEE submittals examined a number of other external hazards, including external flooding, ice formation, and accidents involving hazardous chemicals, transportation (e.g., accidental aircraft impacts), or nearby industrial facilities. These evaluations followed the screening and evaluation approaches specified in Supplement 4 to GL 88-20 (NRC 1991). No risks to the plant from external floods, ice formation, or accidents involving hazardous chemicals, transportation, or nearby facilities, were identified that might lead to core damage with a predicted frequency in excess of 10^{-6} per year (Con Ed 1995 and NYPA 1997). For IP3, scenarios involving hydrogen explosions within the turbine building, the pipe trench between the PAB and containment, the hydrogen shed area in the containment access facility, and the pipe chase on the 73-ft elevation of the northeast corner of the PAB were identified that, in total, could result in core damage with an estimated frequency slightly above 10^{-6} per year. As a result, Phase II SAMA 53 was identified to evaluate the change in plant risk from plant modifications to install an excess flow valve to reduce the risk associated with hydrogen explosions inside the turbine building or PAB. Entergy noted that the risks from deliberate aircraft impacts were explicitly excluded, since this was being considered in other forums, along with other sources of sabotage.

Based on the aforementioned results, Entergy estimated that the external event CDF is approximately 2.8 and 4.52 times that of the internal-event CDF for IP2 and IP3, respectively. For IP2, this factor was based on an internal event CDF of 1.79×10^{-5} per year, a seismic CDF of 1.06×10^{-5} per year, a fire CDF of 8.4×10^{-6} per year, and a high-wind CDF contribution of 3.03×10^{-5} per year. For IP3, this factor was based on an internal-event CDF of 1.15×10^{-5} per year, a seismic CDF of 2.65×10^{-5} per year, and a fire CDF of 2.55×10^{-5} per year. Accordingly, the total CDF from internal and external events would be approximately 3.8 times the internal-event CDF for IP2 and 5.5 times the internal event CDF for IP3.

In the SAMA analysis submitted in the ER, Entergy increased the benefit that was derived from the internal-event model by a factor 3.8 and 5.5 to account for the combined contribution from internal and external events for IP2 and IP3, respectively. For SAMA candidates that address only a specific external event and have no bearing on internal-event risk (e.g., IP2 SAMA 66—Harden EDG Building Against High Winds), Entergy derived the benefit directly from the external-event risk model and then increased the benefit by the multipliers identified earlier. This resulted in a bounding benefit for the SAMA candidates addressing a specific external event. The NRC staff agrees with the licensee's overall conclusion concerning the impact of external events and concludes that the licensee's use of a multiplier of 3.8 and 5.5 for IP2 and IP3, respectively, to account for external events is reasonable for the purposes of the SAMA evaluation. This is discussed further in Section G.6.2.

The NRC staff reviewed both the general process used by Entergy to translate the results of the Level 1 PSA into containment releases and the results of the Level 2 analysis, as described in the ER and in response to the NRC staff RAIs (Entergy 2007 and 2008a). The containment designs and the Level 2 analyses are similar for IP2 and IP3. The NRC staff notes that, after reviewing information provided by Entergy, the current Level 2 PSA models are based on the IPE models, with updates to reflect changes to the plant and modeling techniques, including a 3.3 percent and 4.8 percent power uprate for IP2 and IP3, respectively; inclusion of additional PDSs to improve the Level 1–Level 2 PSA interface; and updated accident progression and source term analyses using a later version of the MAAP computer code.

The Level 1 core damage sequences are placed into one of 57 PDS bins that provide the interface between the Level 1 and Level 2 analyses. The PDSs are defined by a set of functional characteristics for system operation that are important to accident progression, containment failure, and source-term definition. The Level 2 models use a single CET with functional nodes representing both systemic and phenomenological events. The CET is used to determine the appropriate release category for each Level 2 sequence. CET nodes are evaluated using supporting fault trees and logic rules.

Entergy characterized the releases for the spectrum of possible radionuclide release scenarios using a set of nine release categories, defined based on the timing and magnitude of the release and whether the containment remains intact, fails, or is bypassed. The frequency of each release category was obtained by summing the frequency of the individual accident progression CET endpoints binned into the release category. The release characteristics for each category were obtained by frequency weighting the release characteristics for each CET endstate contributing to the release category. The source-term release fractions for the CET endstates were estimated based on the results of plant-specific analyses of the dominant CET scenarios using the MAAP (Version 4.04) computer program. The release categories and their frequencies and release characteristics are presented in Tables E.1-10 and E.3-10 of the ER.

During the review of the Level 2 analysis, the NRC staff could not determine the modeling approach used to assess the likelihood of a thermally induced SGTR (TI-SGTR) following core damage in the current IP2 and IP3 PSAs. Entergy explained that TI-SGTR events are considered in the Level 2 analyses for two conditions:

(1) high reactor cooling system (RCS) pressure and steam generators dry (no secondary-side cooling)

(2) high RCS pressure and steam generators initially dry, with recovery of secondary-side cooling before challenging the steam generator tubes

The first condition applies to transient event sequences in which RCS pressure is at the pressurizer PORV setpoint at the time of core damage. No credit is taken for recovery of secondary-side cooling in these sequences. Entergy states that a TI-SGTR probability of 0.01 is used for this case, based on Table 2-1 of NUREG/CR-4551, Volume 2, Revision 1, Part 1, which shows a distribution that ranges from 10^{-5} to 0.1208 and a mean value of 0.018. The second condition applies to SBO sequences in which RCS pressure is at the pressurizer PORV setpoint at the time of core damage. Entergy states that a TI-SGTR probability of 5×10^{-4} is used for this SBO case, based on the expectation that the steam generators will not dry out until after battery depletion and that secondary-side cooling and other mitigating system functions could be recovered before that time. The value is stated as being derived from the transient case value of 0.01 combined with the human error probability of 5.2×10^{-2} for failure to align AFW following ac power recovery. Entergy explained that a stuck-open main steam safety valve or other secondary-side depressurization event is required to create the large differential pressure needed for the conditional TI-SGTR probabilities assumed above and that the Level 2 analyses conservatively did not account for the probability that these additional failures do not occur (Entergy 2008b). A sensitivity analysis that increases the probability of the TI-SGTR was developed at the staff's request and is described in Section G.6.2.

The NRC staff's reviews of the Level 2 IPEs for IP2 and IP3 concluded that the analyses addressed the most important severe accident phenomena normally associated with large dry containments and identified no significant problems or errors (NRC 1995 and 1996). It should be noted, however, that the current Level 2 models are revisions to those of the IPE. The Level 2 PSA models were included in the WOG peer reviews mentioned previously. The changes to the Level 2 models to update the methodology and to address the peer review recommendations are described in Sections E.1.4 and E.3.4 of the ER (Entergy 2007) and in response to an RAI concerning peer review findings related to the Level 2 PSA model (Entergy 2008a).

In the RAI response, Entergy provided a detailed discussion of all the changes that resulted from the incorporation of the WOG peer review of the Level 2 PRA. For IP2, the licensee indicated that there were two Level C F&Os related to the Level 2 analysis. One issue dealt with treatment of containment failure from energetic events (e.g., direct containment heating, hydrogen combustion, in-vessel steam explosions, and ex-vessel steam explosions). The other issue related to treatment of a stuck-open main steam safety valve following an SGTR core damage event. Entergy indicated that all peer review recommendations associated with the WOG review were incorporated in Revision 0 of the IP2 PSA (3/2005).

For IP3, Entergy indicated that there were six F&Os from the WOG peer review team related to the Level 2 analysis:

- One F&O was related to the containment strength that was considered for a plant-specific containment structural analysis.
- One Level A F&O recommended that the LERF definition include the release of iodine as well as cesium and tellurium.
- Two Level B F&Os were related to justification for the value used for ex-vessel explosions, and an overestimation of the “Alpha mode”-induced containment failure probability.
- One Level C F&O recommended crediting repair and recovery of systems that affect containment performance.
- One Level D F&O was related to documentation.

Entergy indicated that all Level A and B F&Os were resolved and that changes were incorporated as necessary in Revision 1 of the IP3 PSA (6/2001). Entergy also stated that the Level C and D F&Os were addressed, as appropriate, in the next revision of the model (Revision 2, 2/2007).

Based on the NRC staff's review of the Level 2 methodology, the fact that the Level 2 model was reviewed in more detail as part of the WOG peer review and updated to address peer review findings, and Entergy's responses to the RAIs, the NRC staff concludes that the Level 2 PSAs for IP2 and IP3 are technically sound and provide an acceptable basis for evaluating the benefits associated with various SAMAs.

As indicated in the ER, the estimated IP2 and IP3 reactor core radionuclide inventories used in the MACCS2 input are based on the current core configuration and a power level of 3216 megawatt thermal (MWt). The information was derived from Westinghouse Electric Company, Core Radiation Sources to Support IP2 and IP3 2 Power Uprate Project, and Westinghouse Electric Company, Core Radiation Sources to Support IP2 and IP3 3 Stretch Power Uprate (SPU) Project, CN-REA-03-40 (3/7/2005). In response to an RAI, Entergy confirmed that the current core design and operational practice are consistent with this analysis and that there are no planned future changes to reactor power level or fuel management strategies that would affect the reactor core radionuclide inventory used in the MACCS2 analysis (Entergy 2008a).

The NRC staff reviewed the process used by Entergy to extend the containment performance (Level 2) portion of the PSA to an assessment of offsite consequences (essentially a Level 3 PSA). This included consideration of the source terms used to characterize fission product releases for the applicable containment release categories and the major input assumptions used in the offsite consequence analyses. The MACCS2 code was used to estimate offsite consequences. Plant-specific input to the code includes the source terms for each release category and the reactor core radionuclide inventory (both discussed above), site-specific meteorological data, projected population distribution within an 80-kilometer (50-mile) radius for the year 2035, emergency evacuation modeling, and economic data. This information is provided in Sections E.1.5 and E.3.5 of the ER for IP2 and IP3, respectively (Entergy 2007).

Entergy used site-specific meteorological data for the 5 years, 2000 through 2004, as input to the MACCS2 code. Entergy averaged the data over this interval for this study. The 5-year data included 43,848 consecutive hourly values of windspeed, wind direction, precipitation, and temperature recorded at the IP2 and IP3 meteorological tower from January 2000 to

December 2004. Missing data were estimated using data substitution methods. These methods include substitution of missing data with valid data from the previous hour and substitution of valid data collected from other elevations on the meteorological tower. The NRC staff notes that previous SAMA analyses have shown little sensitivity to year-to-year differences in meteorological data and concludes that the approach taken for collecting and applying the meteorological data in the SAMA analysis is reasonable.

The population distribution the licensee used as input to the MACCS2 analysis was estimated for the year 2035 based on information from the New York Statistical Information System from 2000 to 2030, the New Jersey Department of Labor and Workforce Development from 2000 to 2025, the Connecticut State Data Center from 2000 to 2020, and the Pennsylvania State Data Center from 2000 to 2020. These data were used to project county-level resident populations to the year 2035 using regression analysis. The 2035 transient population was assumed to be the 2004 transient-to-permanent population ratio multiplied by the extrapolated permanent population. The 2004 transient data were obtained from State tourism agencies. The NRC staff notes that Entergy's projected 2035 population within a 50-mile radius of IP2 and IP3 reported in Tables E.1-12 and E.3-12 of the Entergy ER (19.2 million people) is approximately 15 percent greater than the 50-mile population obtained from NRC SECPOP2000 code (16.8 million) for the year 2003 (NRC 2003). This represents an average annual growth rate of 0.4 percent, which comports with Entergy's estimated growth rates reported in section 2.6.1 of the Entergy ER. The NRC staff considers the methods and assumptions for estimating population reasonable and acceptable for the purposes of the SAMA evaluation.

Entergy did not credit evacuation either as part of the base-case analysis or for estimating the benefit from SAMA cases. Entergy assumed a "no evacuation scenario" to conservatively estimate the population dose. In response to a RAI, Entergy clarified that the "no evacuation scenario" assumes that individuals within the 10-mile evacuation zone continue normal activity following a postulated accident without taking emergency response actions such as evacuation or sheltering. Relocation actions within a 50-mile radius of the plant are still modeled in the "no evacuation scenario." As such, individuals within hot spots or high-radiation areas anywhere within the 50-mile zone are assumed to be relocated outside the 50-mile zone until long-term protective actions reduce radiation levels (Entergy 2008a). As used in the MACCS2 code, "evacuation" refers to the prompt movement of the population out of an affected region (e.g., certain sectors of the EPZ) during the emergency-phase time period immediately following an accident, in accordance with the emergency evacuation plan. "Relocation" refers to the movement of the population out of an affected region (e.g., within hot spots or high radiation areas) during the intermediate phase or long term phase based on longer-term dose considerations. The NRC staff concludes that the evacuation and relocation assumptions and analysis are generally conservative and acceptable for the purposes of the SAMA evaluation.

Much of the site-specific economic data was obtained from the 2002 Census of Agriculture (USDA 2002). These include the value of farm and nonfarm wealth. Other data, such as population relocation cost, daily cost for a person who is relocated, and cost of farm and nonfarm decontamination were obtained from the Code Manual for MACCS2 (NRC 1997c). The data from the MACCS2 Code Manual were inflation-adjusted using the consumer price index corresponding to the year 2005. Information on regional crops was obtained from the 2002 Census of Agriculture. Crops for each county were mapped into the seven MACCS2 crop categories.

MACCS2 requires an average value of nonfarm wealth (identified as VALWNF in MACCS2). The county-level nonfarm property value was used as a basis for deriving VALWNF and resulted in a value of $163,631 per person. This does not explicitly account for the economic value associated with tourism and business. In the ER, Entergy assessed the impact of including tourism and business losses using a sensitivity case. This sensitivity case assumed a loss of $208,838 per person in the affected region, as opposed to $163,631 per person in the base case. The NRC staff questioned the basis for the modified VALWNF value ($208,838 per person) and the rationale for treating the loss of tourism and business in a sensitivity case rather than in the baseline analysis (NRC 2007). In response, Entergy described the basis for the modified VALWNF value and explained that the impact of lost tourism and business was not modeled in the baseline analysis because the level of tourism and business activity can be reestablished in time. Nevertheless, Entergy provided the results of a revised uncertainty analysis using the modified VALWNF value (Entergy 2008a). As a result, three additional potentially cost-beneficial SAMAs were identified (SAMAs 9 and 53 for IP2 and SAMA 53 for IP3). In response to an RAI, Entergy indicated that these SAMAs have been submitted for engineering project cost-benefit analysis to obtain a more detailed examination of their viability and implementation costs (Entergy 2008b). As described in Section G.6.2, the NRC staff has adopted the case incorporating lost tourism and business as its base case, given that it may take years to re-establish the level of tourism and business activity following a severe accident.

The NRC staff concludes that the methodology used by Entergy to estimate the offsite consequences for IP2 and IP3 provides an acceptable basis from which to proceed with an assessment of the risk reduction potential for candidate SAMAs because the key elements of the methodology are consistent with standard practice. Accordingly, the NRC staff based its assessment of offsite risk on the CDF and offsite doses reported by Entergy.

G.3 Potential Plant Improvements

This section discusses the process for identifying potential plant improvements, an evaluation of that process, and the improvements evaluated in detail by Entergy.

G.3.1. Process for Identifying Potential Plant Improvements

Entergy's process for identifying potential plant improvements (SAMAs) consisted of the following elements:

- review of the most significant basic events from the current, plant-specific PSA
- review of potential plant improvements identified in the IP2 and IP3 IPE and IPEEE
- review of Phase II SAMAs from license renewal applications for nine other pressurized water reactors
- review of dominant contributors to seismic and fire events in the current seismic and fire analyses
- review of other NRC and industry documentation discussing potential plant improvements

Based on this process, an initial set of 231 candidate SAMAs for IP2 and 237 candidate SAMAs for IP3, referred to as Phase I SAMAs, was identified. In Phase I of the evaluation, Entergy performed a qualitative screening of the initial list of SAMAs and eliminated SAMAs from further consideration using one of the following criteria:

- The SAMA is not applicable at IP2 and IP3 because of design differences.
- The SAMA has already been implemented at IP2 and IP3.
- The SAMA is similar in nature and could be combined with another SAMA candidate.

Based on this screening, 163 IP2 SAMAs and 175 IP3 SAMAs were eliminated, leaving 68 unique SAMAs for IP2 and 62 unique SAMAs for IP3. The remaining SAMAs, referred to as Phase II SAMAs, are listed in Tables E.2-2 and E.4-2 of the ER (Entergy 2007). In Phase II, a detailed evaluation was performed for each of the remaining SAMA candidates, as discussed in Sections G.4 and G.6 below. To account for the potential impact of external events, the estimated benefits based on internal events were multiplied by a factor of 3.8 for IP2 and 5.5 for IP3, as previously discussed.

G.3.2. Review of Entergy's Process

Entergy's efforts to identify potential SAMAs focused primarily on areas associated with internal initiating events but also included explicit consideration of potential SAMAs for seismic and fire. The initial list of SAMAs generally addressed the accident sequences considered to be important to CDF from functional, initiating event, and risk-reduction worth (RRW) perspectives at IP2 and IP3 and included selected SAMAs from prior SAMA analyses for other plants.

Entergy provided a tabular listing of the PSA basic events, sorted according to their RRW for CDF (Entergy 2007). SAMAs affecting these basic events would have the greatest potential for reducing risk. Entergy used an RRW cutoff of 1.005, which corresponds to about a 0.5-percent change in CDF, given the 100 -percent reliability of the SAMA. This equates to a benefit of approximately $7,000 for IP2 and IP3 (based on a total benefit of about $1.3 million for each unit for eliminating all severe accidents caused by internal events). Entergy also provided and reviewed the LERF-based RRW events down to an RRW of 1.005. Entergy correlated the top CDF and LERF events with the SAMAs evaluated in Phase I or Phase II and showed that, with a few exceptions, all of the significant basic events are addressed by one or more SAMAs (Entergy 2007). Of the basic events of high-risk importance that are not addressed by SAMAs, each is closely tied to other basic events that had been addressed by one or more SAMAs.

Entergy considered the potential plant improvements described in the IPE and IPEEE in the identification of plant-specific candidate SAMAs for internal and external events. As a result of the IPE, four major procedural/hardware improvements were identified for each unit. The IP2 enhancements are to (1) upgrade IP2 gas turbine black-start capability, (2) install an additional EDG building fan, (3) monitor changes in the operating position of PORV block valves, and (4) implement periodic testing of all the EDG building fans. The IP3 enhancements are to (1) revise emergency operating procedures (EOPs) to instruct operators to align the backup city water supply to the AFW pumps, should the CST outlet valve fail as indicated by a low-suction-flow alarm, (2) revise the alarm response procedure for a high AFW pump room temperature, to direct operators to open the rollup door to the AFW pump room for ventilation, (3) install a switchgear room high-temperature alarm and implement an associated procedure to direct

operators to block open doors to the 480-V ac switchgear room, and (4) revise EOPs to emphasize the need to align the safe-shutdown equipment to MCC 312A during events involving the loss of all 480-V ac safeguard buses while offsite power is available, as well as during fire-related events. These improvements have all been implemented and therefore were not considered further in the SAMA analysis.

As a result of the IPEEEs, several improvements were identified for external events. The IP2 enhancements are to (1) replace the hold-down bolts for the CCW surge tank with higher tensile strength bolts, (2) add surveillance of the control building drain flapper valve flow, (3) add weather stripping to doors between the transformer area and the switchgear room, and (4) add screens on the 480-V switchgear room equipment. The IP3 enhancements are to (1) restore the carbon dioxide (CO_2) suppression system to automatic mode within the switchgear room, (2) reroute the EDG exhaust fans and the auxiliary cables so that a fire in a single EDG cell would not affect multiple EDGs, and (3) install an excess flow valve to reduce the risk associated with hydrogen explosions inside the turbine building or PAB. With the exception of the last item, all of these improvements have been implemented and therefore were not considered further in the SAMA analysis. As noted in Section E.3.3.3 of the ER, IP3 SAMA 53 (install an excess flow valve to reduce the risk associated with hydrogen explosions) was proposed as a result of the IPEEE analysis and retained for the Phase II evaluation.

Several concerns were raised in the IPEEE regarding the seismic-induced failures of fire protection equipment (primarily for IP3). As mentioned above, these seismic-fire interactions were judged to be of little risk significance (NRC 2001). One plant improvement identified in Table 2.4 of NUREG-1742 (NRC 2002) addressed the potential spurious operation of the EDG room's CO_2 system and subsequent shutdown of the EDG ventilation system during a seismic event. Entergy subsequently installed a quality assurance Category I, seismic class I actuation permission auxiliary control panel for CO_2 discharge into the EDG building. Since shutdown of EDG ventilation caused by spurious operation of the CO_2 system during a seismic event is not considered in the seismic PSA model, the seismic CDF was not affected by this modification.

As noted in Section E.1.3.3.1 of the ER, the IP2 CDF for SBO events with gas turbines unavailable could be reduced by (1) aligning the IP3 Appendix R diesel to IP2, (2) installing an IP2 Appendix R diesel, (3) upgrading the EDG building for high winds, and (4) protecting the alternate power source from tornadoes and high winds. However, with the exception of the third item, these modifications were not evaluated as candidate SAMAs because a modification to replace the existing gas turbines with an IP2 SBO/Appendix R diesel generator capable of being used to recover power to the vital buses following an SBO is planned for the near future. The planned modification includes provisions for aligning the IP3 Appendix R generator to IP2 and for protecting the new alternate power source from tornadoes and high winds.

For a number of the Phase II SAMAs listed in the ER, the NRC staff found that information provided did not sufficiently describe the proposed modifications or other considerations that might have been taken into account in estimating the benefit and implementation cost. Therefore, the NRC staff requested, and the licensee provided, more information on certain proposed modifications listed for the Phase II SAMA candidates (NRC 2007, Entergy 2008a).

For several SAMA candidates, the staff questioned if lower cost alternatives could have been considered, including:

- the implementation of improved instrumentation and procedures to help cool down and depressurize the RCS before RWST depletion
- the implementation of a procedure for recovery of steam dump to condenser from the unaffected steam generator
- the implementation of a procedure for recovery of the main feedwater valve/condensate post-SI actuation
- the purchase or manufacture of a "gagging device" that could be used to close a stuck-open steam generator safety value on an SGTR before core damage occurred
- The reactivation of the IP3 postaccident containment venting system (a system that is still active on IP2 but was deactivated on IP3)

In response, Entergy indicated that most of the low-cost alternatives to aid in the mitigation of an SGTR (4 out of the 5 alternatives dismissed above) have been already implemented and provided specific reasons why the cost of these alternative SAMA candidates would be high enough that the decision on the final SAMA selection would not have been affected. However, the alternative associated with the gagging device was found to be potentially cost beneficial (Entergy 2008a and 2008b). The evaluation of these SAMAs is discussed further in Section G.6.2.

The NRC staff notes that the set of SAMAs submitted is not all inclusive, since additional, possibly even less expensive, design alternatives can always be postulated. However, the NRC staff concludes that the benefits of any additional modifications are unlikely to exceed the benefits of the modifications evaluated and that the alternative improvements would not likely cost less than the least expensive alternatives evaluated, when the subsidiary costs associated with maintenance, procedures, and training are considered.

The NRC staff concludes that Entergy used a systematic and comprehensive process for identifying potential plant improvements for IP2 and IP3 and that the set of SAMAs evaluated in the ER, together with those identified in response to the NRC staff inquiries, is reasonably comprehensive and therefore acceptable. The search included reviewing insights from the plant-specific risk studies and reviewing plant improvements considered in previous SAMA analyses. While explicit treatment of external events in the SAMA identification process was limited, the NRC staff recognizes that the prior implementation of plant modifications for seismic and fire events, and the absence of external-event vulnerabilities, reasonably justifies examining primarily the internal-event risk results for this purpose.

G.4 Risk-Reduction Potential of Plant Improvements

Entergy evaluated the risk-reduction potential of the remaining 68 IP2 and 62 IP3 SAMAs. The SAMA evaluations were performed using realistic assumptions with some conservatism. On balance, such calculations overestimate the benefits and are conservative.

For all of the SAMAs, Entergy used model requantification to determine the potential benefits. The CDF and population-dose reductions were estimated using the latest version of the IP2 and IP3 PSA models. The changes made to the models to quantify the impact of the SAMAs are detailed in Tables E.2-2 and E.4-2 of the ER (Entergy 2007). Table G-6 lists the assumptions

considered to estimate the risk reduction for each of the evaluated SAMAs, the estimated risk reduction in terms of the percentage of reduction in CDF and population dose, and the estimated total benefit (present value) of the averted risk. The estimated benefits reported in Table G-6 reflect the combined benefit for both internal and external events. The determination of the benefits for the various SAMAs is further discussed in Section G.6.

The NRC staff questioned the assumptions used in evaluating the benefits or risk-reduction estimates of a number of SAMAs provided in the ER (NRC 2007). For example, the NRC staff requested information regarding the plant features or modeling assumptions that result in the CCW pumps having limited risk importance. In response, Entergy stated that both units are unique in that the capability exists to initiate backup cooling to key components in the event the primary CCW cooling function is lost. The use of backup city water cooling to the charging pumps enables continued seal injection and therefore reduces the likelihood of an RCP seal LOCA. In IP2, city water backup or primary water can be used to cool the safety injection and residual heat removal (RHR) pumps. In IP3, city water backup is available to cool RHR Pump 31. Also, CCW is not required in either plant during the injection phase of the response to a LOCA. The NRC staff considers the explanation of the plant features, as clarified, to be reasonable and therefore acceptable for the purposes of the SAMA evaluation.

For a number of the Phase II SAMAs listed in the ER, the description of the improvement and the associated analyses appeared either inconsistent between the two units or were unclear. Therefore, the NRC staff asked the applicant to provide more detailed descriptions of the modifications for several of the Phase II SAMA candidates (NRC 2007). In response, Entergy provided additional information on those SAMA candidates that further explained the SAMA modifications and the differences between units that account for the different analysis assumptions for each unit (Entergy 2008a). Entergy also provided further clarifications and discussion regarding the analysis assumptions and their bases. As an example, the licensee clarified a major difference in operation of a turbine-driven AFW pump between the two units that affects the disposition of several SAMA candidates. In its response, Entergy indicated that the units respond differently upon depletion of the station batteries. IP2 has pneumatic level and pressure instruments that allow operators to monitor key parameters and effectively control AFW flow after the batteries are depleted, whereas IP3 does not have this instrumentation. Although it is still possible for the operators to manipulate AFW flow, the current IP3 model does not credit this manual operation.

In the SAMA analysis submitted in the ER, Entergy increased the benefit that was derived from the internal-event model by factors of 3.8 and 5.5 to account for the combined contribution from internal and external events for IP2 and IP3, respectively. The NRC staff agrees with the licensee’s overall conclusion concerning the impact of external events and concludes that the licensee’s use of a multiplier of 3.8 and 5.5 for IP2 and IP3, respectively, to account for external events is reasonable for the purposes of the SAMA evaluation. This is discussed further in Section G.6.2.

For SAMA candidates that only address a specific external event and have no bearing on internal-event risk (e.g., IP2 SAMA 66—Harden EDG Building Against High Winds), Entergy derived the benefit directly from the external-event risk model and then increased the benefit by the multipliers identified earlier. The NRC staff notes that the use of multipliers for these SAMAs (conceptually, to account for additional benefits in internal events) is unnecessary, since

these SAMAs have no bearing on internal events. However, use of the multipliers adds conservatism to the benefit estimate for these SAMA candidates.

IP3 SAMA 53 (install an excess-flow valve to reduce the risk associated with hydrogen explosions) was identified to reduce the risk associated with hydrogen explosions inside the turbine building or PAB. The proposed plant modification involves the installation of a nonelectric excess-flow valve. The benefit of this SAMA is also calculated in a bounding manner. As discussed in Section G.6.2, this SAMA was found to be potentially cost beneficial, based on revised analyses submitted in response to an NRC request.

The NRC staff has reviewed Entergy's bases for calculating the risk reduction for the various plant improvements and concludes that the rationale and assumptions for estimating risk reduction are reasonable and generally conservative (i.e., the estimated risk reduction is higher than what would actually be realized). Accordingly, the NRC staff based its estimates of averted risk for the various SAMAs on Entergy's risk reduction estimates.

G.5 Cost Impacts of Candidate Plant Improvements

Entergy estimated the costs of implementing the candidate SAMAs through the application of engineering judgment and use of other licensees' estimates for similar improvements. The ER stated that the cost estimates conservatively did not include the cost of replacement power during extended outages required to implement the modifications, nor did they include contingency costs associated with unforeseen implementation obstacles. The cost estimates provided in the ER also did not account for inflation, which is considered another conservatism.

The NRC staff reviewed the bases for the licensee's cost estimates. For certain improvements, the NRC staff also compared the cost estimates to estimates developed elsewhere for similar improvements, including estimates developed as part of other licensees' analyses of SAMAs for operating reactors and advanced light-water reactors. The NRC staff reviewed the costs and found them to be reasonable and generally consistent with estimates provided in support of other licensees' analyses.

Table G-6. Final Potentially Cost-Beneficial SAMAs for IP2 and IP3 [1]

SAMA	Assumptions	% Risk Reduction		Total Benefit ($)		Cost ($)
		CDF	Population Dose	Baseline [2] (Int + Ext Events)	Baseline With Uncertainty	
IP2 SAMAs						
9 - Create a reactor cavity flooding system.	Eliminate containment failure caused by concrete-core interaction.	0	48	1.8M	3.8M	3.7M
28 - Provide a portable diesel-driven battery charger.	Eliminate failure of local operation of the turbine-driven AFW pump during SBO scenarios.	5	10	441K	928K	494K
44 - Use fire water system as backup for steam generator inventory.	Eliminate failure of the turbine-driven AFW pump and local operation of AFW during SBO.	33	15	1.0M	2.1M	1.7M
53 - Keep both pressurizer PORV block valves open.	Eliminate failure of PORV block valves to open.	18	4	386K	812K	800K
54 - Install flood alarm in the 480-V ac switchgear room	Reduce control folding initiator frequencies by a factor of 3.	20	40	1.8M	3.8M	200K
56 - Keep RHR heat exchanger discharge MOVs normally open.	Eliminate failure of RHR heat exchanger discharge MOVs to open.	2	18	45K	94K	82K
60 - Provide added protection against flood propagation from stairwell 4 into the 480-V ac switchgear room.	Eliminate flood initiated by a break in fire protection piping in stairwell 4.	5	9	408K	860K	216K
61 - Provide added protection against flood propagation from the deluge room into the 480-V ac switchgear room.	Eliminate flood initiated by a break in the 10" fire protection piping in the deluge room at elevation 15'.	10	20	898K	1.8M	192K
65 - Upgrade the ASSS to allow timely restoration of seal injection and cooling.	Eliminate control building flooding initiators.	20	20	1.8M	3.8M	560K

Table G-6 (continued)

SAMA	Assumptions	% Risk Reduction		Total Benefit ($)		Cost ($)
		CDF	Population Dose	Baseline[2] (Int + Ext Events)	Baseline With Uncertainty	
IP3 SAMAs						
30 - Provide a portable diesel-driven battery charger.	Reduce internal switchgear room floods 5% and increase the time available to recover offsite power before local operation of AFW is required from 2 hours to 24 hours during SBO scenarios.	4[3]	1[3]	100K[3]	145K[3]	494K
52 - Open city water supply valve for alternative AFW pump suction.	Eliminate loss of the normal suction path to the AFW system.	1	1	71K	103K	50K
53 - Install an excess flow valve to reduce the risk associated with hydrogen explosions.	Eliminate hydrogen ruptures inside the turbine building.	2	2	160K	232K	228K
55 – Provide the capability of powering one SI pump or RHR pump using the Appendix R bus (MCC 312A).	Eliminate operator failure to align MCC 312A.	16	18	1.3M	2.0M	1.3M
61 - Upgrade the ASSS to allow timely restoration of seal injection and cooling.	Eliminate control building flooding initiators.	17	20	1.4M	2.1M	560K
62 - Install flood alarm in the 480-V ac switchgear room.	Eliminate control building flooding initiators.	17	20	1.4M	2.1M	197K

[1]The information reproduced by combining the information from ER Tables E.2-2 and E.4-2 and Entergy's response to RAI 4e (Entergy 2008a).
[2]Reported benefit values account for risk reduction in both internal and external events and include the economic impact of lost tourism and business following a severe accident. The values do not account for analysis uncertainties.
[3]SAMA 30 was identified as cost beneficial in the ER. However, an error in the original benefit calculation was discovered subsequent to the ER, as described in Entergy's response to RAI 5g (Entergy 2008a). Reported values in Table G-6 reflect correction of the calculational error. SAMA 30 is no longer cost beneficial after corrections.

The NRC staff questioned the high cost estimate ($800,000) for changing the pressurizer PORV block valves from normally closed to normally open in conjunction with IP2 SAMA 53 (NRC 2008a). In response, Entergy clarified that a modification had been previously implemented allowing closure of the block valves when operating pressure is less than 2235 pounds per square inch gauge (psig). If the reactor coolant pressure increases to 2300 psig, the current circuitry alarms and sends a signal to open the block valves. The SAMA would reverse this operating approach and may require adding or changing the auto-open feature to a lower value. Entergy provided a breakdown of the estimated cost, which included a $236,000 contingency cost. As Section 4.21 of the ER states that contingency costs are excluded, the staff requested clarification of this apparent inconsistency. In response, Entergy stated that the site-specific implementation cost estimates include some contingency costs to account for the high degree of uncertainty associated with the preliminary cost estimates and that, given the bounding nature of the benefit analysis, it is reasonable to include contingency costs in these estimates. To eliminate the confusion between Section 4.21 of the ER and the stated practice above, Entergy revised Section 4.21, eliminating the contingency exclusion clause (Entergy 2008b). Considering that this SAMA has been added to the list of potentially cost-beneficial SAMAs (see Section G.6), the staff finds the cost estimate for SAMA 53 to be acceptable. In addition, no other improvement cost estimates were identified as outliers. Therefore, the impact of including contingency costs does not appear to be consequential.

The NRC staff concludes that the cost estimates provided by Entergy are sufficient and appropriate for use in the SAMA evaluation.

G.6 Cost-Benefit Comparison

Entergy's cost-benefit analysis and the NRC staff's review are described in the following sections.

G.6.1. Entergy's Evaluation

The methodology used by Entergy was based primarily on the NRC's guidance for performing a cost-benefit analysis (i.e., NUREG/BR-0184, "Regulatory Analysis Technical Evaluation Handbook" (NRC 1997a). The guidance involves determining the net value for each SAMA according to the following formula:

Net Value = (APE + AOC + AOE + AOSC) - COE, where

APE = present value of averted public exposure ($)

AOC = present value of averted offsite property damage costs ($)

AOE = present value of averted occupational exposure costs ($)

AOSC = present value of averted onsite costs ($)

COE = cost of enhancement ($)

If the net value of a SAMA is negative, the cost of implementing the SAMA is larger than the benefit associated with the SAMA, and it is not considered cost beneficial. Entergy's derivation of each of the associated costs is summarized below.

NUREG/BR-0058 has recently been revised to reflect the agency's policy on discount rates. Revision 4 of NUREG/BR-0058 states that two sets of estimates should be developed—one at 3 percent and one at 7 percent (NRC 2004). Entergy performed the SAMA analysis using 7 percent and provided a sensitivity analysis using the 3 percent discount rate in order to capture SAMAs that may be cost-effective using the lower discount rate, as well as the higher, baseline rate (Entergy 2007). This analysis is sufficient to satisfy NRC policy in Revision 4 of NUREG/BR-0058.

<u>Averted Public Exposure (APE) Costs</u>

The APE costs were calculated using the following formula:

APE = Annual reduction in public exposure (Δperson-rem/year)

x monetary equivalent of unit dose ($2000 per person-rem)

x present value conversion factor (10.76 based on a 20-year period with a 7 percent discount rate)

As stated in NUREG/BR-0184 (NRC 1997a), the monetary value of the public health risk after discounting does not represent the expected reduction in public health risk caused by a single accident. Rather, it is the present value of a stream of potential losses extending over the remaining lifetime (in this case, the renewal period) of the facility. Thus, it reflects the expected annual loss caused by a single accident, the possibility that such an accident could occur at any time over the renewal period, and the effect of discounting these potential future losses to present value. For the purposes of initial screening, which assumes elimination of all severe accidents caused by internal events, Entergy calculated an APE of approximately $474,000 for IP2 and $527,000 for IP3 for the 20-year license renewal period.

Averted Offsite Property Damage Costs (AOC)

The AOCs were calculated using the following formula:

AOC = Annual CDF reduction

x offsite economic costs associated with a severe accident (on a per-event basis)

x present value conversion factor

For the purposes of initial screening, which assumes all severe accidents caused by internal events are eliminated, Entergy calculated an annual offsite economic cost of about $45,000 for IP2 and $53,000 for IP3 based on the Level 3 risk analysis. This results in a discounted value of approximately $483,000 for IP2 and $568,000 for IP3 for the 20-year license renewal period.

<u>Averted Occupational Exposure (AOE) Costs</u>

The AOE costs were calculated using the following formula:

AOE = Annual CDF reduction

x occupational exposure per core damage event

x monetary equivalent of unit dose

x present value conversion factor

Entergy derived the values for AOE from information provided in Section 5.7.3 of the regulatory analysis handbook (NRC 1997a). Best estimate values that provided for immediate occupational dose (3300 person-rem) and long-term occupational dose (20,000 person-rem over a 10-year cleanup period) were used. The present value of these doses was calculated using the equations provided in the handbook, in conjunction with a monetary equivalent of unit dose of $2000 per person-rem, a real discount rate of 7 percent, and a time period of 20 years to represent the license renewal period. For the purposes of initial screening, which assumes all severe accidents caused by internal events are eliminated, Entergy calculated an AOE of approximately $7,000 for IP2 and $4,000 for IP3 for the 20-year license renewal period.

Averted Onsite Costs

Averted onsite costs (AOSC) include averted cleanup and decontamination costs and averted power replacement costs. Repair and refurbishment costs are considered for recoverable accidents only and not for severe accidents. Entergy derived the values for AOSC based on information provided in Section 5.7.6 of NUREG/BR-0184, the regulatory analysis handbook (NRC 1997a).

Entergy divided this cost element into two parts—the onsite cleanup and decontamination cost, also commonly referred to as averted cleanup and decontamination costs (ACC), and the replacement power cost (RPC).

ACCs were calculated using the following formula:

ACC = Annual CDF reduction

x present value of cleanup costs per core damage event

x present value conversion factor

The total cost of cleanup and decontamination subsequent to a severe accident is estimated in NUREG/BR-0184 to be $\$1.5 \times 10^9$ (undiscounted). This value was converted to present costs over a 10-year cleanup period and integrated over the term of the proposed license extension. For the purposes of initial screening, which assumes all severe accidents caused by internal events are eliminated, Entergy calculated an ACC of approximately $208,000 for IP2 and $133,000 for IP3 for the 20-year license renewal period.

Long-term RPCs were calculated using the following formula:

RPC = Annual CDF reduction

x present value of replacement power for a single event

x factor to account for remaining service years for which replacement power is required

x reactor power scaling factor

Entergy based its calculations on the value of 1071 megawatt electric (MWe) and scaled up from the 910 MWe reference plant in NUREG/BR-0184 (NRC 1997b). Therefore, Entergy applied a power-scaling factor of 1071/910 to determine the RPCs. For the purposes of initial screening, which assumes all severe accidents caused by internal events are eliminated, Entergy calculated an RPC of approximately $166,000 for IP2 and $107,000 for IP3, and an

AOSC of approximately $374,000 for IP2 and $240,000 for IP3 for the 20-year license renewal period.

Using the above equations, Entergy estimated the total present dollar-value equivalent associated with completely eliminating severe accidents caused by internal events at IP2 and IP3 to be about $1.3 million for each unit. Use of a multiplier of 3.8 for IP2 and 5.5 for IP3 to account for external events increases the value to $5.1 million for IP2 and $7.4 million for IP3 and represents the dollar value associated with completely eliminating the risk of severe accidents caused by all internal and external events at IP2 and IP3, respectively.

Entergy's Results

If the implementation costs for a candidate SAMA exceeded the calculated benefit, the SAMA was considered by Entergy not to be cost beneficial. In the baseline analysis (using a 7 percent discount rate) and the sensitivity analysis (using a 3 percent discount rate) contained in the ER, Entergy identified 10 potentially cost-beneficial SAMAs (five for IP2 and five for IP3). Based on consideration of analysis uncertainties, Entergy identified two additional potentially cost-beneficial SAMAs for IP2 in the ER (IP2 SAMAs 44 and 56).

In response to an NRC staff request, Entergy provided the results of a revised uncertainty analysis in which the impact of lost tourism and business was accounted for in the baseline analysis (rather than as a separate sensitivity case). The revised uncertainty analysis resulted in the identification of two additional potentially cost-beneficial SAMAs for IP2 (IP2 SAMAs 9 and 53) and one additional potentially cost-beneficial SAMA for IP3 (IP3 SAMA 53).

The potentially cost-beneficial SAMAs for IP2 are the following:

- SAMA 9—Create a reactor cavity flooding system to reduce the impact of core-concrete interaction from molten core debris following core damage and vessel failure (cost beneficial in revised analysis, with uncertainties).
- SAMA 28—Provide a portable diesel-driven battery charger to improve dc power reliability. A safety-related disconnect would be used to charge a selected battery. This modification would enhance the long-term operation of the turbine-driven AFW pump on battery depletion.
- SAMA 44—Use fire water as a backup for steam generator inventory to increase the availability of the steam generator water supply to ensure adequate inventory for the operation of the turbine-driven AFW pump during SBO events (cost beneficial with uncertainties).
- SAMA 53—Keep both pressurizer PORV block valves open. This modification would reduce the CDF contribution from loss of secondary heat sink by improving the availability of feed and bleed (cost beneficial in revised analysis, with uncertainties).
- SAMA 54—Install a flood alarm in the 480-V ac switchgear room to mitigate the occurrence of internal floods inside the 480-V ac switchgear room.
- SAMA 56—Keep RHR heat exchanger discharge valves, motor-operated valves 746 and 747, normally open. This procedure change would reduce the CDF contribution from transients and LOCAs (cost beneficial with uncertainties).

- SAMA 60—Provide added protection against flood propagation from stairwell 4 into the 480-V ac switchgear room to reduce the CDF contribution from flood sources within stairwell 4 adjacent to the 480-V ac switchgear room.
- SAMA 61—Provide added protection against flood propagation from the deluge room into the 480-V ac switchgear room to reduce the CDF contribution from flood sources within the deluge room adjacent to the 480-V ac switchgear room.
- SAMA 65—Upgrade the alternate safe shutdown system (ASSS) to allow timely restoration of RCP-seal injection and cooling from events that cause a loss of power from the 480-V ac vital buses.

The potentially cost-beneficial SAMAs for IP3 are the following:

- SAMA 30—Provide a portable diesel-driven battery charger to improve dc power reliability. A safety-related disconnect would be used to charge a selected battery. This modification would enhance the long-term operation of the turbine-driven AFW pump on battery depletion.
- SAMA 52—Institute a procedure for opening the city water supply valve for alternative AFW system pump suction to enhance the availability of the AFW system.
- SAMA 53—Install an excess flow valve to reduce the risk associated with hydrogen explosions inside the turbine building or PAB (cost beneficial in revised analysis, with uncertainties).
- SAMA 55—Provide the capability of powering one safety injection pump or RHR pump using the Appendix R diesel (MCC 312A) to enhance RCS injection capability during events that cause a loss of power from the 480-V ac vital buses.
- SAMA 61—Upgrade the ASSS to allow timely restoration of RCP-seal injection and cooling from events that cause a loss of power from the 480-V ac vital buses.
- SAMA 62—Install a flood alarm in the 480-V ac switchgear room to mitigate the occurrence of internal floods inside the 480-V ac switchgear room.

In response to an NRC staff inquiry regarding estimated benefits for certain SAMAs and lower cost alternatives, one additional potentially cost-beneficial SAMA was identified (applicable to SGTR events in both units), and one SAMA that was previously identified as potentially cost beneficial was found no longer cost beneficial based on correction of an error in the ER (IP3 SAMA 30). The potentially cost-beneficial SAMAs and Entergy's plans for further evaluation of these SAMAs are discussed in more detail in Section G.6.2.

6.1.1 Review of Entergy's Cost-Benefit Evaluation

The cost-benefit analysis performed by Entergy was based primarily on NUREG/BR-0184 (NRC 1997a) and was implemented consistent with this guidance.

SAMAs identified primarily on the basis of the internal events analysis could provide benefits in certain external events, in addition to their benefits in internal events. To account for the additional benefits in external events, Entergy multiplied the internal event benefits for each internal event SAMA by an amount equal to the ratio of the sum of the internal and external

event CDF to the internal event CDF. This ratio is approximately 3.8 for IP2 and 5.5 for IP3. Potential benefits in external events were estimated in this manner, since the external-event models are generally less detailed than the internal-event models and do not lend themselves to quantifying the benefits of the specific plant changes associated with internal-event SAMAs. For example, the benefits of a procedural change associated with an important internal event sequence cannot be readily assessed using the seismic-risk model if that operator action or system is not represented in the seismic-risk model. The use of a multiplier on the benefits obtained from the internal events PSA to incorporate the impact of external events implicitly assumes that each SAMA would offer the same percentage reduction in external-event CDF and population dose as it offers in internal events. While this provides only a rough approximation of the potential benefits, such an adjustment was considered appropriate, given the large risk contribution from external events relative to internal events and the lack of information on which to base a more precise risk reduction estimate for external events. In view of the remaining conservatism in the external events CDF, and the licensee's further evaluation of the impacts of the use of a multiplier on the SAMA screening (as part of the uncertainty assessment discussed below), the NRC staff agrees that the use of these multipliers for external events is reasonable.

For SAMA candidates that only address a specific external event and have no bearing on internal-event risk, Entergy derived the benefit directly from the external-event risk model and then increased the benefit by the multipliers identified earlier. The NRC staff notes that the use of multipliers for these SAMAs (conceptually, to account for additional benefits in internal events) is unnecessary, since these SAMAs have no bearing on internal events. However, use of the multipliers adds conservatism to the benefit estimate for these SAMA candidates.

Entergy considered the impact that possible increases in benefits from analysis uncertainties would have on the results of the SAMA assessment. In the ER, Entergy presents the results of an uncertainty analysis of the internal-event CDF for IP2 and IP3, which indicates that the 95th percentile value is a factor of 2.1 times the mean CDF for IP2 and 1.4 times the mean CDF for IP3. Entergy assessed the impact on the SAMA screening if the estimated benefits for each SAMA were further increased by these uncertainty factors. For purposes of this assessment, Entergy applied a multiplier of 8 to the internal-event benefits for each unit to account for both internal and external events, with analysis uncertainty. The multiplier of 8 slightly exceeds the product of the external-event multiplier and the uncertainty factor for each unit (i.e., 3.8x2.1=8.0 for IP2, and 5.5x1.4=7.7 for IP3) and adds a small amount of additional conservatism. Although not cost beneficial in the baseline analysis, Entergy included any additional SAMAs identified as potentially cost beneficial in the uncertainty analysis within the set of potentially cost-beneficial SAMAs that it intends to examine further for implementation.

Entergy also provided the results of additional sensitivity analyses in the ER, including use of a 3 percent discount rate, use of a longer plant life, and the consideration of economic losses by tourism and business (which were not included in the baseline analysis). These analyses did not identify any additional potentially cost-beneficial SAMAs beyond those already identified through the uncertainty analysis.

The NRC staff questioned the rationale for treating the loss of tourism and business in a sensitivity case rather than in the baseline analysis (NRC 2007). Incorporation of tourism and business losses within the baseline analysis could result in identification of additional cost-beneficial SAMAs, particularly when the baseline benefits are multiplied to account for

uncertainties. In response, Entergy explained that the impact of lost tourism and business was not modeled in the baseline analysis because the level of tourism and business activity can be reestablished in time. Nevertheless, Entergy provided the results of an additional uncertainty case showing the impact of lost tourism and business combined with analysis uncertainty. This uncertainty case resulted in the identification of two additional potentially cost-beneficial SAMAs for IP2 (IP2 SAMAs 9 and 53) and one additional potentially cost-beneficial SAMA for IP3 (IP3 SAMA 53). Given that it may take years to reestablish the level of tourism and business activity following a severe accident, the NRC staff has conservatively adopted the case incorporating lost tourism and business as its base case and has reflected the results of that case in Table G-6.

In responding to an NRC RAI, Entergy identified and corrected an error in the benefit analysis for IP3 SAMA 30 (provide a portable battery charger for monitoring instrumentation necessary to allow manual operation of the turbine-driven AFW pump), which results in this SAMA no longer being potentially cost beneficial. As indicated in ER Section E.4.3, the benefit of this SAMA was estimated based on the assumption that the SAMA would increase the time available to recover offsite power before local operation of AFW is required from 2 hours to 24 hours, and would also reduce internal switchgear room floods by 5 percent (which bounds the benefit of using a portable diesel-driven battery charger in switchgear flood events). According to Entergy, the original analysis inadvertently reduced the contribution from internal switchgear room floods by more than 5 percent (Entergy 2008a). Entergy's reevaluation of the benefits for this SAMA, consistent with the intended bounding case, resulted in a reduction in the baseline benefit to about $146,000, including the impacts of lost tourism and business and analysis uncertainties. As such, this SAMA is no longer cost beneficial. The revised benefit estimate is reflected in Table G-6. The NRC staff notes that the benefit associated with several other SAMA candidates that could increase the time available to recover offsite power before local operation of AFW is required from 2 hours to 24 hours (e.g., IP3 SAMA 24 (provide additional dc battery capacity) was estimated at about $51,000, including the impacts of lost tourism and business and analysis uncertainties. Therefore, a revised benefit estimate of $145,000 for IP3 SAMA 30, which also includes the additional benefit from reducing the contribution of internal switchgear room floods by 5 percent, appears reasonable. Entergy indicates that the implementation cost associated with IP3 SAMA 30 (i.e., $494,000) was specifically estimated for IP3. The proposed plant modification involves purchasing, installing, and maintaining a diesel-driven generator to charge the 125-V dc batteries. Safety-related quick-disconnects would be used to charge the selected battery. The diesel generator would be installed in a weather enclosure outside the turbine or control building, requiring fire barrier penetration sealing. Calculation of cable size, as well as procedure development and training, would be required (Entergy 2007). In view of the scope of these modifications and the fact that the modifications involve a safety-related dc system, the estimated costs appear reasonable. Accordingly, the staff agrees that this SAMA would not be cost beneficial for IP3.

The NRC-sponsored severe accident analyses performed subsequent to the time of the IPE suggest that the probability of a TI-SGTR, given a core-damage event with high primary-side pressure and a depressurized, dry secondary side, may be higher than the value used in the IP2 and IP3 PSAs. In response to an NRC request, Entergy provided the results of a sensitivity study in which it increased the conditional TI-SGTR probability from 0.01 (used in the baseline analysis) to 0.25, which is comparable to the values reported in NUREG-1570 (NRC 1998). Entergy identified the candidate SAMAs potentially affected by the TI-SGTR assumption and

reassessed the benefits for these SAMAs, subject to the increased conditional failure probability and the impact of analysis uncertainties. Entergy identified no additional cost-beneficial SAMAs as a result of this reassessment. Entergy also noted that the IP2 and IP3 steam generators have only 0.19 percent and 0.12 percent of the tubes plugged for IP2 and IP3, respectively, and would be classified as "pristine," in accordance with the Westinghouse criteria for categorizing steam generator tube integrity. With no observed corrosion, Entergy concludes—and the NRC staff concurs—that this sensitivity study is conservative relative to the application of the NUREG-1570 results for pristine generators (Entergy 2008b).

The NRC staff noted that for certain SAMAs considered in the ER, there may be alternatives that could achieve much of the risk reduction at a lower cost. The NRC staff asked the licensee to evaluate several lower cost alternatives to the SAMAs considered in the ER, including SAMAs that had been found to be potentially cost beneficial at other PWR plants. These alternatives were (1) implementation of improved instrumentation and/or procedures to aid in the mitigation of a SGTR, (2) implementation of a procedure for recovery of steam dump to condenser from the unaffected steam generator to aid the mitigation of a SGTR, (3) implementation of a procedure for recovery of the main feedwater/condensate postsafety injection actuation to aid in the mitigation of a SGTR, (4) reactivation of the IP3 postaccident containment venting system, and (5) purchase or manufacture of a "gagging device" that could be used to close a stuck-open steam generator safety valve on a faulted steam generator before core damage occurs (NRC 2007a and NRC 2007b). Entergy provided a further evaluation of these alternatives, as summarized below.

- Improve SGTR instrumentation and/or valve procedures. Operator actions to cool and depressurize the RCS to cold shutdown conditions following and SGTR before depleting RWST inventory are already contained in EOPs. EOPs also direct plant personnel to initiate RWST makeup, given a low RWST level without a corresponding increase in the containment recirculation sump water level, or if the ruptured steam generator narrow-range level indication is high.

- Institute a procedure for recovery of steam dump to condenser. Procedures for recovery of steam dump to condenser from the unaffected steam generator are currently available at both units.

- Recover main feedwater/condensate. For IP2, the operators are currently directed to attempt to establish a secondary heat sink with AFW, main feedwater, or condensate, should the AFW system initially not function or subsequently fail during implementation of the EOPs. For IP3, procedural guidance currently exists for reestablishing condensate flow, but there is no guidance to use main feedwater following a loss of the secondary heat sink. Thus, the development of guidance on aligning main feedwater for secondary heat removal was evaluated as a potential SAMA for IP3.

- Reactivate the IP3 containment venting system. IP3 has three alternate methods of containment depressurization and combustible gas control. These methods are backflow to the steam ejector line, containment pressure relief line, and the containment purge system. All of the venting functions require similar operator actions. Given these various alternatives, failure to vent would be dominated by human error and would not be substantially reduced by providing an additional means of venting.

With regard to the steam generator safety gagging device, which was found to be potentially cost beneficial at another pressurized-water reactor seeking license renewal, Entergy provided a separate assessment of the benefits and implementation costs. Entergy estimated the benefit associated with successfully gagging a stuck-open main steam safety valve following an SGTR by assuming all early steam generator isolation failures and all TI-SGTRs would be eliminated. The total benefits were estimated to be about $2.9 million for IP2 and $4.4 million for IP3. The implementation cost, including purchasing and storing a dedicated gagging devise, revising procedures, and providing training, was estimated to be about $50,000 for each unit. As such, the results indicate that this SAMA is potentially cost beneficial for both units. Entergy indicates that this additional SAMA has been submitted for an engineering project cost-benefit analysis for a more detailed examination of its viability and implementation cost (Entergy 2008b). The NRC staff concurs with Entergy's findings regarding these alternative SAMAs because the NRC staff finds the additional information provided by Entergy for the aforementioned alternative SAMAs to be technically sound.

The NRC staff notes that all nine potentially cost-beneficial SAMAs for IP2 (IP2 SAMAs 9, 28, 44, 53, 54, 56, 60, 61, and 65) and five potentially cost-beneficial SAMAs for IP3 (IP3 SAMAs 52, 53, 55, 61, and 62), identified in either Entergy's baseline analysis or supplemental analyses provided in response to the NRC requests, as well as the additional SAMA regarding a dedicated gagging device for SGTR events (applicable to both units), are included within the set of SAMAs that Entergy will consider further for implementation. The NRC staff concludes that, with the exception of the potentially cost-beneficial SAMAs discussed above, the costs of the other SAMAs would be higher than the associated benefits (i.e., no additional SAMAs appear to be cost-beneficial).

G.7 Conclusions

Entergy compiled a list of 231 candidate SAMAs for IP2 and 237 SAMAs for IP3, based on a review of the most significant basic events from the current plant-specific PSA, insights from the plant-specific IPE and IPEEE, and a review of other industry documentation. An initial screening removed SAMA candidates that (1) were not applicable at IP2 and IP3, (2) were already implemented or their intent had been met, or (3) were similar in nature and could be combined with another SAMA candidate. Based on this screening, 163 IP2 and 175 IP3 SAMAs were eliminated, leaving 68 IP2 and 62 IP3 candidate SAMAs for evaluation.

For the remaining SAMA candidates, more detailed evaluation was performed as shown in Table G-6. The cost-benefit analyses in the ER showed that five IP2 and five IP3 SAMA candidates were potentially cost beneficial in either the baseline analysis or sensitivity analysis using a 3 percent discount rate. Entergy performed additional analyses to evaluate the impact of parameter choices and uncertainties on the results of the SAMA assessment. As a result, four additional IP2 SAMAs and one additional IP3 SAMA were identified as potentially cost beneficial. In addition, a SAMA regarding a dedicated gagging device for SGTR events was identified as potentially cost beneficial for both units. Correction of an error in the benefit analysis for IP2 SAMA 30 resulted in it no longer being considered cost beneficial. Entergy has indicated that all nine potentially cost-beneficial SAMAs for IP2 (IP2 SAMAs 9, 28, 44, 53, 54, 56, 60, 61, and 65) and five potentially cost-beneficial SAMAs for IP3 (IP3 SAMAs 52, 53, 55,

61, and 62), as well as the additional SAMA regarding a dedicated gagging device for SGTR events, will be considered further for implementation at IP2 and IP3.

The NRC staff reviewed the Entergy analysis and concludes that the methods used and the implementation of those methods were sound. The treatment of SAMA benefits and costs support the general conclusion that the SAMA evaluations performed by Entergy are reasonable and sufficient for the license renewal submittal. Although the treatment of SAMAs for external events was somewhat limited, the likelihood of there being cost-beneficial enhancements in this area was minimized by improvements that have been realized as a result of the IPEEE process and inclusion of a multiplier to account for external events.

The NRC staff concurs with Entergy's identification of areas in which risk can be further reduced in a cost-beneficial manner through the implementation of the identified, potentially cost-beneficial SAMAs. Given the potential for cost-beneficial risk reduction, the NRC staff agrees that further evaluation of these SAMAs by Entergy is warranted. However, these SAMAs do not relate to adequately managing the effects of aging during the period of extended operation. Therefore, they need not be implemented as part of license renewal pursuant to Title 10 of the *Code of Federal Regulations*, Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants" (10 CFR Part 54).

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Appendix H

U.S. Nuclear Regulatory Commission Staff Evaluation of Environmental Impacts of Cooling System

Appendix H

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H.1 Environmental Impacts of Cooling System

Environmental issues associated with the operation of a nuclear power plant during the renewal term are discussed in the U.S. Nuclear Regulatory Commission (NRC) document, NUREG-1437, Volumes 1 and 2, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants" (hereafter referred to as the GEIS) (NRC 1996, 1999).[(a)] The GEIS includes a determination of whether the analysis of the environmental issues could be applied to all plants and whether additional mitigation measures would be warranted. Issues are then assigned a generic (Category 1) or site-specific (Category 2) designation. As set forth in the GEIS, generic issues are those that have the following characteristics:

(1) The environmental impacts associated with the issue have been determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics.

(2) A single significance level (i.e., SMALL, MODERATE, OR LARGE) has been assigned to the impacts (except for collective offsite radiological impacts from the fuel cycle and from high-level waste and spent fuel disposal).

(3) Mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are likely not to be sufficiently beneficial to warrant implementation.

No additional plant-specific analysis is required for generic issues unless new and significant information is identified. Site-specific issues do not have all the above characteristics, and a plant-specific review is required.

This appendix addresses the issues that are listed in Table B-1, Appendix B, Subpart A, of Title 10 of the *Code of Federal Regulations* (CFR), Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," and that are related to the operation of the cooling systems of Indian Point Nuclear Generating Unit Nos. 2 and 3 (IP2 and IP3) during their renewal term. Section H.1 addresses the impingement of fish and shellfish applicable to the IP2 and IP3 cooling systems. Section H.2 addresses the entrainment of fish and shellfish applicable to the IP2 and IP3 cooling systems. Section H.3 addresses the combined effects of impingement and entrainment, and Section H.4 discusses cumulative impacts. Finally, Section H.5 lists the references for Appendix H. Category 1 and Category 2

issues that are not applicable to IP2 and IP3, because they are related to plant design features or site characteristics not found at IP2 and IP3, are listed in Appendix F.

H.1.1. Impingement of Fish and Shellfish

Impingement occurs when organisms are trapped against cooling water intake screens or racks by the force of moving water. Impingement can kill organisms immediately or gradually, by exhaustion, suffocation, injury, or exposure to air when screens are rotated for cleaning. The potential for injury or death is generally related to the amount of time an organism is impinged, its susceptibility to injury, and the physical characteristics of the screenwash and fish return system that is employed. Studies of impingement losses associated with the operation of IP2 and IP3 cooling systems were conducted annually from 1975 to 1990. Before the installation of modified Ristroph screen systems in 1991, impingement mortality was assumed to be 100 percent. Beginning in 1985, studies were conducted to evaluate whether the addition of Ristroph screens would decrease impingement mortality for representative species. The final design (Version 2), as reported in Fletcher (1990), appeared to reduce impingement mortality, based on a pilot study, in comparison to the existing (original) system in place at IP2 and IP3 (Table H-1). The impingement survival estimates reported in Fletcher (1990) were not validated, however, after the new Ristroph screens were installed at IP2 and IP3 in 1991.

Table H-1 Assumed Cumulative Mortality and Injury of Selected Fish Species after Impingement on Ristroph Screens

Species	Percent Dead and Injured
Alewife	62
American Shad	35
Atlantic Tomcod	17
Bay Anchovy	23
Blueback Herring	26
Hogchoker	13
Striped Bass	9
Weakfish	12
White Catfish	40
White Perch	14

Source: Fletcher 1990

H.1.1.1. Summary of Impingement Monitoring Studies

The former owners of IP2 and IP3 conducted impingement monitoring between 1975 and 1990 using a variety of techniques. Between January 1975 and June 1981, fish were collected and sorted during a daily intake screen washing between 0800 and 1200 hours (hr). In July 1981

and continuing through October 1990, fish were collected during intake screen washings between 0800 and 1200 hr on selected days determined from a stratified random design intended to reduce the overall sampling effort without affecting data use and utility. Between October and December 1990, IP2 was sampled every Tuesday, and IP3 was not sampled because of a plant outage. During all collections, the wash water was circulated to draw a portion of the fish and debris into the forebay, where it was drained through a sluice containing a 1-millimeter (mm) (0.375-inch (in.)) square mesh screen. Collection efficiency was estimated in 1974, 1975, and 1977 at IP2. The results of these studies suggested that the collection efficiency was highly variable (ranging from 2 percent to 45 percent based on the recovery of dyed fish) and averaged 29 percent (Con Edison 1976; Con Edison 1979). Collection efficiency at IP3 in 1976 and 1977 ranged from 58 percent to 86 percent recovery of dyed fish with an average of 71 percent (Con Edison 1977, 1979). The difference in the collection efficiency at the two units was associated with the differences in the type of screens (fixed versus traveling screens) and the method used for screen washing. To estimate the total number of fish impinged, the total number of fish collected was multiplied by an adjustment factor representing the inverse of the collection efficiency. From 1975 to 1978, adjustment factors of 3.5 and 1.4 were used for IP2 and IP3, respectively (Con Edison 1980).

Analysis of variance and the correlation of environmental and IP2 and IP3 operation variables were employed to explain the variation in collection efficiency. Early studies suggested that collection efficiency increased during periods of low water temperature. In 1979, the adjustment factor became a function of the time of year, based on the increase in collection efficiency when water temperatures were less than 15 degrees Celsius (C) (59 degrees Fahrenheit (F)). Thus, cool water adjustment factors of 2.1 and 1.2 were adopted to estimate the number of fish impinged at IP2 and IP3, respectively, during January through April, November, and December. For May to October, the adjustment factor was 3.8 for IP2 and 1.5 for IP3. In 1981, the collection efficiency was estimated with a regression relationship with temperature:

IP2 efficiency= E_2 = -0.00945 (Temperature degrees C) + 0.54708; and

IP3 efficiency= E_3 = -0.00792 (Temperature degrees C) + 0.71640 (Con Edison 1984).

These regression relationships were updated in 1982, and screen-specific adjustments were devised from studies conducted in 1985 and 1986 (Table H-2).

Impingement monitoring designs changed through time (Con Edison 1980, 1984; Con Edison and NYPA 1986, 1987, 1988, and 1991) as follows. In 1979, the daily variation in impingement counts was analyzed to determine its effect on the precision and accuracy of reduced sampling plans. Starting in July 1981, a sampling plan employing a seasonally stratified random sample developed from these results was used for all further impingement studies except the last quarter of 1990. Instead of sampling daily, IP2 and IP3 were sampled a total of 110 days per year (a 30-percent sampling fraction with approximately 92-percent accuracy) (Con Edison 1984). Days were selected at random within four calendar strata defined by similar water temperatures and variance in the number of fish impinged (January–March, April–June, July–September, and October–December). The number of days sampled per stratum was proportional to the number of days available and the variance in impingement for all taxa combined (Table H-3) (Con Edison 1984). The number of days allocated to strata was updated in 1985 to take advantage of current data trends and again in 1990 because of known plant

outages. Even though IP2 and IP3 had different numbers of samples allocated to each stratum, sampling was conducted on the same day at both units to the extent possible.

During 1981, the New York State Department of Environmental Conservation (NYSDEC) required daily sampling when total impingement counts were greater than 10,000 fish. Daily sampling was required to continue until the total was below 10,000 fish. Because these sampling dates were not part of the stratified design, they were used in place of random dates that were associated with unplanned unit outages. Outages were defined as circulating pump outages and were not necessarily associated with cessation of power generation. In 1981, randomly selected days that fell on planned outages were not replaced. From 1982 to October 1990, to minimize the effect of planned and unplanned outages on the selected days for collection, a randomly selected replacement day within the given stratum was sampled. In October 1990, a systematic sampling design was employed that required sampling at IP2 each Tuesday. No sampling was conducted at IP3 from October 1990 to December 1990 because of an extended outage.

Sampling for blue crabs began in April 1983 and continued though December 1990. Sampling was conducted on all days of plant operation. The total number of impinged crab and their total weight were obtained for each sampling. In addition, the carapace width, total weight, and observed condition were recorded for each collected individual.

Table H-2 Estimates of Collection Efficiency Based on Temporal Averages, Regressions as a Function of Temperature, and Specific Screens

Year	IP2 Conventional Screen	IP3 Conventional Screen	Ristroph Screen Version[1]
1975–1978	29 percent	71 to 73 percent	None installed
1979–1980	Jan.–April and Nov.–Dec. = 48 percent	Jan.–April and Nov.–Dec. = 83 percent	None installed
	May–Oct. = 26 percent	May–Oct. = 66 percent	
1981	$E_2 = -0.00945\ T + 0.54708$	$E_3 = -0.00792\ T + 0.71640$	None installed
1982–1985	$E_2 = -0.00871\ T + 0.51858$	$E_3 = -0.00792\ T + 0.71640$	None installed

Table H-2 **(continued)**

Year	**IP2 Conventional Screen**	**IP3 Conventional Screen**	**Ristroph Screen Version**[1]
1986	E_2 = -0.00871 T + 0.51858	E_3 = -0.00792 T + 0.71640	Jan.–Mar. = 70.8 percent Apr.–June = E_2 or E_3 July–Aug. = 18.7 percent Sept. = 29.6 percent Oct.–Dec. = E_2 or E_3
1987–1990	E_2 = -0.00871 T + 0.51858	E_3= -0.00792 T + 0.71640	Jan.–Mar. = 74.4 percent Apr.–June = E_2 or E_3 July–Aug. = 18.7 percent Sept. = 29.6 percent Oct.–Dec. = E_2 or E_3

[1] Number of Ristroph Screens at IP2. In 1986, a Ristroph Screen was installed on Intake Bay 26.
E_2 – Collection Efficiency at IP2
E_3 = Collection Efficiency at IP3
T = Temperature in degrees C

Sources: Con Edison 1980, 1984; Con Edison and NYPA 1986, 1987, 1988, and 1991

Table H-3 Number of Days Allocated to Each Quarter Based on the Stratified Random Sampling Design

Stratum	**Dates**	**Total Days**	**Allocation to IP2 in 1981; 1982–84; 1985–89; and 1990**	**Allocation to IP3 in 1981; 1982–84; 1985–89; and 1990**
Winter	Jan. 1–Mar. 31	90	N/A[a]; 30; 23; 23	N/A; 27; 35; 35
Spring	Apr. 1–June 30	91	N/A; 10; 8; 8	N/A; 18; 20; 20
Summer	July 1–Sept. 30	92	11; 11; 11; 11	31; 31; 31; 31
Fall	Oct. 1–Dec. 31	92	59; 59; 68; 13	34; 34; 24; 0

[a] N/A = Not Applicable, the reduced sampling began July 1, 1981 (Con Edison 1984)
Sources: Con Edison 1984; Con Edison and NYPA 1986, 1987, 1988, and 1991

For all impingement studies, fish were sorted and counted completely if either the identified species was white perch, striped bass, or tomcod, or the total number collected for a given species was less than 100 individuals (with heads). All other sorted samples were enumerated by subsampling and weighing to four general length classes. This information was used to determine the total sample size. To estimate the number of fish impinged, the estimated daily counts (taken before July 1981) were multiplied by the collection efficiency adjustment factor (Con Edison 1984). During the period of stratified random sampling (July 1981–1990), the

mean of the estimated number of fish counted within a stratum was multiplied by the collection efficiency adjustment factor and the number of days of plant operation (Con Edison 1984).

H.1.1.2. Historic Assessment of Impingement Impacts

As discussed in the previous section, numerous studies have been conducted to evaluate the effects of impingement associated with the Indian Point cooling systems. Studies have also been conducted to evaluate the trends of fish populations in the Hudson River. Entergy Nuclear Operations, Inc. (Entergy, or the applicant) and NYSDEC have used the results of these studies to evaluate the potential for adverse effects associated with the operation of the Indian Point cooling systems., The results of these assessments are described below. Nongovernmental groups and members of the public have also evaluated publicly available information and data associated with the Hudson River and have expressed the opinion that many species of fish in the river are in decline and that the entrainment of juvenile and adult fish at Indian Point is contributing to the decline, destabilization, and ultimate loss of these important aquatic resources.

<u>Applicant Assessment</u>

In the draft environmental impact statement (DEIS) (CHGEC 1999) and environmental report (ER) (Entergy 2007), the applicant acknowledged that some impinged fish survive and others die. Mortality can be immediate or occur at a later time (latent or long-term mortality), and mortality rates depend on the species, the size of the fish, the water's temperature and salinity, the design of the screens, the water velocity through the screen, the length of time the fish was impinged, and the design and operation of the fish return system. Impingement effects were examined by evaluating conditional mortality rates (CMRs) and trends associated with population abundance for eight selected taxa representing 90 percent of those fish species collected from screens at IP2 and IP3, including striped bass, white perch, Atlantic tomcod, American shad, bay anchovy, alewife, blueback herring, and spottail shiner. Estimates of the CMR, defined as the fractional reduction in the river population abundance of the vulnerable age group caused by one source of mortality only, were assumed to be the same as or lower than that which occurred in past years, caused by the installation of Ristroph screens and fish return systems at IP2 and IP3. For species exhibiting low impingement mortality (e.g., striped bass, white perch, and Atlantic tomcod), future impingement effects were expected to be substantially lower than they were before the installation and use of the present protective measures.

Central Hudson Gas and Electric Corporation (CHGEC) (1999) concluded that the maximum expected total impingement CMR was 0.004 for white perch and less for all other taxa. The ER (Entergy 2007) stated that the results of in-river population studies performed from 1974 to 1997 have not shown any negative trend in overall aquatic river species populations attributable to plant operations:

> More than 30 years of extensive fisheries studies of the Hudson River in the vicinity of IP2 and IP3 support current operations. The results of the studies performed from 1974 to 1997, the period of time covered in the DEIS, are referenced and summarized in the DEIS, and have not shown any negative trend in overall aquatic river species populations attributable to plant operations...

The ER also stated that ongoing studies continue to support these conclusions. Thus, the applicant determined impingement impacts to be small, suggesting that the withdrawal of water from the Hudson River for the purposes of once-through cooling for IP2 and IP3 did not have any demonstrable negative effect on representative Hudson River fish populations, nor did it warrant further mitigation measures.

To support this assessment, the applicant provided two reviews, Barnthouse et al. (2002) and Barnthouse et al. (2008). These reviews addressed the status and trends of fish populations and communities of the Hudson River estuary in relation to the operation of Bowline Point, IP2 and IP3, and Roseton generating stations, which currently share a State Pollutant Discharge Elimination System (SPDES) permit. Barnthouse et al. (2002) was based on a review of the DEIS, comments on the DEIS abundance indices though 2000 (CHGEC 1999), and the annual Year Class Report (ASA 2000). Barnthouse et al. (2008) was based on abundance indices through 2005, the spawning stock biomass-per-recruit model (SSBR), and CMR estimates. Although both reviews recognized that the long-term population trends reflected the combined effects of entrainment and impingement, the 2008 report focused on entrainment and suggested that the existing retrofits (Ristroph screens and fish returns) have resolved the concerns regarding impingement. Additional discussions concerning the results of the Barnthouse et al. (2008) analyses are provided in Section H.2.

<u>NYSDEC Assessment</u>

With respect to the operation of the IP2 and IP3 cooling systems, the NYSDEC regulatory role includes protecting aquatic resources from impacts associated with impingement, entrainment, and thermal and chemical discharges. Based on activities conducted under the Hudson River Settlement Agreement (HRSA), subsequent Consent Orders, and existing agreements with the operators of IP2 and IP3, Roseton, and Bowline Point power generation stations, NYSDEC has concluded that IP2 and IP3 have achieved some reductions in intake volumes through the use of dual-speed and variable-flow pumps and have improved impingement survival through the installation of modified Ristroph traveling screens (NYSDEC 2003a). However, NYSDEC states that “while these represent some level of improvement compared to operations with no mitigation or protection, there are still significant unmitigated mortalities from entrainment and impingement at all three of the HRSA facilities.” In a petition submitted to the NRC, dated November 30, 2007, the NYSDEC stated the following:

> The plants' outdated design and operation have caused significant adverse environmental impacts to the Hudson River. These impacts include impingement, entrainment, and heat shock to numerous fish species in the Hudson, including the endangered sturgeon… In the alternative, even if the NRC were to grant the license renewal application, it could only do that by conditioning the renewal on the construction and use of closed-cycle cooling water intake systems at IP2 and IP3. As was stated in the above contention on impingement and entrainment, the perpetuation of once-through cooling here, with its long history of massive injury and destruction of tens of millions of Hudson River fish, is simply no longer tenable, either in fact or in law.

NYSDEC stated further that the applicant would need a Clean Water Act Section 316(b) determination, a demonstration that the current cooling water intake structure reflects the best technology available for minimizing adverse environmental impacts (NYSDEC 2007). However, the NYSDEC states the following:

> Entergy has not and could not demonstrate that its once-through cooling water intake structures at IP2 and IP3 reflects the best technology available for minimizing adverse environmental impacts. Indeed, the New York State Department of Environmental Conservation has determined in the pending SPDES permit renewal proceeding that closed-cycle cooling, and not once-through cooling, represents the best technology available for minimizing adverse environmental impacts.

H.1.1.3. NRC Staff Assessment of Impingement Impacts

To assess impingement impacts, the NRC staff evaluated weekly estimated impingement numbers at IP2 and IP3 from January 1975 to November 1980, and seasonally estimated impingement numbers from January 1981 and December 1990. The combined numbers of young of year (YOY), yearling, and older fish were used for analysis since these data were available for all years of sampling.

A total of 127 identified fish taxa and blue crab were collected at IP2 and IP3 during this 15-year period. At IP2, the estimated number of representative important species (RIS) fish (as defined in Table 2-4 in the main text) impinged made up greater than 85 percent of all impinged taxa (Figure H-1, solid lines). Until 1984, the RIS fish made up greater than or equal to 95 percent of all impinged taxa. This percentage has significantly decreased at a rate of 0.8 percent per year (linear regression; $n = 16$; $p = 0.002$) from 1985 to 1990. When blue crab are included with the RIS fish, the estimated number impinged made up greater than 90 percent of all impinged taxa for all but one year. Total impingement trends for all fish and blue crab are presented in Figure H-1 (dashed line) and show impingement approached or exceeded 4 million in 1977 and 1981. Impingement of all fish and blue crab was lowest in 1984 (about 0.5 million) and 1990 (about 1 million (Figure H-1, dashed line).

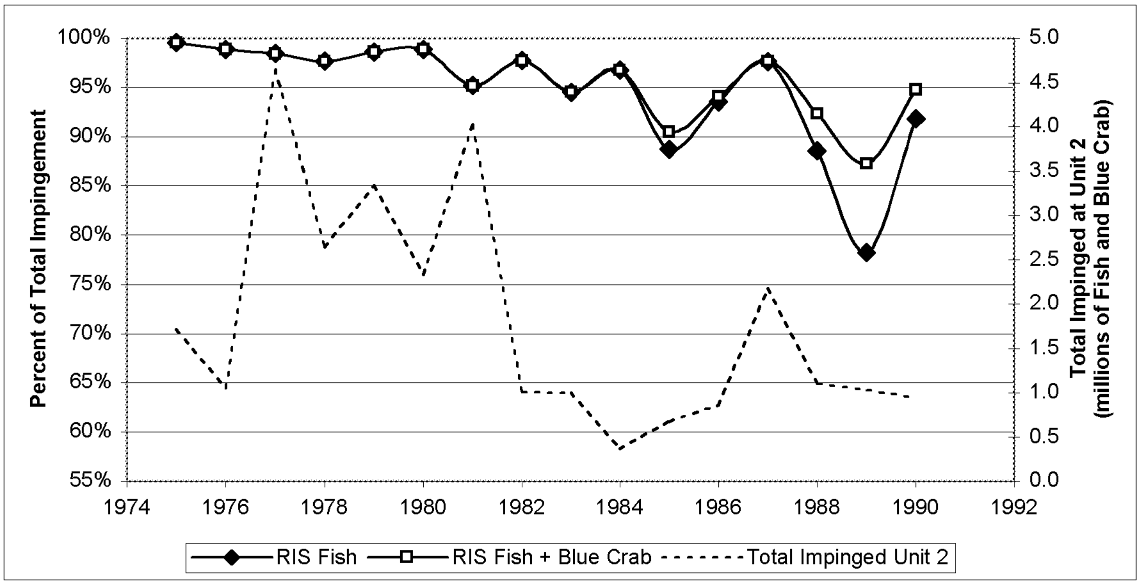


Figure H-1 Percentage of impingement comprised of RIS fish and RIS fish plus blue crab in relation to the total estimated impingement at IP2 (data from Entergy 2007b)

At IP3, the estimated number of RIS fish impinged made up greater than or equal to 95 percent of all impinged taxa except for the last 3 years (Figure H-2, solid lines). A significant decrease in this percentage was observed during that time at a rate of 1.7 percent per year (linear regression; $n = 15$; $p = 0.005$). When blue crabs are included with the RIS fish, the estimated number impinged was greater than 85 percent for all but one year. Except for 1983, which had extensive outages, IP2 had, on average, 2.6 times greater numbers of fish and crab impinged annually than IP3. The highest total impingement occurred in 1976 at just over 1.8 million fish and blue crab; the lowest occurred in 1983 at less than 0.1 million (Figure H-2, dashed line).

Total impingement trends at IP2 and IP3 suggest that the total number of fish and blue crab impinged tended to decrease between 1977 and 1982, then leveled off between 1982 and 1990. From 1975 to 1990, the number of days of operation at IP2 and IP3 has shown a general increase of 8 days per year for IP2 and 5 days per year for IP3 (linear regression, $p = 0.004$ and $p = 0.286$ for IP2 and IP3, respectively). The total volume circulated at IP2 and IP3 combined has also shown a general increase of 26.2 10^6 cubic meters (m^3) (linear regression, $p = 0.164$). If the IP2 and IP3 cooling systems are considered a relatively constant sampler of Hudson River aquatic biota (recognizing the slight increase in frequency and volume of water circulated), then the decrease in the percent of RIS impinged and total impingement would suggest that RIS and all other taxa within the vicinity of IP2 and IP3 have decreased from a high in 1977 to a relatively constant lower level of impingement between 1984 and 1990. This will be explored further in Section H.3.

To determine trends in RIS impingement, NRC Staff examined quarterly data from IP2 and IP3 from 1975 to 1990 (Table H-4). The two major time periods (1975–1980) and (1981–1990)

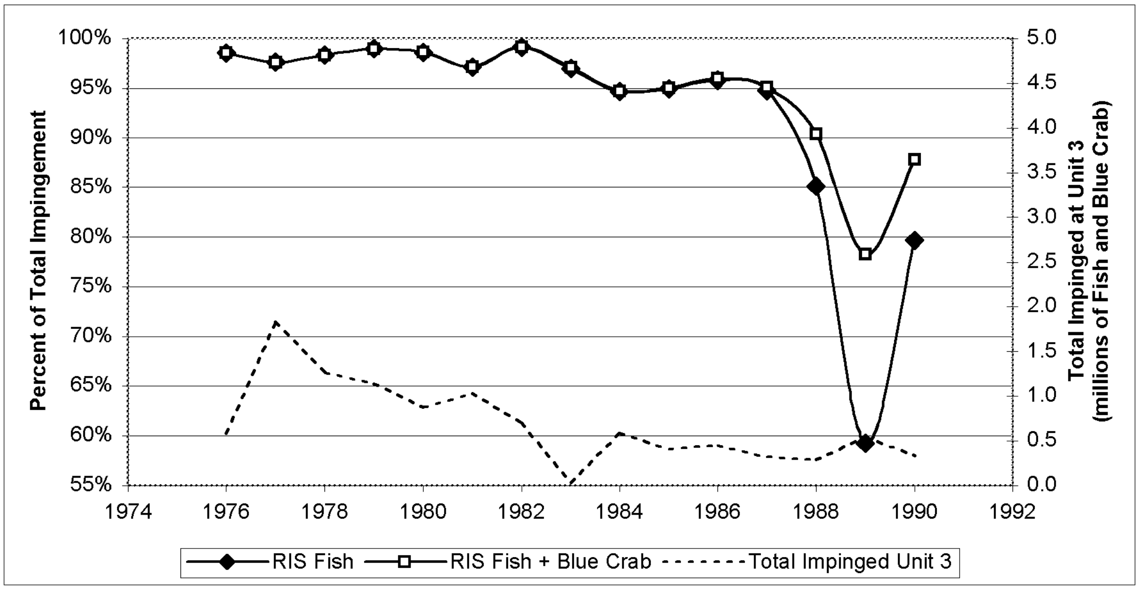


Figure H-2 Percentage of impingement comprised of RIS fish and RIS fish plus blue crab in relation to the total estimated impingement at IP3 (data from Entergy 2007b)

were analyzed separately to account for the differences in impingement sampling strategies discussed above. Summed over all years, six RIS fish species accounted for 93 percent (IP2) and 89 percent (IP3) of the total number of RIS impinged, including contributions from blue crab. During January to March sampling events for both units and all years, white perch were the most commonly impinged species, accounting for 89 to 96 percent of the RIS impinged. Impingement of RIS was more variable during other sampling periods but was generally dominated by four species (white perch, Atlantic tomcod, bay anchovy, blueback herring). The notable exception to this pattern occurs between 1981 and 1990, when the percentage of hogchoker and weakfish increased near both units during spring and summer sampling periods compared to estimates obtained from 1975 to 1980 (Table H-4). Greenwood (2008) suggested that cooling systems associated with IP2 and IP3 are considered an efficient environmental sampler. Impingement data suggest that a change in the species composition in the vicinity of IP2 and IP3 may have occurred in the 1980s.

As a result of the HRSA, operational measures were implemented to reduce the loss of aquatic resources to impingement. These measures included the installation of dual-speed intake pumps at IP2 in 1984, installation of variable-speed pumps at IP3 in 1985, and the installation of modified Ristroph screens and fish return systems in 1991. The plant operators also developed programs to employ flow-reduction measures and scheduled outages to reduce impingement and entrainment impacts. Flow rates are dependent on intake water temperature, with increased flow required when water temperatures rise above 15 degrees C. For example, the average monthly water temperatures taken near Poughkeepsie, New York from 1992 to 2006 (Figure H-3) suggest to NRC Staff that greater flow would be required during the months of May through October. This roughly corresponds to the second and third quarters of impingement sampling (April–September timeframes in Table H-4). Although the seasonal percentage of annual impingement of RIS fish was not significantly different between seasons (analysis of variance (ANOVA), p = 0.095 with a coefficient of variation (CV) = 68 percent and p = 0.27 with

a CV = 84 percent for IP2 and IP3, respectively), they were generally lower between April and June and similar across the remaining three quarters (Figure H-4). Thus, even though there is a greater volume of water used between May and October (analysis of variance (ANOVA), p = 0.02 with a CV = 41 percent and p = 0.53 with a CV = 61 percent for IP2 and IP3, respectively), impingement does not increase during these periods. Instead, the seasonal pattern of impingement may be a reflection of when susceptible fish are present near the facility.

Table H-4 Average Percentage Impingement of RIS Compared to Total Impingement per Season for 1975–1980 and 1981–1990 for Selected Taxa (data from Entergy 2007b)

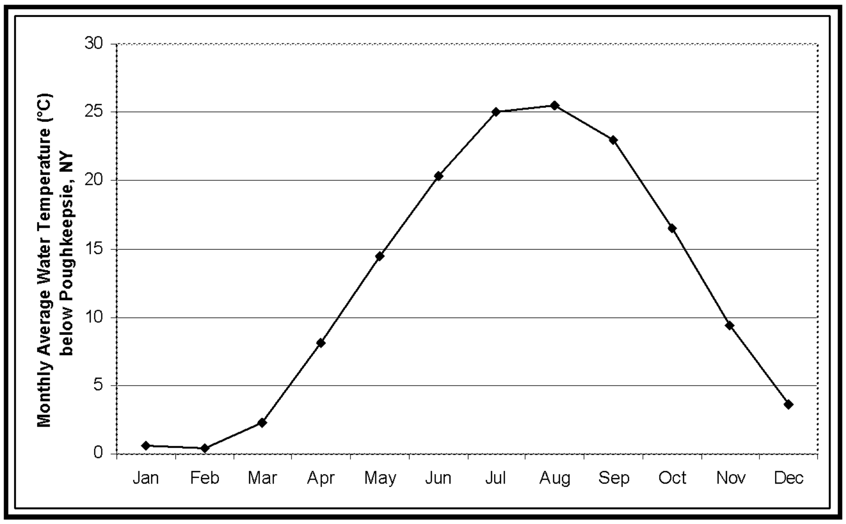
IP2 COOLING SYSTEM

RIS Species	1975–1980				1981–1990				Percent of RIS Taxa[1]
	Jan–Mar	Apr–Jun	Jul–Sep	Oct–Dec	Jan–Mar	Apr–Jun	Jul–Sep	Oct–Dec	
White Perch	96	35	17	39	92	38	13	55	48
Atlantic Tomcod	1	55	27	1	1	38	27	4	16
Bay Anchovy	0	2	32	7	0	7	21	10	11
Blueback Herring	0	0	10	46	0	1	2	13	14
Hogchoker	0	3	4	3	0	9	13	4	2
Weakfish	0	0	3	0	0	0	12	4	2
Percent of RIS Fish	96	95	94	95	93	92	89	88	93

IP3 COOLING SYSTEM

RIS Species	1975–1980				1981–1990				Percent of RIS Taxa[1]
	Jan–Mar	Apr–Jun	Jul–Sep	Oct–Dec	Jan–Mar	Apr–Jun	Jul–Sep	Oct–Dec	
White Perch	95	55	10	43	89	54	19	52	50
Atlantic Tomcod	0	23	40	2	0	17	19	3	17
Bay Anchovy	0	3	23	2	0	7	18	5	8
Blueback Herring	0	3	6	38	0	4	3	27	10
Hogchoker	0	0	8	1	1	7	16	3	3
Weakfish	0	0	3	0	0	0	10	2	1
Percent of RIS Fish	96	84	89	86	91	89	86	91	89

[1] RIS Taxa include Blue Crab



Source: U.S. Geological Survey Surface Water Data, http://waterdata.usgs.gov/usa/nwis/uv?site_no=01372058

Figure H-3 Average monthly water temperature taken from below Poughkeepsie, NY, from 1992 to 2006

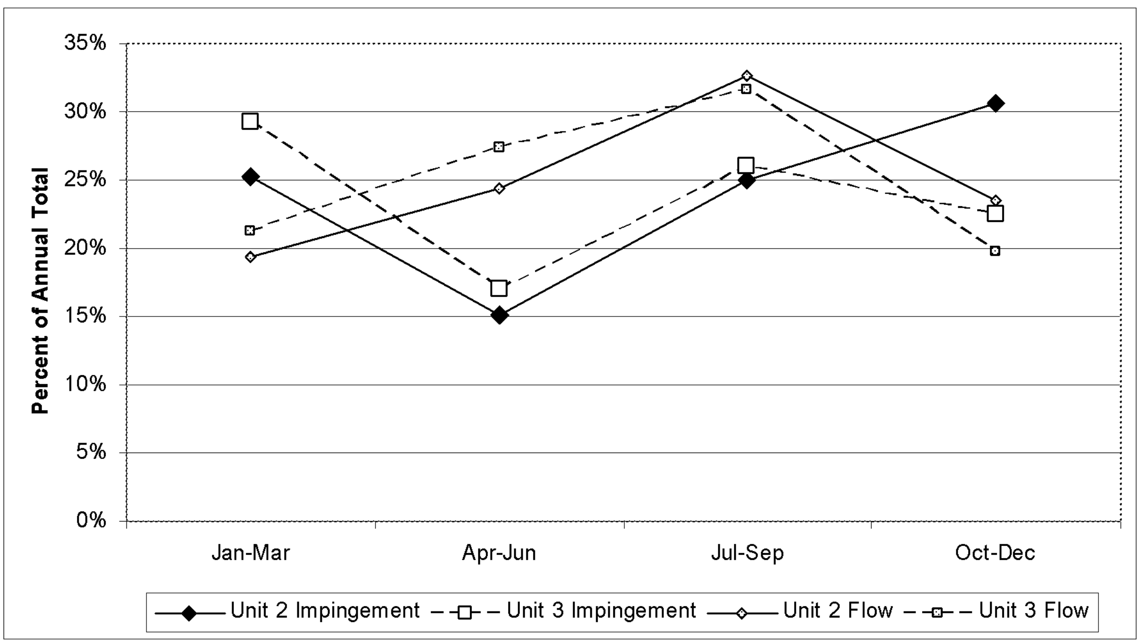


Figure H-4 Seasonal percentage of RIS fish impinged out of the annual total taxa impinged and the seasonal percentage of the volume circulated out of the annual total volume circulated from 1975–1990 (data from Entergy 2007b)

Based on the above NRC Staff analyses, the species with the highest percentage of impingement at IP2 and IP3 from 1975 to 1990 were white perch, Atlantic tomcod, blueback herring, bay anchovy, and hogchoker. Impingement trends for both units show that each of

these species was impinged during at least one sampling season in quantities representing at least 10 percent of the total impingement counts for that period. During some sampling seasons, a single species represented over 90 percent of the total impingement (e.g., white perch during January to March). Impingement magnitude does not appear to be directly related to flow; rather, the available information suggests that the frequency of impingement is associated with seasonal patterns of fish and their proximity to IP2 and IP3. The environmental significance of impingement is explored further in Section H-3.

H.1.2. Entrainment of Fish and Shellfish in Early Life Stages

Entrainment occurs when small aquatic life forms are carried into and through the cooling system as water is withdrawn for use in the plant's cooling system. Entrainment can affect organisms smaller than the screen mesh (0.25 to 0.5 in.) that are carried into the plant with the pumped water mass and have limited swimming ability to escape. This includes phytoplankton, microzooplankton, and macrozooplankton. Entrained organisms also include the young life stages of fish (eggs, larvae, post-yolk-sac larvae (YSL), and juveniles) and shellfish.

Entrained organisms pass through the circulating pumps and are carried with the flow through the intake conduits toward the condenser units. They are then drawn through one of the many condenser tubes used to cool the turbine exhaust steam and enter the discharge canal for return to the water. As entrained organisms pass through the intake, they may be injured from abrasion or compression. Within the cooling system, they encounter physical impacts in the pumps and condenser tubing, pressure changes, sheer stress, thermal shock, and chemical exposure to chlorine and residual industrial chemicals discharged at the diffuser ports (Mayhew et al. 2000). Death can occur immediately (direct effect) or after being discharged (indirect effect) from an inability to escape predators, a reduced ability to forage, or other factors.

The former owners of IP2 and IP3 conducted studies of entrainment loss associated with IP2 and IP3 in 1981 and then annually from 1983 to 1987. Entrainment survival is a particularly controversial subject. The U.S. Environmental Protection Agency (EPA) assumes that the mortality associated with entrainment is 100 percent (NYSDEC 2003a). Consolidated Edison Company of New York (Con Edison) and New York Power Authority (NYPA 1984) assume that, for the more delicate species (bay anchovy, American shad, clupeids), mortality was 100 percent. However, for other species, mortality could be separated into thermal and mechanical components and overall was less than 100 percent. By 1987, Con Edison estimated the survival of entrained bay anchovy up to 52 percent (EA 1989). This assessment recognizes that 96-hr survival of fish following entrainment is not a measure of the potential reduction in ability to forage and avoid predation within hours or days of being discharged at the diffuser ports. Thus, indirect losses for a given species from entrainment for the purpose of this assessment are unknown.

H.1.2.1. Summary of Entrainment Survival Monitoring Studies

Entrainment studies to evaluate the survival of entrainable aquatic organisms (eggs, larvae, YSL, small juveniles) have been conducted at IP2 and IP3 since the early 1970s. A variety of sampling gear has been employed. Study endpoints included estimates of immediate and latent mortality by monitoring collected organisms for up to 96 hr. Initial monitoring efforts were based

on the assumption that survival of organisms collected by nets was the same from intake canal samples as it was from discharge canal samples. It was discovered, however, that differences in water velocity at intake and discharge sampling stations may have affected ichthyoplankton survival, and subsequent studies demonstrated that the survival of striped bass eggs and larvae collected using fixed nets were velocity dependent. Based on these results, entrainment survival sampling at IP2 and IP3 in 1977 and 1978 was expanded to include new sampling gear designed to reduce or eliminate the effects of intake and discharge water velocity on apparent postcollection survival. The primary change involved the use of centrifugal pumps to transport water into a flume and larval collection table, where water quality conditions could be optimized and samples concentrated for survival and latent mortality analyses. In spite of these refinements, entrainment survival estimates derived from the pump/larval table collection system were again compromised by poor ichthyoplankton survival in control samples collected in front of intakes representing initial larval conditions before passage through the IP2 and IP3 cooling systems.

Subsequent revisions to sampling gear have been employed in 1979, 1980, and 1989, and are discussed below. Because the survival estimates conducted before 1979 were significantly compromised by sampling gear design and choice, NRC staff focused on the later studies to evaluate entrainment mortality at IP2 and IP3. Sampling was also conducted in 1985 to determine the effects of entrainment mortality resulting from an upgrade to the pumping system associated with IP2. The results of this study are not directly comparable to the 1979 and 1980 studies, because a different sampling design was employed.

Details of the 1979 entrainment survival and related studies are presented in EA (1981a). Entrainment survival studies were conducted during two separate sampling periods, the late winter season from March 12–22, 1979, to evaluate the larvae of Atlantic tomcod (*M. tomcod*), and in the spring–summer season from April 30 to August 14, 1979, to evaluate early life-stages of striped bass (*M. saxatilis*), white perch (*M. americana*), herring (Clupeidae), and anchovies (Engraulidae). During the winter season, sampling with a pump/larval table collection system was conducted at the intakes associated with IP2 and IP3, in the IP3 effluent before it enters the discharge canal, and in portions of the discharge canal containing effluent water from both units. The shutdown of IP3 from March 20–22 provided an opportunity to evaluate Atlantic tomcod larval survival under one- and two-unit operation. During the spring–summer season, a raft-mounted flume collection was used for the first time at IP2 and IP3. This system was designed to reduce sampling stress on target organisms by taking advantage of head pressure created caused by a difference between water levels on either side of the flume apparatus. The shutdown of IP2 after June 16, 1979, provided an opportunity to assess the survival of other species during both one- and two-unit operation.

For the Atlantic tomcod study during the winter of 1979, sampling was initiated upon notification of the first occurrence of tomcod larvae and conducted on 4 consecutive nights per week over the 2-week sampling period from March 12–22, for a total of 8 sampling days. Sampling occurred between 1700 and 0200 hr to coincide with the diel period of peak larval abundance. At the beginning of the study, both IP2 and IP3 units were operating, but an unscheduled shutdown of IP3 occurred on March 20 and continued through the remainder of the study. Although the unit did not generate power, two circulating water pumps continued to operate. Thus, for the tomcod study, a total of 11 circulating pumps were operating from March 12–19 (6 at IP2, 5 at IP3), and a total of 8 pumps were operating from March 20–22 (6 at IP2, 2 at IP3).

The pump/larval table collection system used for the tomcod study consisted of a modular two-screen collection flume that allowed collection of larval samples with minimal sampling stress associated with turbulent flow or temperature changes. Sample water was delivered to the table by two centrifugal pumps equipped with flowmeters. Collected entrainment samples were transferred to an onsite laboratory for sorting, where icthyoplankton were sorted and classified as live (fish, eggs), stunned (fish only), or dead (fish and eggs). Dead eggs and larvae were preserved; live or stunned fish or eggs were transferred to holding facilities to determine latent effects on survival at 3, 6, 12, 24, 48, 72, and 96 hr. Specific sampling procedures are discussed in EA (1981a).

The spring–summer sampling to evaluate entrainment survival of striped bass, white perch, herrings, and anchovies was conducted from April 30 to August 14, 1979, coincident with the primary spawning and nursery seasons of these species. Samples were collected on 2 consecutive nights each week for a total of 32 sampling days from 1800 to 0200 hr that coincided with maximum abundance. As described above, a pumpless, rear-draw plankton sampling flume mounted on rafts was employed during this study to minimize stress associated with the use of centrifugal pumps. The volume of water samples collected from all samplers was measured with integrated flowmeters, and vertical 505-micron (μm) mesh screens were employed to divert entrained organisms into collection boxes, where they were concentrated and processed to determine latent survival as described for the tomcod study.

Details of the 1980 entrainment survival and related studies are presented in EA (1982). In 1980, entrainment survival sampling at IP2 and IP3 was conducted from April 30 to July 10. Sampling was focused on entrainable life stages of striped bass (*M. saxatilis*), white perch (*M. americana*), herrings (Clupeidae), and anchovies (Engraulidae). Juvenile Atlantic tomcod (*M. tomcod*) were also collected. To correct possible sources of gear-related effects on study results, the rear-draw and pumpless plankton flumes used in 1979 were modified with flow diffusion panels and slotted standpipes installed behind the angled diversion screens. These refinements were intended to more evenly distribute the water across the surface of the screens and eliminate localized areas of high-velocity flow that may have caused impingement. This, along with other improvements to the sampling system, was expected to decrease the gear-related mortality observed in control samples from the intakes at IP2 and IP3.

Entrainment survival sampling for striped bass, white perch, herring and anchovies was conducted from April 30 to July 10, 1980, coinciding with the primary spawning and nursery seasons of these taxa. Samples were collected on 4 consecutive nights each week for a total of 44 sampling days between the hours of 1600 and 0200. Sampling was conducted at discharge canal station DP and at the IP3 intake using the modified real-draw plankton sampling flumes. Live and dead icthyoplankton collected during the study were sorted at the onsite laboratory immediately after sample collection and classified as live (fish and eggs), stunned (fish only), or dead (fish and eggs). Dead eggs and larvae were preserved; live or stunned fish or eggs were transferred to holding facilities to determine latent effects with checks at 3, 6, 12, 24, 48, 72, and 96 hr.

During the summer and early fall of 1984, dual-speed cooling water pumps were installed at IP2. In 1985, variable-speed pumps were installed at IP3. The specific objectives of the 1988 entrainment studies were to (1) estimate the initial and extended survival of ichthyoplankton entrained at IP2 and IP3 and compare the results to those from previous years, (2) determine whether live and dead ichthyoplankton are randomly dispersed in the IP2 and IP3 discharge

canal at sampling station D2, and (3) assess whether the thermal and mechanical components of entrainment stress are independent. The study description that follows was obtained from EA (1989).

The 1988 study EA (1989) was designed to sample 180 m^3 per day with each flume system. One flume was deployed at intake Station I3; two flumes were deployed at discharge station D2. The original design required that flumes be operated 3 days per week from May 23 to June 30, 1989, resulting in 18 total sampling days. Specific daily volume requirements and numbers of sampling days were developed to ensure sufficient numbers of organics were collected. Because of a number of logistical challenges, the actual number of sampling days was 13, from June 8–30. The flume design and collection procedures employed in 1988 were consistent with previous studies described above. Average daily sample volumes collected at the intake were 143.3 m^3, and the daily combined volume sampled by both flumes in the discharge canal was 271.2 m^3. The sampling program was conducted during afternoon and evening hours (1300–2300). Live and dead icthyoplankton collected during the study were sorted at the onsite laboratory immediately after sample collection and classified as described above. Other studies conducted in 1988 included sampling stress evaluations to provide a better understanding of mortality caused by sampling stress at intake versus discharge sampling locations, direct release studies to augment entrainment studies based on wild animal captures, and net studies in the discharge canal to provide additional information on icthyoplankton distribution.

The results of entrainment survival from the 1977–80, 1985, and 1988 studies are presented in EA (1989) for initial intake survival (EA 1989, Figure 4-8), initial discharge survival (EA 1989, Figure 4-9), and overall entrainment survival (EA 1989, Figure 4-10). Summary information for the 1979, 1980, and 1988 study years are summarized in Table H-5 below:

Table H-5 Entrainment Survival Estimates for Study Years 1979, 1980, and 1988

Species	Initial Intake Proportion Survival	Initial Discharge Proportion Survival	Estimated Entrainment Proportion Survival
Bay Anchovy PYSL	~0.09–0.32	~0.01–0.05	~0.12–0.52
Striped Bass YSL	~0.52–0.95	~0.61	~0.62–0.72
Striped Bass PYSL	~0.50–0.95	~0.70–0.78	~0.68–0.80
White Perch PYSL	~0.15–0.95	~0.19–0.85	~0.30–0.92
Alosa spp. PYSL	~0.25–0.90	~0.30–0.60	~0.30–0.65

Adapted from Figures 4-8–4-10 in EA (1989)

H.1.2.2. Summary of Entrainment Abundance Monitoring Studies

During 1981, EA employed an Automated Abundance Sampler (AUTOSAM) to collect icthyoplankton samples from IP2 and IP3. Middepth water samples were collected twice a week during May–August from discharge station D2. Each sampling effort consisted of collecting 90-minute (min) composite samples within eight 3-hr sampling intervals extending over a 24-hr period. Ichthyoplankton samples were sorted, identified to species and life stage, and counted (EA

1981b). In 1983, entrainment abundance samples were again collected at discharge canal station D2 from May 3 to August 13, 1983, using the AUTOSAM collector. From May 3–18, each sample consisted of a 90-min composite sample within eight 3-hr sampling periods. From May 19 to August 13, the 90-min composites reflect a shorter collection time to reduce clogging caused by the presence of detritus. Ichthyoplankton samples were sorted, identified to species and life stage, and counted (EA 1984). In 1984, icthyoplankton samples were collected from discharge canal station D2 from May 3 to August 11, 1984. Sampling equipment, collection procedures, and sample processing were consistent with past sampling efforts described above (EA 1985).

In 1985, ichthyoplankton samples were taken continuously (24 hr/day) from May 1 to August 11. Each sample consisted of one 3-hr period, resulting in eight samples per day. Total sample volumes were 150 m^3. Replicate sampling to determine variance estimates was conducted on Wednesdays and Thursdays of each week. Samples were collected by pumping water through a 10-centimeter (cm) (4-in.) diameter pipe submerged to a depth of 3 m at discharge canal Station D2 and passing the collected water into a plankton net with a codend cup. The collected sample was transferred to a sample jar, preserved, and transferred to a laboratory for sorting, identification to species and life stage, and enumeration (Normandeu 1987a). Pump samples to quantify ichthyoplankton entrained at IP2 and IP3 were collected from May 1 to August 10, 1986, at discharge canal station D2. Sampling duration was 3 hr without replication from May 1 to May 14, and 2 hr from May 15 to August 10 to increase the number of collected samples. Replicate sampling to provide variance estimates were collected 5 days per week from May 16 through August 10. Sampling equipment and processing were consistent with the 1985 sampling study (Normandeu 1987b). In 1987, pump samples to determine ichthyoplankton entrainment abundance were collected 24 hr per day from May 6 to August 10 from discharge canal station D2. Sample duration was 2 hr, which allowed a large number of samples to be collected. Replicate sampling to provide variance estimates was collected 5 days per week from May 6 to August 7 (Normandeu 1988).

H.1.2.3. Historic Assessment of Entrainment Impacts

As discussed in Sections 4.1.2.1 and 4.1.2.2, numerous studies have been conducted to estimate the quantity of RIS that are entrained by the Indian Point cooling systems and evaluate the survival of these species after entrainment occurs. Studies have also been conducted to evaluate the trends of fish populations in the Hudson River. The applicant and NYSDEC have used the results of these studies to evaluate the potential for adverse effects associated with the operation of the Indian Point cooling systems. The results of these assessments are described below. As described in Section 4.1.1.2, nongovernmental groups and members of the public have also evaluated publicly available information and data associated with the Hudson River and have expressed the opinion that many species of fish in the river are in decline and that entrainment of eggs, larval, and juvenile fish at Indian Point is contributing to the decline, destabilization, and ultimate loss of these important aquatic resources.

<u>Applicant Assessment</u>

In the environmental report for IP2 and IP3 (Entergy 2007), the applicant presents estimates of CMR for American shad, Atlantic tomcod, bay anchovy, river herring, striped bass, and white

perch and discusses the results of the assessment conducted by Barnthouse et al. (2002). The conclusions of the ER are as follows:

> More than 30 years of extensive fisheries studies of the Hudson River in the vicinity of IP2 and IP3 support current operations. The results of the studies performed from 1974 to 1997, the period of time covered in the DEIS, are referenced and summarized in the DEIS, and have not shown any negative trend in overall aquatic river species populations attributable to plant operations. Ongoing studies continue to support these conclusions [ASA]. In addition, current mitigation measures implemented through the HRSA and retained in the four Consent Orders, the current agreements with NYSDEC, and the outcome of the draft SPDES Permit proceeding, will ensure that entrainment impacts remain SMALL during the license renewal term. Therefore, withdrawal of water from the Hudson River for the proposes of once-through cooling at the site does not have any demonstrable negative effect on representative Hudson River fish populations, nor does it warrant further mitigation measures.

Additional impact assessment information was also provided to the NRC staff in Barnthouse et al. (2008) that used environmental risk-assessment techniques to evaluate the potential for adverse impacts to Hudson River RIS from a variety of natural and anthropogenic stressors, including the operation of the IP2 and IP3 cooling water intake system (CWIS), fish pressure, the presence of zebra mussels, predation by striped bass, and water temperature. Summary results available in Barnthouse et al. (2008) are presented in Table H-6. Using this information, the authors concluded the following:

> Considered together, the evidence evaluated in this report shows that the operation of IP2 and IP3 has not caused effects on early life stages of fish that reasonably would be considered “adverse” by fisheries scientists and/or managers. The operation of IP2 and IP3 has not destabilized or noticeably altered any important attribute of the resource.

Table H-6 Summary of Impact Assessment for IP2 and IP3

Species	Suspected Cause of Apparent Hudson River Decline
American Shad	CWIS and zebra mussel hypothesis rejected. Most likely cause: fishing, with striped bass predation a potential contributing factor. (Barnthouse et al. 2008, Table 5)
Atlantic Tomcod	CWIS hypothesis rejected. Temperature a significant influence, but cannot explain post-1990 decline. Most likely cause of decline: striped bass predation. (Barnthouse et al. 2008, Table 6)
Bay Anchovy	CWIS hypothesis rejected. Striped bass predation most likely cause of change. (Barnthouse et al. 2008, Table 8).
River Herring	CWIS and zebra mussel hypothesis rejected. Most likely cause: striped bass predation. (Barnthouse et al. 2008, Table 7).
Striped Bass	CWIS and zebra mussel hypothesis rejected. Most likely cause: fishing. (Barnthouse et al. 2008, Table 3)
White Perch	CWIS hypothesis rejected. Zebra mussel and striped bass predation may have contributed to declines occurring in later years, but other unknown causes were responsible for declines occurring between 1975 and 1985. (Barnthouse et al. 2008, Table 4)

Source: Entergy 2008, adapted from Barnthouse et al. 2008

NYSDEC Assessment

In 2003, NYSDEC developed a Final Environmental Impact Statement (FEIS) (NYSDEC 2003a) in response to the DEIS submitted by the operators of IP2 and IP3, Roseton, and Bowline Point (CHGEC 1999). In the FEIS, NYSDEC noted that "while the DEIS was acceptable as an initial evaluation and assessment, it was not sufficient to stand as the final document, and additional information as to alternatives and evaluation of impacts must be considered." The Public Comment Summary portion of the FEIS presents a summary of comments received on the 1999 DEIS (CHGEC 1999); a subsequent section, Responses to Comments, provides the NYSDEC reply. In response to comments associated with the "cropping of fish populations by power plants," NYSDEC provided a detailed response. The following excerpt is from pages 53 and 54 of the document:

> Rather than "selective cropping", the impacts associated with power plants are more comparable to habitat degradation; the entire natural community is impacted. These "once-through cooling" power plants do not selectively harvest

individual species. Rather, impingement and entrainment and warming of the water impact the entire community of organisms that inhabit the water column. For example, these impacts diminish a portion of the forage base for each species that consumes plankton (drifting organisms in the water column) or nekton (mobile organisms swimming through the water column) so there is less food available for the survivors. In an intact ecosystem, these organisms serve as compact packets of nutrients and energy, with each trophic (food chain) level serving to capture a diffuse resource and make it more concentrated. Ichthyoplankton (fish eggs, larvae and very small fish which drift in the water column) and small fish feed on a base of zooplankton (drifting animal life) and phytoplankton (drifting plant life). The loss of these small organisms in the natural community may be a factor that leads to harmful algal blooms. The small fish themselves serve as forage for the young of larger species, which serve as forage for larger individuals, and so on up the food chain, more correctly understood as a "trophic pyramid." Once-through cooling mortality "short-circuits" the trophic pyramid and compromises the health of the natural community. For example, while an individual bay anchovy might ordinarily serve as food for a juvenile striped bass or even for a common tern, entrainment and passage through a power plant's cooling system would render it useful only as food to lower trophic level organisms. It could no longer provide its other ecosystem functions of consuming phytoplankton, digesting and concentrating it into its tissues, and ranging over a wide area, distributing other nutrients as manure. This is just a single example from a very complex natural system, where the same basic impact is multiplied millions of times over more than one hundred fish species.

NYSDEC also expressed concern about entrainment in the 2003 "Fact Sheet" pertaining to SPDES license renewal at IP2 and IP3 (NYSDEC 2003b, Attachment B, 1. Biological Effects):

1. Biological Effects

Each year Indian Point Units 2 and 3 (collectively "Indian Point") cause the mortality of more than a billion fish from entrainment of various life stages of fishes through the plant and impingement of fishes on intake screens. Entrainment occurs when small fish larvae and eggs (with other aquatic organisms) are carried into and through the plant with cooling water, causing mortality from physical contact with structures and thermal stresses. Impingement occurs when larger fish are caught against racks and screens at the cooling water intakes, where these organisms may be trapped by the force of the water, suffocate, or otherwise be injured. Losses at Indian Point are distributed primarily among 7 species of fish, including bay anchovy, striped bass, white perch, blueback herring, Atlantic tomcod, alewife, and American shad. Of these, Atlantic tomcod, American shad, and white perch numbers are known to be declining in the Hudson River (ASA Analysis and Communications 2002). Thus, current losses of various life stages of fishes are substantial.

Finally, in the petition submitted to the NRC on November 30, 2007, regarding the relicensing of IP2 and IP3 (NYSDEC 2007), the agency comments on impingement and entrainment impacts:

Impingement and Entrainment Contention

The operation of Indian Point consumes and returns approximately 2.5 billion gallons of Hudson River water each day. The River is an important estuarine ecosystem, and this operation has significant adverse impacts to the fish that call the Hudson home. Large fish are "impinged" on screens at the water intake where they are severely stressed and then suffocated. Smaller fish are "entrained" in the water intake, pulled through the operating plant and killed. This relentless process has continued relatively unabated for almost 40 years, and the applicant now seeks 20 more years. This must not continue because the environmental costs are too high. The NRC must fully consider the alternative of closed cycle cooling to mitigate these significant adverse impacts in this license renewal proceeding.

H.1.2.4. NRC Staff Assessment of Entrainment Impacts

Entergy (2007b) provided to NRC weekly average densities of entrained taxa for a given life stage for IP2 and IP3 for analysis. The data were collected from May to August in 1981 and 1983 through 1985, from January to August in 1986, and from May to August in 1987. The sum of the mean densities of all life stages for a given taxon and season (January–March, April–June, July–September, and October–December) times the volume of circulated water was used to estimate the mean number entrained per taxon and season.

NRC found a total of 66 taxa identified during entrainment monitoring in the data supplied. There were no blue crabs, shortnose or Atlantic sturgeon, or gizzard shad identified in the 1981–1987 entrainment data. Because of the difficulty in identification of early life stages, RIS included those taxa identified only to family or genera (herring family, *Alosa* spp., anchovy family, and *Morone* spp.). The percent RIS fish entrained and total fish entrained were compared to the total estimated mean number (Figure H-5). Except for 2 weeks in 1984 and 1985 (1 week in May and June) for which amphipods (*Gammarus* sp.) were recorded, the percentage RIS fish entrained was greater than 90 percent of entrained taxa. The number of amphipods collected in 2 weeks in 1984 was two times greater than identified fish collected over 15 weeks within the same year. Linear regression ($n = 6$; $p = 0.02$) indicated that the number of identified fish entrained decreased at a rate of 1.6 billion fish per year, a result consistent with the decrease observed in the number of fish impinged.

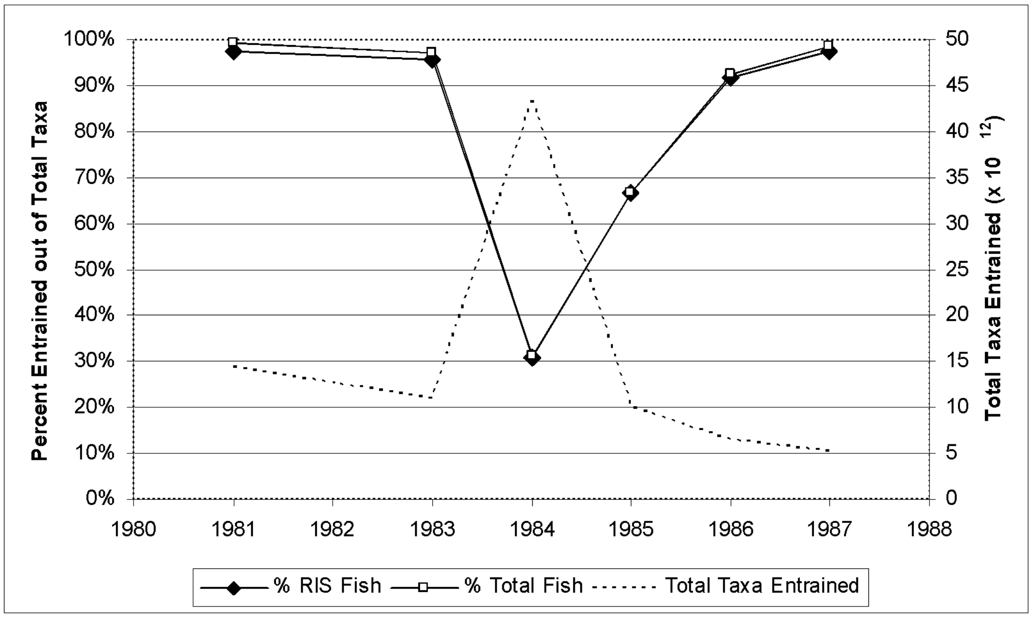


Figure H-5 Percentage of entrainment comprised of RIS fish and total fish in relation to the total estimated entrainment at IP2 and IP3 combined (data from Entergy 2007b)

A seasonal pattern in the percentage entrainment of each RIS out of the total RIS fish entrained was evaluated (Table H-7). Entrainment of herring, American shad, *Alosa* spp., white perch, and striped bass was mainly observed in the second quarter (April–June). Entrainment of weakfish and hogchoker was mainly observed in the third quarter (July–September). Rainbow smelt and Atlantic tomcod were observed in entrainment samples only in the first quarter (January–March) of 1986. Based on the available information, species representing 10 percent or greater of total RIS entrained for at least one sampling period were alewife, bay anchovy, American shad, rainbow smelt, striped bass, Atlantic tomcod, and white perch (Table H-7). Entrainment losses may affect populations directly by reducing the number of individuals available for recruitment and indirectly through the removal of potential food for predators. The environmental significance of entrainment is explored further in Section H.3.

H.1.3. Combined Effects of Impingement and Entrainment

The combined effects of impingement and entrainment were evaluated by the applicant in the DEIS (CHGEC 1999) by estimating CMR, which is intended to represent the fractional reduction in abundance of the vulnerable age groups (primarily those fish hatched during the current year) from a single source. The CMR is model-dependent and has been a source of controversy since it was developed. The NRC Staff analysis presented here will instead rely on the extensive fishery datasets collected under the direction and oversight of the NYSDEC.

Table H-7 Percentage Entrainment of RIS by Year and Season (data from Entergy 2007b)

Year/	1981		1983		1984		1985		1986			1987	
Season	2	3	2	3	2	3	2	3	1	2	3	2	3
Herring Family	2.2	<0.05	40	<0.05	24	<0.05	0.3	-[a]	-	31	<0.05	1.2	-
Blueback Herring	-	<0.05	<0.05	0.1	<0.05	<0.05	-	<0.05	-	<0.05	<0.05	-	-
Alewife	-	-	-	<0.05	<0.05	-	-	-	-	<0.05		<0.05	
American Shad	0.1	<0.05	0.1	<0.05	3.9	<0.05	<0.05	-	-	0.1	-	<0.05	<0.05
Alosa Species	7.4	<0.05	30	<0.05	36	<0.05	0.6	-	0.4	<0.05	-	<0.05	-
Atlantic Menhaden	-	-	-	-	-	-	0.1	-	-	0.3	-	-	-
Anchovy Family	3.1	8.2	<0.05	43	1.1	8.4		-	-	-	-	-	-
Bay Anchovy	46	91	0.1	53	16	86	73	99	-	4.0	99	47	99
Rainbow Smelt	-	-	<0.05	-	0.2	<0.05	<0.05	<0.05	64	2.0	0.2	0.8	0.1
White Catfish	-	-	-	-	-	<0.05	-	-	0.1	<0.05	-	-	-
Atlantic Tomcod	0.9	-	0.1	<0.05	1.2	0.1	6.8	<0.05	34	1.8	-	1.4	<0.05
White Perch	15	0.1	14	0.6	6.0	0.4	5.8	0.1	2.3	27	0.4	8.6	0.3
Striped Bass	25	<0.05	8.0	0.8	9.4	3.0	11	<0.05	-	31	0.2	38	0.3
Morone Species	-	-	6.6	0.2	1.2	0.1	2.7	<0.05	-	2.9	<0.05	2.9	<0.05
Bluefish	-	-	-	-	-	<0.05	-	<0.05	-	-	-	-	-
Weakfish	-	0.3	-	1.2	-	2.2	0.1	0.7	-	-	0.4	<0.05	<0.05
Hogchoker	-	-	-	<0.05	-	<0.05	-	-	-	-	-	-	-
Spottail Shiner	<0.05	0.3	<0.05	0.6	<0.05	0.2	<0.05	0.3	-	<0.05	0.3	<0.05	0.1

(a) Season 1 is January–March, 2 is April–June, 3 is July–September.
(b) – indicates no identified observation.
Units = percent

The purpose of this analysis is to determine the potential for adverse impacts to the aquatic resources of the Hudson River estuary associated with the operation of IP2 and IP3 once-through cooling systems during the relicensing period. The National Environmental Policy Act, as amended (NEPA), requires an ecologically relevant analysis of potential impacts that is more holistic than a general fisheries biology approach. Fisheries biology tends to focus on single species issues, such as sustaining a harvest rate, no matter what the effect may be on other species within the system. Thus, although still simplistic, this analysis considers potential impacts across trophic levels.

The operation of the IP2 and IP3 cooling systems can directly affect the aquatic communities of the Hudson River through impingement, entrainment, or thermal releases. Loss of YOY, yearling and older fish, blue crabs (*Callinectes sapidus*), and other aquatic species can occur from impingement against intake screens. Eggs, YSL, post-yolk-sac larvae (PYSL), and juvenile fish and invertebrates small enough to pass through the intake screens (9.5-mm or 0.375-in. square mesh) may become entrained within the intake units of the once-through cooling system and experience adverse effects associated with mechanical, chemical, and thermal stressors. Releases of heated noncontact cooling water through subsurface diffuser ports into the Hudson River can result in heat- or cold-shock effects. Cooling system operation can also result in indirect effects to aquatic resources. Impingement may injure, stun, or debilitate an organism, reducing its ability to avoid predation, capture prey, or grow and reproduce in a normal manner. Entrainment of larval or small juvenile forms not resulting in death may reduce viability or survival success. Entrainment can also create an indirect adverse impact to estuarine food webs by removing potential prey items from predators, or altering and redistributing the aquatic organic carbon represented by entrained organisms. In addition, the release of heated water can result in sublethal effects, including changes in reproduction or development, increased susceptibility to other environmental stressors, or behavioral changes associated with avoiding thermal plumes.

Evaluating the potential for adverse impacts of the IP2 and IP3 cooling systems to the aquatic resources of the Hudson River estuary presents a significant challenge for a variety of reasons. First, the potential stressor of interest (the IP2 and IP3 cooling systems) occupies a fixed position on the Hudson River, while RIS associated with the Hudson River generally have large spatial and temporal distributions that can change for each life stage. Thus, evaluation of causal relationships between potential stressors and receptors is difficult and requires a systems-level understanding that may not be possible with existing environmental information. Second, the Hudson River estuary represents a dynamic, open-ended system containing a complex food web that is hydrologically connected from freshwater locations near the Troy Dam to the Atlantic Ocean. Detectible trends at population levels that suggest adverse effects may be attributable to a variety of anthropogenic and natural stressors, including the activities at IP2 and IP3. Finally, because the Hudson River estuary represents a complex system with hundreds of aquatic species, it is necessary to focus primarily on a subset of RIS. While this simplifies the assessment of impact, it also introduces additional uncertainties that must be acknowledged and addressed.

The GEIS defines impingement, entrainment, and heat shock from cooling system operation as Category 2 issues requiring site-specific review. Levels of impact associated with these issues are defined as potentially SMALL, MODERATE, or LARGE, consistent with the criteria that the NRC established in Footnote 3 to Table B-1, Appendix B, 10 CFR Part 51, as follows:

- SMALL—Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.
- MODERATE—Environmental effects are sufficient to alter noticeably, but not to destabilize, any important attributes of the resource.
- LARGE—Environmental effects are clearly noticeable and are sufficient to destabilize any important attributes of the resource.

To evaluate whether the operation of the IP2 and IP3 cooling systems adversely affects RIS, NRC Staff employed a modified weight-of-evidence (WOE) approach as represented in Figure H-6. The approach used impingement and entrainment monitoring data obtained from the IP2 and IP3 facilities, data from the lower Hudson River collected during the Long River Survey (LRS), Fall Juvenile/Fall Shoals Survey (FJS/FSS), and Beach Seine Survey (BSS), as described in Table 2-3 in the main text, and coastal fishery trend data, when available. Lines of evidence (LOE) associated with the population trends and strength of connection were developed. The WOE is a technique used to integrate multiple LOE, or types of variables, to make a single decision concerning the magnitude of impact and its association with a potential stressor (IP2 and IP3 cooling systems). The WOE approach employed was based on Menzie et al. (1996) and consisted of the following steps depicted in Figure H-7:

(1) Identify the environmental component or value to be protected.

(2) Develop LOE and quantifiable measurements to assess the potential for adverse environmental effects and evaluate whether the IP2 and IP3 cooling systems are contributing to the effect.

(3) Quantify the use and utility of each measurement for supporting the impact assessment.

(4) Develop quantifiable "decision rules" for interpreting the results of each measurement.

(5) Use the WOE to integrate the results, assign a level of potential impact, and determine if adverse effects in RIS populations, if present, are related to the operation of the IP2 and IP3 cooling systems.

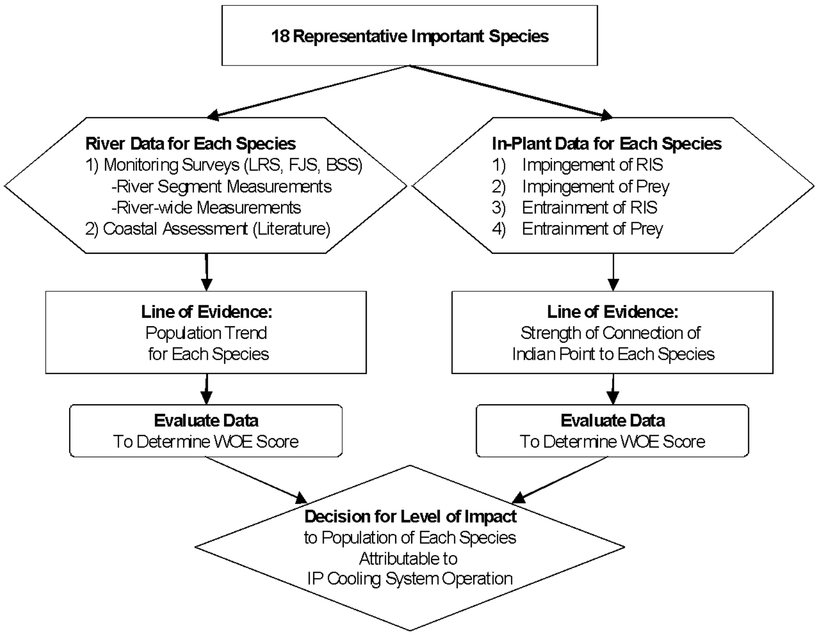


Figure H-6 General weight-of-evidence approach employed to assess the level of impact to population trends attributable to IP cooling system operation

These steps are discussed below in more detail. Supporting information for the statistical analyses used in this determination is presented in Appendix I. A WOE approach was not used to evaluate thermal effects, because recent monitoring or modeling data were not available.

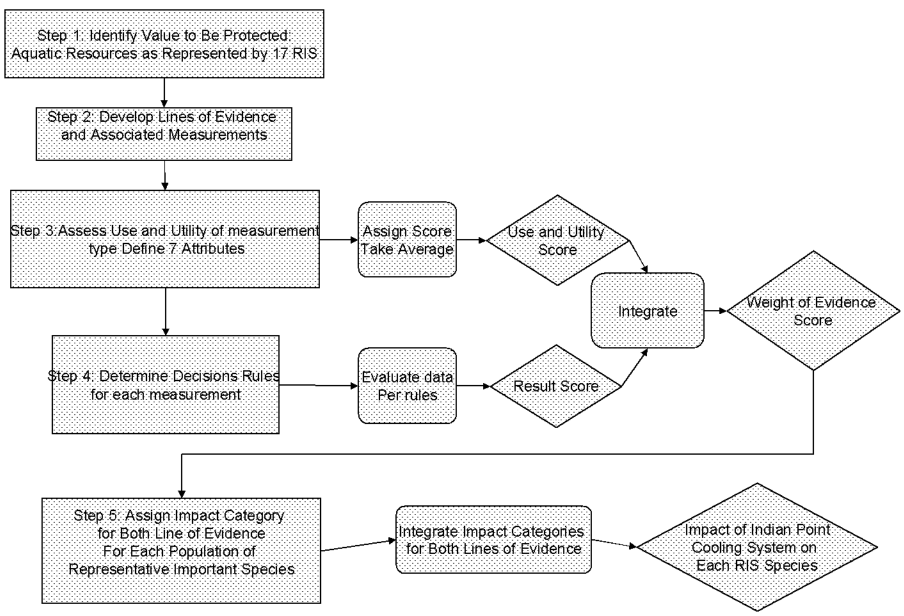


Figure H-7 Steps used to conduct the weight-of-evidence assessment

Step 1: Identify the Environmental Component or Value To Be Protected

For this assessment, the environmental component to be protected is the Hudson River aquatic resources as represented by the 18 RIS identified in Table 2-4 in the main text. These species represent a variety of feeding strategies and food web classifications and are considered ecologically, commercially, or recreationally important. The WOE approach focuses primarily on the potential impacts to YOY and yearling fish and their food sources. Although eggs, larvae, and PYSL are important components to the food web, the natural mortality to these life stages is high, as noted by Barnthouse et al. (2008) and Secor and Houde (1995). In contrast, fish surviving to YOY and older are more likely to add to the adult breeding population and are at greater risk from the cooling system operation. Any factor that increases (or decreases) the survival of those fish during juvenile and yearling stages can affect the sustainability of the population.

The conceptual model considers that the dynamics of the system are subject to large changes based on a wide variety of controlling factors. Phytoplankton and zooplankton communities form the basis of the food web and are used by a variety of fish and invertebrates during their development from larvae to adults. Plankton abundances generally increase during the spring and summer, coinciding with the emergence of larval and juvenile forms of fish and invertebrates after spawning. For some species, such as striped bass, PYSL and juvenile forms initially eat small, planktonic prey, then switch to larger prey as they grow. For other species, such as herring and alosids, adults remain planktivores. Predator-prey relationships within the estuary are complex and are influenced by a variety of physical, chemical, spatial, and temporal factors. Within this system, predation may be inter- or intraspecific, and operate at a variety of levels simultaneously. There are also a variety of controlling factors that may exert influence on the estuarine food web and inhabitants of the estuary. Physical and chemical fluctuations can serve as cues for reproduction and promote or inhibit growth, the nature and extent of predation can result in shifts in food web dynamics, and the influence of invasive or exotic species and anthropogenic activities can affect year-classes or result in long-term changes to populations.

After reviewing available information, the NRC staff could not determine if the operation of the IP2 and IP3 cooling systems is adversely affecting the RIS through the phytoplankton and zooplankton populations present near the facilities. It is possible, however, that the entrainment of these food web constituents can alter or influence the food web by removing potential prey items from the water column and reintroducing and redistributing them in the river in an altered state. As a result, the form and distribution of organic carbon can be fundamentally changed, even though the overall mass-balance remains the same. A similar effect may exist for larval forms that experience entrainment and are thus unavailable in their natural state for predation. Impingement losses may also alter the food web by removing potential predator or prey items from the system or by changing the dynamics of the relationships at critical periods. At the higher levels of the food web, large predators such as bluefish, weakfish, and striped bass may be affected by alterations to the food web in ways that are not always obvious. For instance, work by Baird and Ulanowicz (1989) suggested that, even though striped bass and bluefish in the Chesapeake Bay ecosystem were both piscivorous predators, 63 percent of the bluefish intake depended indirectly on benthic organisms, whereas striped bass depended mainly on planktonic organisms.

Within this food web context, the IP2 and IP3 cooling systems can be viewed as hybrid predators. Although the operation of the cooling water systems exerts a predatory effect at

multiple levels within the estuarine food web, the fixed position of the plants in the environment, their relatively continuous operation, and their lack of sensitivity to traditional environmental stressors that affect predators place them in a unique position within the estuarine system. The cooling system also functions as an environmental sampling device through impingement and entrainment. To fully explore the potential adverse impacts of cooling system operation to the aquatic resources of the Hudson River estuary, it is necessary to examine both the direct impacts associated with losses caused by impingement, entrainment, and heat, and the indirect impacts of these potential stressors that may work through the food web and contribute to detectible long-term changes to RIS populations.

Step 2: Identify Lines of Evidence and Quantifiable Measurements

The LOE and measurements used by NRC Staff to assess the impacts of the IP2 and IP3 cooling systems on RIS in the Hudson River estuary are presented in Table H-8. The first LOE (LOE-1) was a population-trend analysis using data from the three surveys conducted for the Hudson River utilities and from recent coastal fisheries information, when available. Population trends over time are often used to assess long-term changes in population abundance or species composition and to provide information on sustainability.

For Measure 1-1, the river-segment trends were based on the fish caught within River Segment 4 (IP2 and IP3) or, if this sampling area had a consistently low catch, an adjoining segment (River Segments 2 through 6), whichever had a greater catch (Figure 2-6 in the main text). The river-segment data were the weekly catch-per-unit-effort (CPUE) and catch density from the FJS, BSS, and LRS. The annual estimate of the population response was the 75^{th} percentile of the weekly data for a given year, because it was not as sensitive as the mean to the few large observations collected each year.

For Measure 1-2, riverwide population trends were based on the annual CPUE and the annual abundance index derived by the applicant. Commercial harvest data were used to represent coastal population trends. Population trends also formed the basis of the WOE analysis used by the NRC staff to assess the cumulative impacts of IP2 and IP3 activities, as well as other anthropogenic and natural environmental stressors, including the potential effects of zebra mussels in the freshwater portion of the Hudson River.

Table H-8 Lines of Evidence and Measurements Used To Assess Cooling System Impacts

LOE-1: ASSESSMENT OF POPULATION TRENDS OF RIS	
Measurement 1-1	River-segment RIS population trends from FSS and BSS (and LRS for tomcod)
Measurement 1-2	Riverwide RIS population trends from FSS and BSS (and LRS for tomcod)
Measurement 1-3	Coastal population trends from State or Federal regulatory agency databases

Table H-8 (continued)

LOE-2: ASSESSMENT OF STRENGTH OF CONNECTION	
Measurement 2-1	Impingement of RIS
Measurement 2-2	Entrainment of RIS
Measurement 2-3	Impingement of RIS prey
Measurement 2-4	Entrainment of RIS prey

The second LOE (LOE-2) measures the strength of the connection between the operation of the IP2 and IP3 cooling systems and the aquatic resources in the Hudson River. NRC Staff derived measurements of connection strength from monitoring data at IP2 and IP3 from 1975–1990 that provide information on impingement and entrainment rates for RIS and prey of RIS. As discussed above, the operation of the cooling system can result in direct mortality of RIS or may debilitate or damage organisms in a manner that causes latent mortality.

Impingement and/or entrainment can also remove and reintroduce RIS prey into the aquatic system in a manner that alters food web dynamics and produces indirect effects that may result in decreased recruitment, changes in predator-prey relationships, changes in population feeding strategies, or movements of populations closer to or farther away from the cooling system intakes or discharges. Staff based the analysis of impingement on the concordance of two ranked proportions. The first proportion was the ratio of the number of YOY and yearling fish of each species impinged in relation to the sum of all fish impinged. The second proportion was the ratio of each species abundance in the river near IP2 and IP3 relative to the total abundance of all 18 RIS. A large rank for both proportions would mean that the proportion impinged for the given RIS and the proportion abundance in the river were both large. The ratio of these two ranks would then be close to 1, suggesting that the stationary sampler was sampling proportionately to the abundance in the river (a medium strength of connection).

Likewise, NRC Staff based the effects of entrainment on the concordance of two ranked proportions. The first proportion was the estimated number entrained for all life stages for a given species in relation to the abundance of all fish entrained. The second proportion was the ratio of each species abundance in the river near IP2 and IP3 relative to the total abundance of all RIS. The estimated number entrained was the sum of the mean density for each life stage and sampling date within a given quarter of the year multiplied by the volume of circulated water (flow). Staff also considered potential food web impacts to RIS associated with the loss of prey caused by impingement or entrainment, based on the relationship presented in the conceptual model.

Step 3: Quantify the Use and Utility of Each Measurement

The following attributes of each measurement within each LOE were adapted from Menzie et al. (1996) and were assigned an ordinal score corresponding to a ranking of its use and utility as low (1), medium (2), or high (3).

(1) Strength of Association Between the Measured Parameter and the Aquatic Community—the extent to which the measurement parameter is representative of, correlated with, or applicable to the assessment of the target fish community

(2) Stressor-specificity—the extent to which the measurement parameter is associated with the specific stressor (e.g., impingement mortality)

(3) Site-specificity—the extent to which data, media, species, environmental conditions, and other factors relate to the site of interest

(4) Sensitivity of the Measurement Parameter for Detecting Changes—the ability to detect a response in the measurement parameter

(5) Spatial Representativeness—the degree of compatibility between the study area, location of measurements or samples, locations of stressors, and locations of biological receptors and their points of exposure

(6) Temporal Representativeness—the temporal compatibility between the measurement parameter and the period during which effects of concern would occur

(7) Correlation of Stressor to Response—the degree to which a correlation is observed between levels of response, and the strength of that correlation

Staff then calculated overall use and utility scores for each measurement within each LOE as the average of the individual attribute scores. For a given LOE, the average score for all attributes was used to characterize the overall use and utility of the measurement as low, medium, or high, using the following definitions:

- low use and utility—overall score of <1.5 (questionable for decision-making)
- medium use and utility—overall score of ≥ 1.5 and ≤ 2 (adequate for decision-making)
- high use and utility—overall score of >2 (very useful for decision-making)

The results of these evaluations are presented for each LOE and supporting measurements in Tables 4-2 and 4-3. For LOE-1, RIS population trends, measurements with the highest use and utility are those that provide information on long-term trends in RIS populations at river-segment and riverwide scales (Table H-9). Comprehensive data sets extending over 30 years yield high use and utility for assessing impacts. As measurements of populations become more spatially distributed, the ability to use the measurement to assess impacts associated with IP2 and IP3 decreases.

When assessing the strength of the connection between the IP2 and IP3 cooling systems and the aquatic environment (i.e., the ability of the IP2 and IP3 cooling systems to affect RIS populations in the Hudson River estuary), measurements associated with loss of prey caused by entrainment have the highest use and utility values (Table H-10) because stressor-specificity is higher than for the other measures. Even though the sensitivity of the measure is lower because of food web complexities, the loss of a food base for YOY predators has a greater

impact on more individuals than the direct loss of single individuals. While the evaluation of food-web impacts associated with the impingement and entrainment of RIS prey is complex, other investigators have found that alterations to lower levels of complex food web relationships result in measurable impacts at higher trophic levels. For instance, work by Ulanowicz (1995) suggests that when ecosystems are disturbed or stressed, the resulting changes in carbon flow can result in the disappearance of higher trophic-level predators or a reallocation of trophic positioning at the higher levels. Frank et al. (2007) report the potential for a "top-down" response that can affect lower trophic level prey items, though the existence of this phenomenon is debatable.

Table H-9 Use and Utility of Each Measurement Type To Evaluate RIS Population Trends Potentially Associated with IP2 and IP3 Cooling System Operation

Use and Utility Attribute	River-Segment RIS Community Trends	Riverwide RIS Community Trends	Coastal RIS Community Trends
Strength of Association between Measurement and Community Response	3	2	1
Stressor-specificity	2	1	1
Site-Specificity of Measurement in Relation to the Stressor	2	1	1
Sensitivity (Variability) of Measurement	2	2	1
Spatial Representativeness	3	2	1
Temporal Representativeness	3	3	3
Correlation of Stressor to Response	2	1	1
Overall Utility Score	2.4	1.7	1.3
Overall Assessment[a]	High	Medium	Low

(a) Overall Assessment: scores <1.5: low utility (questionable use for decision-making); 1.5≤ scores ≤2.0: medium utility (adequate for decision-making); scores >2.0: high utility (very useful for decision-making)

Table H-10 Use and Utility of Each Measurement Type To Evaluate the Strength of Connection between the IP2 and IP3 Cooling Systems and Hudson River RIS Populations

Use and Utility Attribute	RIS Impinged	RIS Entrained	RIS Prey Impinged	RIS Prey Entrained
Strength of Association between Measurement and Community Response	1	1	1	3
Stressor-Specificity	2	2	2	3
Site-Specificity of Measurement in Relation to the Stressor	2	2	2	2
Sensitivity (Variability) of Measurement	2	1	2	1
Spatial Representativeness	3	3	3	3
Temporal Representativeness	2	1	2	1
Correlation of Stressor to Response	1	1	2	2
Overall Utility Score	1.9	1.6	2.0	2.1
Overall Assessment[a]	Medium	Medium	Medium	High

(a) Overall Assessment: scores <1.5: low utility (questionable use for decision-making); 1.5 ≤ scores ≤2.0: medium utility (adequate for decision-making); scores >2.0: high utility (very useful for decision-making)

Step 4: Develop Quantifiable Decision Rules for Interpreting the Results of Each Measurement

For all population trend assessments in the first LOE, NRC Staff used a two-step process to assign the level of potential for an adverse impact suggested by a given measurement. The first step was to evaluate the shape of the resulting best-fit model and the second step was to evaluate the annual variability in the data to determine whether or not the abundance data could support a claim of potential adverse impact. The shape of the trend data was evaluated using simple linear regression and segmented regression as a function of time with a single join point (see the statistical approach below and Appendix I for specific details). The segmented regression analysis allowed a delayed response and two time periods to evaluate trends. The model with the smallest error mean square was chosen as the better fit and used to assess the level of potential adverse impact. In the second step, staff used the proportion of data outside a defined level of noise to assess whether the potential adverse impact could be supported.

Based on four possible outcomes, the following decision rules were used to evaluate RIS population trend data. A population trend result score of either 1, 2, or 4 is assigned as follows:

- A SMALL potential for an adverse impact to an RIS population was determined if population trends had slopes that were not significantly different from zero (i.e., no detectable slope) and had ≤40 percent annual abundances falling outside a predetermined level of noise (defined here as +/-1 standard deviation from the mean of the first 5 years of data). This suggested that the RIS population had not changed detectably over time, and adverse environmental impacts were unlikely. Measurements satisfying this description were assigned a result score of 1.

- A MODERATE potential for an adverse impact to an RIS population was determined if population trends had slopes that were not significantly different from zero (i.e., no detectable slope) but had greater than 40 percent of abundance observations outside the defined level of noise. If this response was observed, an adverse environmental impact was probable. Measurements satisfying this description were assigned a result score of 2.
- A MODERATE potential for an adverse impact to an RIS population was determined if population trends with slopes that were significantly different from zero (i.e., detectable slope) but had ≤40 percent annual abundances falling outside a predetermined level of noise. If this response was observed, an adverse environmental impact was probable but estimated below the detection limit set by the annual variability. Measurements satisfying this description were assigned a result score of 2.
- A LARGE potential for an adverse impact to an RIS population was determined if population trends had slopes that were significantly different from zero (i.e., detectable slope) and had greater than 40 percent of annual abundance outside the defined level of noise (i.e., support for potential impact). This response was considered clearly noticeable, and an adverse environmental impact was likely. Measurements satisfying this description were assigned a result score of 4.

This "1224" ranking is sometimes called "standard competition ranking."

To evaluate the strength of connection between the operation of the IP2 and IP3 cooling systems and the observed RIS population declines, decision rules were developed for assessing the influence of impingement and entrainment directly on RIS and the potential effects on RIS food web dependencies caused by loss of prey to impingement and entrainment. Details of the development of the ratio of ranked proportions are discussed in the statistical approach below and in Appendix I. A strength-of-connection result score of 1, 2, or 4 is assigned as follows:

- Low Strength of Connection: The ratio of ranked proportions of impinged or entrained RIS or RIS prey relative to total impingement or entrainment and the ranked proportion of the population size in the river relative to the total RIS abundance is less than 0.5. The species is considered underrepresented in the cooling system impingement or entrainment samples, and thus, there is minimal evidence to suggest the IP2 and IP3 cooling systems are affecting the RIS. Measurements satisfying this description were assigned a result score of 1.
- Medium Strength of Connection: The ratio of ranked proportions of impinged or entrained RIS or RIS prey relative to total impingement or entrainment and the ranked proportion of the population size in the river relative to the total RIS abundance is greater than or equal to 0.5 and less than 1.5. The species is considered proportionally represented in the cooling system impingement or entrainment samples, and thus, there is some evidence to suggest the IP2 and IP3 cooling systems are affecting aquatic resources. Measurements satisfying this description were assigned a result score of 2.
- High Strength of Connection: The ratio of ranked proportions of impinged or entrained RIS or RIS prey relative to total impingement or entrainment and the ranked proportion of the population size in the river relative to the total RIS abundance is greater than or

equal to 1.5. The species is considered overrepresented in the cooling system impingement or entrainment samples, and thus, there is strong evidence to suggest the IP2 and IP3 cooling systems are affecting the RIS. Measurements satisfying this description were assigned a result score of 4.

Step 5: Integrate the Results and Assess Impact

NRC Staff derived separate WOE scores for the population trend LOE and the strength of connection LOE. The above decision rules enabled the NRC to assign levels of impact to RIS populations and strength of connection between the IP2 and IP3 cooling systems and the observed RIS population declines with the weighted mean equation:

$$\text{WOE Score} = \frac{\sum_i (\text{overall utility score}_i)(\text{decision rule result score}_i)}{\sum_i \text{overall utility score}_i},$$

where i = 1 to the number of measurements; the overall utility score$_i$ is defined in Tables H-9 and H-10; and the result score$_i$ equals 1, 2, or 4, based on the above decision rules.

For population trend analyses, impact categories were defined as follows:

- small impact: WOE score <1.5
- small–moderate impact: WOE score = 1.5
- moderate impact: WOE score >1.5 but <2.0
- moderate–large: WOE score = 2.0
- large: WOE score >2

Staff used a similar scaling system to evaluate the strength of connection between the operation of the IP2 and IP3 cooling systems and the observed RIS population decline, using the primary scaling terms low, medium, and high.

The resulting impact categories for the population trend and strength of connection LOE were then integrated by applying the logic developed by EPA for evaluating the ecological effects of environmental stressors (EPA 1998). Ecological risk assessment (EPA 1998) requires a connection between the stressor and the response to assign any level of impact. For the purpose of this assessment, the stressor is the IP2 and IP3 cooling systems, while the receptor is the aquatic community, as represented by the RIS populations, and the degree of exposure is quantified by the strength of connection.

Statistical Approach for Each Line of Evidence

The decision rules developed above to determine the level of adverse impact to the aquatic resources of the Hudson River estuary associated with the operation of the IP2 and IP3 once-through cooling systems use (1) population trend data to provide a measure of potential impacts to the aquatic resources, and (2) impingement and entrainment data to provide a measure of the strength of connection between IP2 and IP3 operations and the aquatic environment. The statistical approach used to evaluate each measurement is described below. Results were

compared to the decision rules to assign a result score that was then integrated using the weighted mean presented above. WOE was then used to integrate the measures of potential impact with the measures of strength of connection to assign a level of impact attributable to the operation of the IP2 and 3 cooling systems.

<u>Statistical Approach to Assessing Long-Term RIS Population Trends</u>: Simple linear regression and segmented regression with a single join point were statistically fit to an annual measure of abundance (y) for each RIS using Prism Version x, 2005. The form of the segmented regression model was:

$$y = \begin{cases} a + S_1 x \text{ for } x < J_p \\ a + J_p(S_1 - S_2) + S_2 x \text{ for } x \geq J_p \end{cases}$$

where x was the year, *a* was the intercept, S_1 and S_2 were early (associated with years < J_p) and recent slopes of the line, and J_p was the estimated point in time when the slope changed (i.e., the join point). The model with the smallest mean squared error (MSE) was chosen as the better fit to the data. If the best-fit model was the simple linear regression and the slope was statistically significant (negative or positive, $\alpha = 0.05$), a population trend was detected. If the slope was not significantly different from zero, then a population trend was not detected. If the best-fit model was the segmented regression and either slope, S_1 or S_2, was statistically significant ($\alpha = 0.05$), then a population trend was considered detected. If both slopes S_1 and S_2 were not significantly different from zero ($\alpha = 0.05$), then the trend was not considered detected. Note that an NRC impact level of small (value = 1) was defined as the lowest level of potential adverse impact.

To evaluate whether abundance data were indicative of potential aquatic impacts, staff standardized all data by subtracting the mean of the first 5 years of data and then dividing by the standard deviation based on all years of data. The first 5 years (1979–1983) were chosen as the standard because the CV of abundance either leveled out at n = 5, or it was preceded by a rapid change in direction (Figure H-8). For density and CPUE data, staff compared population trends between the BSS and FJS to determine if the shift from the epibenthic sled to the beam trawl in 1985 was influencing the shape of the response. If the FJS data had standardized observations consistently less than the standardized BSS data after 1985, then the FJS data were split into pre- and post-1985 for analysis.

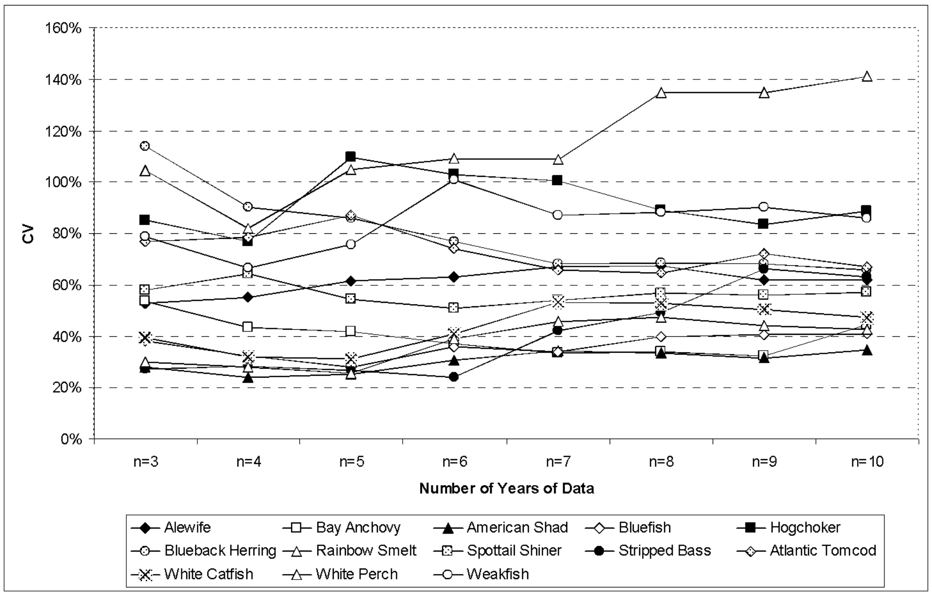


Figure H-8 Coefficient of variation of the abundance index for an increasing number of data points (data from Entergy 2007b)

An assessment of adverse impact was only supported if greater than 40 percent of the standardized observations were outside the bounds of ± 1. For a normal bell-shaped distribution with a mean of zero and a standard deviation of one, 32 percent of the observations are outside the bounds of ± 1 standard deviation (Snedecor and Cochran 1980). Thus, observations outside the boundaries of ±1 standard deviation from the mean of the first 5 years were considered outside of the natural variability (noise). If greater than 40 percent of the standardized observations were outside this defined level of noise, then a potential for adverse impact was considered supported. Table H-11 provides an overview of the eight possible outcomes for the assessment.

Table H-11 Comparison of Possible Outcomes When Assessing Population Trends of RIS in the Hudson River Studies

Best-fit Model	Statistical Outcome		Potential for Impact and Result Score
	Significant Slope(s)	Noise[1]	
Simple Linear Regression	No	No	Small—1
	No	Yes	Moderate—2
	Yes	No	Moderate—2
	Yes	Yes	Large—3
Segmented Regression	Neither	No	Small—1
	Neither	Yes	Moderate—2
	Either or Both	No	Moderate—2
	Either or Both	Yes	Large—3

[1]Noise: Absolute values for 40 percent of standardized observations greater than 1.

<u>Statistical Approach to Assessing Strength of Connection</u>: To determine the strength of connection between the operation of the IP2 and IP3 cooling systems and the RIS that exist in the Hudson River near the facility, NRC Staff evaluated the two types of environmental samplers: (1) impingement and entrainment data obtained from the operators of IP2 and IP3 (a stationary environmental sampler along the shore of the Hudson) and (2) long-term aquatic resource studies conducted in the river by power plant operators under the supervision of State agencies (e.g. LRS, FJS, BSS). The null hypothesis was that the proportional representation of RIS obtained from the fishery studies should be equal to the proportional representation evident from the impingement and entrainment samples. The nature of this relationship was explored for each RIS, and the overall strength of connection was evaluated by comparing concordance of ranks as described below.

When evaluating the proportional representation, the focus is on comparing the results obtained from impingement and entrainment samples at the IP2 and IP3 facilities with the representation observed in the aquatic community near the facility. Using entrainment as an example, Table H-12 provides an overview of the three possible outcomes for the comparison.

Table H-12 Comparison of Possible Outcomes When Assessing Proportional Representation of RIS in Cooling System and Fishery Studies

Outcome	Result
$E_i / E_{RIS} = S_i / S_{RIS}$	The proportional representation of a given RIS in the cooling system entrainment samples (E_i / E_{RIS}) is equal to the proportional representation obtained from the fishery studies (S_i / S_{RIS}), suggesting the RIS is equally represented in both the cooling system samples and fishery studies.
$E_i / E_{RIS} < S_i / S_{RIS}$	The proportional representation in the cooling system entrainment samples is less than the representation observed in the fishery studies, suggesting the cooling system sampler is underrepresenting the Hudson River population near IP2 and IP3.
$E_i / E_{RIS} > S_i / S_{RIS}$	The proportional representation in the cooling system entrainment samples is greater than the representation observed in the fishery studies, suggesting the cooling system sampler is overrepresenting the Hudson River population near IP2 and IP3.

An estimate of the population abundance of a given species (S_i) in the vicinity of IP2 and IP3 was the maximum of the annual density of a given species caught (sum of FJS and BSS 75th percentile of weekly densities) in the river segment near IP2 and IP3 over all years (1975–1990). The estimate of the total RIS community abundance (S_{RIS}) caught in the vicinity of IP2 and IP3 was the sum of the maximum densities of each species. The estimated density of each species impinged or entrained was the 75th percentile of the annual density impinged or entrained over all years and the estimated density of all RIS impinged or entrained was the sum over all species. An estimate of E_i / E_{RIS} was the ratio of the density of an individual species

collected by the plant to the IP2 and IP3 river-segment CPUE plus the density entrained of that individual species. Because of the error and bias in estimating each of these parameters, only the ranks of each ratio were considered a reliable measure of connection. Thus, to estimate the overall strength of connections between the IP2 and IP3 cooling systems and the RIS in the Hudson River near the facility, the estimates of E_i / E_{RIS} and S_i / S_{RIS} for each species were ranked from 1 to 18, and then the ratio of the ranks was compared to the decision rules.

H.1.3.1. Assessment of Population Trends

Studies Used To Evaluate Population Trends

The Hudson River utilities conducted the LRS from 1974 to 2005 and targeted fish eggs, YSL, and PYSL from the George Washington Bridge (river mile (RM) 12) to the Federal Dam at Troy (RM 152), a total of 140 miles (CHGEC et al. 1999). Sampling was conducted during the spring, summer, and early fall, using a stratified random design based on 13 regions and three strata within each region (channel, shoal, and bottom). A 1-m^2 Tucker trawl was used to sample the channel strata; an epibenthic sled-mounted 1-m^2 net similar in design to the Tucker trawl was used to sample the bottom strata, and both gear types were used to sample the shoal strata. Because this survey targeted younger life stages, staff did not use the LRS in this analysis except for YOY Atlantic tomcod data.

The utilities' FJS, also known as the FSS, was conducted from 1974 to 2005 and targeted juveniles, yearlings, and older fish (CHGEC et al. 1999). Samples were collected on alternate weeks from the BSS between Manhattan (RM 0) and the Troy Dam (RM 152) using a stratified random design. Data were used to estimate the abundance of YOY and older fish in offshore habitats. Approximately 200 samples were collected each week from July to December. Between 1974 and 1984, a 1- m^2 Tucker trawl with a 3-mm mesh was used to sample the channel and a 1-m^2 epibenthic sled with a 3-mm mesh was used to sample the bottom and shoal strata. From 1985 to 2005, a 3-m beam trawl with a 38-mm mesh on all but the cod-end replaced the epibenthic sled. Bay anchovy, American shad, and weakfish were sampled with less efficiency with the beam trawl (NYPA 1986). Further, the number and volume of samples in the bottom and shoal strata were generally greater than 2.5 times those in the channel. Thus, all data were evaluated to determine if a shift in the gear type was affecting the observed trend. When the standardized FJS data were consistently less than the standardized BSS data after 1985, staff analyzed the pre- and post-1985 data separately.

The utilities' BSS was conducted from 1974 to 2005 and targeted YOY and older fish in the shore-zone (extending from the shore to a depth of 10 ft) (CHGEC et al. 1999). Samples were collected from April to December but generally every other week from mid-June through early October between the George Washington Bridge (RM 12) and the Troy Dam (RM 152). A 100-ft bag beach seine was used to collect 100 samples during each sampling period from beaches selected according to a stratified random design. A completed tow covers an area of approximately 450 m^2.

NRC Staff obtained coastal population trends for striped bass, American shad, Atlantic sturgeon, river herring, bluefish, Atlantic menhaden, and weakfish from commercial and recreational harvest statistics gathered by the Atlantic States Marine Fisheries Commission (ASMFC). Currently, the ASMFC Interstate Fisheries Management Program coordinates the

conservation and management of 22 Atlantic coastal fish species or species groups. For species that have significant fisheries in both State and Federal waters, the Commission works cooperatively with the relevant East Coast Regional Fishery Management Councils to develop fishery management plans. The Commission also works with the National Marine Fisheries Service to develop compatible regulations for Federal waters. For each of the managed species, the Commission conducts periodic stock assessments. Information on each of the managed species can be found at http://www.asmfc.org/.

Data from all three field surveys from the Hudson River Estuary Monitoring Program (LRS, FJS, and BSS) were provided for this analysis. The three data sets included the annual abundance index per taxon and life stage from 1974 through 2005, the annual total catch and volume sampled per taxon from 1974 through 2005, and the weekly total volume sampled, catch density, and total catch for each river segment and life stage for the 17 RIS fish from 1979 through 2005. The weekly volume, total catch, and catch density were the combined results of each gear type. Analysis of the river-segment and riverwide trends provided a measure of potential injury. Assessment of coastal harvest data obtained through the literature was conducted visually, using the same decision rules derived for the Hudson River data.

Metrics Used by NRC Staff To Evaluate Population Trends

Abundance Index

The abundance index for YOY for each species was based on the catch from a selected sampling program and used by the applicant and its contractors to estimate riverwide mean RIS abundances. The selection process considered the expected location of each species in the river, based on life-history characteristics and the observed catch rates from previous sampling. The abundance index was constructed to account for the stratified random sampling design used by each of the surveys. For the LRS and the FSS, sampling within a river segment was further stratified by river depth and sampled with a separate gear type. For blueback herring, alewife, bay anchovy, hogchoker, weakfish, and rainbow smelt, the YOY abundance index was based on the catch from a single gear type.

The LRS (L_A) and the FJS abundance index (F_A) were similarly constructed and provided unbiased estimates of the total and mean riverwide population abundance for selected species, respectively (Cochran 1997). For Atlantic tomcod, weeks 19 through 22 of the LRS samples were used to calculate the abundance index. The L_A is strictly a sum of the weighted average species densities over sampling weeks (w) instead of an average over weeks as for the F_A.

For the FJS and each gear type, F_A is constructed as a weighted mean of the average species density ($\bar{d}_{rsw}$) for a given river segment (r = 0 to 12), sampling stratum (s = 1 to 3), and week (w = 33 to 40), i.e., $F_A = \frac{1}{n}\sum_w \left(\frac{\sum_r \sum_s v_{rs}\bar{d}_{rsw}}{\sum_r \sum_s v_{rs}} \right) I(0,1)$ for n equal to the number of weeks sampled, v_{rs} equal to the volume of the given river segment and strata sampled, and the indicator function I(0,1) equaling 1 if a given week was sampled and 0 otherwise (CHGEC 1999). For the FJS, strata sampled were the channel, bottom, and shoal for a given river segment. Poughkeepsie and West Point river segments had the greatest channel volume, Poughkeepsie and Tappan Zee had the greatest bottom volume, and Tappan Zee had the

greatest shoal volume. Because the river segment associated with IP2 and IP3 did not have large bottom or shoal volumes, the abundance index would not be sensitive to changes in population trends within the vicinity of IP2 and IP3.

The construction of the BSS abundance index (B_A) provided an unbiased estimate of the mean riverwide population abundance for striped bass, white perch, American shad, bluefish, spottail shiner, and white catfish. A single gear type was used for all years; thus, B_A was constructed as a weighted average density or catch per haul ($\bar{c}_{rw}$) for a given river segment (r = 0 to 12) and week (w = 33 to 40), i.e., $B_A = \frac{1}{n}\sum_w \left(\frac{\sum_r W_r \bar{c}_{rw}}{\sum_r W_r} \right) I(0,1)$ for n equal to the number of weeks sampled, W_r equaled the number of beach segments in the sampling design for a given river segment, and the indicator function I(0,1) equaled 1 if a given week was sampled and 0 otherwise (CHGEC 1999).

Catch-Per-Unit-Effort

NRC Staff used the CPUE to evaluate riverwide and river-segment population trends and was defined for a given species as the sum of the fish caught within a given year divided by the total volume sampled. The CPUE for a given region is a biased (by the ratio of v_s/V) estimate of the population abundance, i.e.,

$$E(CPUE) = E\left(\frac{\sum_s y_s}{\sum_s v_s} \right) = \sum_s \frac{v_s}{V} \mu_s$$

where y_s is the number of fish caught in a given stratum (s = 1 to 3),

μ_s is the mean density of fish in a given stratum,

v_s is the volume sampled in the given stratum, and

V is the total volume sampled).

For the LRS and FJS, a greater fraction of the volume sampled was from the bottom and shoal strata; therefore, the CPUE from each river segment is not sensitive to changes in abundance associated with fish sampled in the channel. For the BSS, there was only one gear type (beach seine); thus, the CPUE from each river segment was equivalent to the density ($\bar{d}_{rsw}$) from the BSS. The river-segment CPUE from the BSS was not used in the analysis.

Staff assumed that the river-segment densities for each of the surveys provided by the applicant were the same average species densities, $\bar{d}_{rsw}$ and $\bar{c}_{rw}$, used to derive the abundance indices. Because multiple gear types were used in the LRS and FJS, the NRC staff assumes that the densities for each gear type probably represented a weighted average.

Analysis of Population Impacts

To assess potential impacts to RIS populations near the IP2 and IP3 facility and within the lower Hudson River, the NRC staff evaluated environmental data from FSS, BSS, and LRS studies, and coastal trends, when available. Detailed information is presented in Appendix I.

River Segment 4

To assess potential impacts to RIS populations near the IP2 and IP3 facilities, the NRC staff evaluated environmental data from FSS, BSS, and LRS studies for River Segment 4, which is located at river kilometers (RKM) 63–76 (RM 39–46) (Figure 2-6 in the main text). The two measurement metrics evaluated using the environmental data were density (estimated number of RIS per given volume of water provided by the applicant) and CPUE (number of RIS captured by the sampler for a given volume of water, derived by the NRC staff). Using these two metrics, the staff determined that potential moderate-to-large adverse population impacts were possible for many RIS, including alewife, bay anchovy, American shad, bluefish, hogchoker, blueback herring, rainbow smelt, spottail shiner, Atlantic tomcod, and white perch (Table H-13). A small potential for adverse population impacts was predicted for striped bass, white catfish, and weakfish. An impact determination for populations of Atlantic menhaden, Atlantic and shortnose sturgeon, gizzard shad, and blue crab could not be made, because these species were not routinely caught in the studies. As described above, the NRC staff defined a large population impact for this river segment and a given RIS as a statistically significant negative slope in population abundance, using regression analyses and an observation of greater than 40 percent of the abundance outside of the defined level of environmental noise, defined as +/- 1 standard deviation from the mean of the first 5 years of data. The decision rules for this analysis are found at the beginning of Section H-3; the complete analysis is presented in Appendix I.

Table H-13 Assessment of Population Impacts for River Segment 4

Lower Hudson River

Species	Density			Catch-per-Unit Effort		River Segment Assessment
	FJS	BSS	LRS	FJS	LRS	
Alewife	Large	Large	N/A[a]	Large	N/A	Large
Bay Anchovy	Large	Small	N/A	Small	N/A	Moderate to Large
American Shad	Large	Large	N/A	Large	N/A	Large
Bluefish	Small	Large	N/A	Large	N/A	Large
Hogchoker	Moderate	Large	N/A	Moderate	N/A	Large
Atlantic Menhaden	N/A	N/A	N/A	N/A	N/A	Unknown
Blueback Herring	Moderate	Moderate	N/A	Moderate	N/A	Moderate to Large
Rainbow Smelt	Moderate	N/A	N/A	Large	N/A	Large
Shortnose Sturgeon	N/A	N/A	N/A	N/A	N/A	Unknown
Spottail Shiner	N/A	Large	N/A	N/A	N/A	Large
Atlantic Sturgeon	N/A	N/A	N/A	N/A	N/A	Unknown
Striped Bass	Small	Small	N/A	Small	N/A	Small
Atlantic Tomcod	Moderate	N/A	Moderate	Small	Moderate	Moderate
White Catfish	Small	N/A	N/A	N/A	N/A	Small
White Perch	Small	Large	N/A	Large	N/A	Large
Weakfish	Small	N/A	N/A	Small	N/A	Small
Gizzard Shad	N/A	N/A	N/A	N/A	N/A	Unknown
Blue Crab	N/A	N/A	N/A	N/A	N/A	Unknown

(a) N/A: not applicable; YOY not present in samples

To assess potential population-level impacts to RIS for the lower Hudson River (RKM 0–245, RM 0–152) (Figure 2-6 in the main text), the NRC staff evaluated abundance index data provided by the applicant and CPUE data obtained from FJS, BSS, and LRS studies. Analysis of abundance index data suggested a large potential for adverse population impacts for three RIS (American shad, white catfish, white perch) and a moderate potential for adverse impacts for bay anchovy, blueback herring, Atlantic tomcod, and weakfish. A small potential for adverse population impacts was predicted for alewife, bluefish, hogchoker, rainbow smelt, spottail shiner, and striped bass (Table H-14). An assessment of impacts could not be made for Atlantic menhaden, Atlantic and shortnose sturgeon, gizzard shad, and blue crab, because few were caught during the monitoring studies. Assessment of population-level impacts using CPUE predicted a potential for moderate-to-large impacts for most RIS. The exceptions were small impacts for spottail shiner, striped bass, and weakfish (Table H-14). As described above, staff could not determine population-level impacts for five RIS.

Table H-14 Assessment of Population Impacts for the Lower Hudson River

Species	Abundance Index	CPUE			Riverwide Assessment
		FJS	BSS	LRS	
Alewife	Small	Moderate	Moderate	N/A[a]	Moderate
Bay Anchovy	Moderate	Small	Moderate	N/A	Moderate
American Shad	Large	Large	Small	N/A	Large
Bluefish	Small	Large	Moderate	N/A	Large
Hogchoker	Small	Moderate	Moderate	N/A	Moderate
Atlantic Menhaden	N/A	N/A	N/A	N/A	Unknown
Blueback Herring	Moderate	Large	Large	N/A	Large
Rainbow Smelt	Small	N/A	Large	N/A	Large
Shortnose Sturgeon	N/A	N/A	N/A	N/A	Unknown
Spottail Shiner	Small	Small	Small	N/A	Small
Atlantic Sturgeon	N/A	N/A	N/A	N/A	Unknown
Striped Bass	Small	Small	Small	N/A	Small
Atlantic Tomcod	Moderate	Moderate	Large	Moderate	Large
White Catfish	Large	N/A	Large	N/A	Large
White Perch	Large	Large	Large	N/A	Large
Weakfish	Moderate	N/A	Small	N/A	Small to Moderate
Gizzard Shad	N/A	N/A	N/A	N/A	Unknown
Blue Crab	N/A	N/A	N/A	N/A	Unknown

(a) N/A: not applicable; YOY not present in samples

<u>WOE Summary of Population Impacts</u>

To integrate all of the available RIS population data for IP2 and IP3 and the lower Hudson River, the NRC staff used a WOE analysis. An overview of this analysis is presented at the beginning of Section H-3; detailed information is presented in Appendix I. The results for this analysis are presented in Table H-15 and predict a moderate-to-large potential for adverse impacts for 13 of the 18 RIS. For two of these (Atlantic menhaden and Atlantic sturgeon), the moderate-to-large potential impact determination was based on only one LOE (coastal trends). A small potential for adverse population-level impacts is predicted for blue crab, based on only one LOE (coastal trends). An impact conclusion regarding the population impacts could not be reached for shortnose sturgeon because of a lack of available data. As described above, the conclusion of a large population impact is based on the detection of a significant negative slope using regression analyses and the observation that greater than 40 percent of the abundance observations were outside the defined level of noise. The decision rules for these analyses are found at the beginning of Section H-3; the complete analysis is presented in Appendix I.

1 **Table H-15 Weight of Evidence Results for the Population Trend Line of Evidence**

Measurement	River Segment Assessment Score	Riverwide Assessment Score	Coastal Assessment Score	WOE Score[(b)]	Impact Conclusion
Utility Score[(a)]	2.4	1.7	1.3		
Alewife	4.0	1.7	2	2.8	Large
Bay Anchovy	2.0	1.7	N/A[(c)]	1.9	Moderate
American Shad	4.0	3.0	4	3.7	Large
Bluefish	3.0	2.3	2	2.5	Large
Hogchoker	2.7	1.7	N/A	2.3	Large
Atlantic Menhaden	Unknown	Unknown	2	2[(d)]	Moderate to Large
Blueback Herring	2.0	3.3	2	2.4	Large
Rainbow Smelt	3.0	2.5	N/A	2.8	Large
Shortnose Sturgeon	Unknown	Unknown	N/A	Unknown	Unknown
Spottail Shiner	4.0	1.0	N/A	2.8	Large
Atlantic Sturgeon	Unknown	Unknown	4	4[(d)]	Large
Striped Bass	1.0	1.0	1	1	Small
Atlantic Tomcod	1.8	2.5	N/A	2.1	Large
White Catfish	1.0	4.0	N/A	2.2	Large
White Perch	3.0	4.0	1	2.8	Large
Weakfish	1.0	1.5	2	1.4	Small
Gizzard Shad	Unknown	Unknown	N/A	Unknown	Unknown
Blue Crab	Unknown	Unknown	1	1[(d)]	Small

(a) Overall Use and Utility Score: Low = < 1.5, Medium = ≥1.5 but ≤ 2.0, High = >2.0

(b) WOE Score: Small = <1.5; Small–Moderate = 1.5; Moderate = >1.5 but <2.0; Moderate–Large = 2.0; Large = >2.0

(c) N/A: Not applicable

(d) Impact assessment based only on coastal trends

H.1.3.2. Analysis of Strength of Connection

To determine whether the operation of the IP2 and IP3 cooling systems had the potential to influence RIS populations near the facility or within the lower Hudson River, the NRC staff conducted a strength-of-connection analysis. A summary of this analysis can be found at the beginning of Section H-3; detailed information on the analysis is presented in Appendix I. The strength-of-connection analysis assumes the IP2 and IP3 cooling systems can affect aquatic resources directly through impingement or entrainment and indirectly by impinging and entraining potential food (prey). By comparing the rank order of RIS caught in the river to the order observed in impingement and entrainment samples, it is possible to evaluate how efficient the IP2 and IP3 cooling systems are at removing RIS from the river (e.g., how strongly it is connected to the RIS of interest). The results of this analysis are presented in Table H-16 and show that a high strength of connection was observed for only two species (bluefish and striped bass). For those species, the IP2 and IP3 cooling systems were removing either the species or its prey at levels that were proportionally higher than those observed in the river studies. This suggests that there is strong evidence that the operation of the cooling systems is affecting these species. For the remaining RIS, the strength of connection ranged from low (minimal evidence of connection) to medium (some evidence of connection). The strength of connection was unknown for five species (Atlantic menhaden, Atlantic and shortnose sturgeon, gizzard shad, and blue crab, because of a lack of available data (Table H-16).

Table H-16 Weight of Evidence for the Strength-of-Connection Line of Evidence

Measurement	Impingement		Entrainment		WOE Score[b]	Strength of Connection
	RIS	Prey	RIS	Prey		
Use and Utility[a]	1.9	2.0	1.6	2.1		
Alewife	2[c]	1	2	1	1.5	Low to Medium
Bay Anchovy	2	1	2	1	1.5	Low to Medium
American Shad	2	1	2	1	1.5	Low to Medium
Bluefish	4	2	2	2	2.5	High
Hogchoker	4	1	2	1	2.0	Medium to High
Atlantic Menhaden	Unknown	1	Unknown	1	Unknown	Unknown
Blueback Herring	2	1	2	1	1.5	Low to Medium
Rainbow Smelt	2	1	4	1	1.9	Medium
Shortnose Sturgeon	Unknown	1	Unknown	1	Unknown	Unknown
Spottail Shiner	1	2	1	2	1.5	Low to Medium
Atlantic Sturgeon	Unknown	1	Unknown	1	Unknown	Unknown
Striped Bass	2	4	2	2	2.5	High

Table H-16 (continued)

Measurement	Impingement		Entrainment		WOE Score[b]	Strength of Connection
	RIS	Prey	RIS	Prey		
Atlantic Tomcod	2	1	2	1	1.5	Low to Medium
White Catfish	2	1	2	1	1.5	Low to Medium
White Perch	2	2	2	2	2.0	Medium to High
Weakfish	2	2	2	2	2.0	Medium to High
Gizzard Shad	Unknown	1	Unknown	1	Unknown	Unknown
Blue Crab	Unknown	1	Unknown	1	Unknown	Unknown

(a) Overall Use and Utility Score: Low = <1.5, Medium = ≥1.5 but ≤2.0, High = >2.0
(b) WOE Score: Low = <1.5; Low–Medium = 1.5; Medium = >1.5 but <2.0; Medium–High = 2.0; High = >2.0
(c) 1 indicates a low strength of connection, 2 indicates a medium potential, and 4 indicates a high potential

H.1.3.3. Impingement and Entrainment Impact Summary

The final integration of population-level and strength-of-connection LOE is presented in Table H-17. This table shows the final conclusions for both LOE—population trends and strength of connection. Assignment of an NRC level of impact (small, moderate, or large) requires information on both a measurable response in the RIS population and clear evidence that the RIS is influenced by the operation of the IP2 and IP3 cooling systems. Thus, when the strength of connection is low, it is not possible to assign an impact level greater than small, because of little evidence that a relationship between the cooling system and RIS exists. Conversely, for an RIS with a high strength of connection to the IP2 and IP3 cooling system operation but evidence of no population decline, the final determination must be small.

Based on the final WOE assessment, a small potential for adverse impacts was predicted for two species (striped bass and weakfish), because there was no evidence of a population decline, even though the strength of connection was medium or high. A small-to-moderate impact was predicted for seven species (alewife, bay anchovy, American shad, blueback herring, spottail shiner, Atlantic tomcod, and white catfish). A moderate impact was predicted for rainbow smelt, and a moderate-to-large impact level was predicted for the hogchoker and white perch. A large impact level was predicted for only one species, the bluefish, based on observed population declines and an apparent high strength of connection to the IP2 and IP3 cooling systems. The level of impact could not be restricted to less than the full range of from small to large for Atlantic menhaden, Atlantic and shortnose sturgeon, gizzard shad, and blue crab, because of a lack of data.

Table H-17 Impingement and Entrainment Impact Summary for Hudson River RIS

Species	Population Line of Evidence	Strength of Connection Line of Evidence	Impacts of IP2 and 3 Cooling Systems on Aquatic Resources
Alewife	Large	Low to Medium	Small to Moderate
Bay Anchovy	Moderate	Low to Medium	Small to Moderate
American Shad	Large	Low to Medium	Small to Moderate
Bluefish	Large	High	Large
Hogchoker	Large	Medium to High	Moderate to Large
Atlantic Menhaden	Moderate to Large	Unknown[(b)]	Unknown[(c)]
Blueback Herring	Large	Low to Medium	Small to Moderate
Rainbow Smelt	Large	Medium	Moderate
Shortnose Sturgeon	Unknown[(a)]	Unknown[(b)]	Unknown[(c)]
Spottail Shiner	Large	Low to Medium	Small to Moderate
Atlantic Sturgeon	Large	Unknown[(b)]	Unknown[(c)]
Striped Bass	Small	High	Small
Atlantic Tomcod	Large	Low to Medium	Small to Moderate
White Catfish	Large	Low to Medium	Small to Moderate
White Perch	Large	Medium to High	Moderate to Large
Weakfish	Small	Medium to High	Small
Gizzard Shad	Unknown[(a)]	Unknown[(b)]	Unknown[(c)]
Blue Crab	Small	Unknown[(b)]	Unknown[(c)]

(a) Population LOE could not be established using WOE; therefore, population LOE could range from small to large.
(b) Strength of connection could not be established using WOE; therefore, strength of connection could range from low to high.
(c) Conclusion of impact could not be established using WOE, therefore, impacts could range from small to large.

As described above, an impact determination of moderate, moderate to large, or large was attributed to four species—bluefish, hogchoker, rainbow smelt, and white perch, which are discussed below. What follows is a discussion of the analysis that supports this determination and the potential implications of the small determination of impact for the striped bass, a species believed to be in recovery, caused by fishing restrictions imposed in the mid-1980s.

Bluefish: Large Potential for Adverse Impact

The analysis of YOY bluefish population trends at IP2 and IP3 and the lower Hudson River, using data from FJS and BSS studies and a recent assessment by the National Oceanic and Atmospheric Administration (NOAA) for coastal trends, resulted in a determination of large impact (Table H-15). For the IP2 and IP3 population assessment (Table H-13), the BSS density metric and the FJS CPUE metric suggested a population decline that has persisted through time. For these metrics, a significant negative slope was observed, based on segmented

regression, and more than 40 percent of the observations were outside the defined level of environmental noise (+/- 1 standard deviation from the mean of the first 5 years of data). Based on the decision rules developed for population data, this was considered a large impact. The only LOE inconsistent with this finding was the small impact associated with FJS density. This LOE predicted a small population impact because there was not a significant negative slope and only a small number of observations (7 percent) were outside the defined level of environmental noise. The population assessment for the lower Hudson River (Table H-14) again showed moderate and large impacts based on BSS and FJS CPUE evaluations and a small potential for impact using the abundance index provided by the applicant. The latter conclusion was based on nonsignificant slopes from the segmented regression and a small number of observations outside the range of environmental noise. Coastal trend data provided by NOAA (Shepherd 2006) suggest that recreational catches have declined precipitously since the late 1980s. This appears to be consistent with the population-level impact assessment for the Hudson River conducted by the NRC staff.

Based on a comparison of FJS and BSS data with impingement and entrainment samples from IP2 and IP3, the rank-order analyses suggest the cooling system is removing a disproportionate number of bluefish from the Hudson River. Thus, the strength of connection for entrainment and impingement was medium and high, respectively (Table H-16). Juvenile bluefish feed on a variety of other fish, including bay anchovy, Atlantic silverside, striped bass, blueback herring, Atlantic tomcod, and American shad. To evaluate the strength-of-connection LOE, bay anchovy and Atlantic tomcod were assumed to be the primary prey. The rank order of these species in impingement and entrainment samples suggested the cooling system was removing an equally proportional number from the river relative to the proportion observed in the river near IP2 and IP3 that could affect YOY bluefish.

Combining the two LOE, the NRC staff arrived at a large potential for adverse impact for Hudson River bluefish from the operation of the IP2 and IP3 cooling systems. This assessment is based, in part, on the losses of bluefish from impingement. Based on the work conducted by Fletcher (1990) on field testing of the Ristroph screen system that was eventually installed at IP2 and IP3 in the early 1990s, impingement survival of bluefish is probably similar to that observed for striped bass (about 9 percent). Because studies to estimate impingement mortality were not conducted after Ristroph screen installation, it is not possible to confirm the assessments of Fletcher (1990). Thus, the staff's conclusion of impact for this species should be considered a conservative assessment.

<u>White Perch: Moderate-to-Large Potential for Adverse Impact</u>

To assess population-level impacts to the white perch near IP2 and IP3 and for the lower Hudson River, the NRC staff evaluated data from FJS and BSS river studies and coastal trends. For the assessment of the Hudson River population near IP2 and IP3, an analysis of BSS density and FJS CPUE data indicated a large potential for adverse impact (Table H-13). Both metrics produced a significant negative slope using segmented regression analysis. The percentage of observations outside the environmental noise was 70 percent for BSS density and 56 percent for FJS CPUE (Appendix I). The population assessment for the lower Hudson River (Table H-14) showed large impacts based on BSS and FJS CPUE evaluations and the abundance index provided by the applicant. The strength of connection assessment (Table H-16) for white perch indicated a medium-to-high degree of connection for all LOE (impingement and entrainment of YOY, impingement and entrainment of perch prey). This

suggests that the IP2 and IP3 cooling systems are removing both YOY and perch prey items (primarily bay anchovy) at levels that are equally proportional relative to their rank order in FJS and BSS environmental samples near IP2 and IP3. Because there was a large potential for adverse effects at the population level and a medium-to-high level of connection between the resource and the IP2 and IP3 cooling systems, the NRC staff concluded that the overall impact of the IP2 and IP3 cooling systems was moderate to large.

As described above, this assessment is based, in part, on the losses of white perch caused by impingement and entrainment. Based on the work conducted by Fletcher (1990), impingement survival of white perch was estimated to be 14 percent based on field-testing of the Ristroph screen system that was eventually installed at IP2 and IP3 in the early 1990s. Work by EA (1989) suggested entrainment mortality of white perch PYSL ranged from 30–92 percent (Table H-5). Because studies to estimate impingement mortality were not conducted after the Ristroph screen installation, it is not possible to confirm the assessments of Fletcher (1990). Thus, the staff's conclusion of impact for this species should be considered a conservative assessment.

Hogchoker: Moderate-to-Large Potential for Adverse Impact

Analysis of population data for YOY hogchoker near IP2 and IP3 (Table H-13) indicated a large potential for adverse impact. River-segment BSS density data had a significant negative slope, based on segmented regression and 78 percent of observations outside the defined level of environmental noise (Appendix I). River-segment FJS density and CPUE data suggested a moderate potential for adverse impact, based on the presence of a significant negative slope from the segmented regression and less than 40 percent of the observations outside the defined level of environmental noise (15 percent for both metrics). As described above, the environmental noise was defined as (+/- 1 standard deviation from the mean of the first 5 years of data). Trend analyses for the lower Hudson River produced a less pronounced effect in YOY populations, resulting in a moderate potential for impact based on Hudson River studies (Table H-14). Coastal trend data were not available.

The strength-of-connection analysis for hogchoker, using the rank order technique, indicated the proportion impinged by the IP2 and IP3 cooling systems was higher than would be expected, based on the densities observed in FJS and BSS studies (Table H-16). The proportion entrained was estimated to be equally proportional to the rank order in FJS and BSS environmental samples near IP2 and IP3. This resulted in an assessment of a medium-to-high strength of connection to the IP2 and IP3 cooling systems. Because hogchokers feed primarily on benthic invertebrates for which no sampling data are available, there was minimal evidence to suggest a connection between hogchoker prey species and the IP2 and IP3 cooling systems.

In the final analyses, the NRC staff concluded that there was a moderate-to-large potential for adverse impacts to the hogchoker from the operation of the IP2 and IP3 cooling systems. This assessment is due, in part, to the losses of this species from impingement. Work by Fletcher (1990) has suggested that impingement mortality for this species is approximately 13 percent for the Ristroph screen system installed at IP2 and IP3 in the early 1990s. Because studies to estimate impingement mortality were not conducted after Ristroph screen installation, it is not possible to confirm the assessments of Fletcher (1990). Thus, the conclusion of impact for this species should be considered a conservative assessment.

Rainbow Smelt: Moderate Potential for Adverse Impact

Population data for areas near IP2 and IP3 (River Segment 4) and the lower Hudson River were obtained from the FJS and BSS studies, using density and CPUE metrics and the abundance index provided by the applicant. For the area of the river near the IP2 and IP3 facilities, NRC analysis of FJS YOY data indicated a moderate (FJS density) and large (FJS CPUE) potential for adverse impacts (Table H-13). The moderate impact was determined from a significant negative slope from the segmented regression; however, less than 40 percent of the density observations were outside the defined environmental noise. The large impact observed with the FJS CPUE data was based on both a significant negative slope from the segmented regression and 78 percent of the observations outside the defined level of environmental noise (Appendix I). These findings are consistent with the disappearance of this species from the lower Hudson River beginning in 1995 (Daniels et al. 2005) and the listing of rainbow smelt as a Species of Concern by NOAA (2007). Evaluation of population trends for this species for the lower Hudson River (Table H-14) suggests a large impact based on BSS CPUE and a small impact based on the abundance index. Because the abundance index (derived for this species from the FJS channel data) may be more heavily influenced by population trends from the river segment near Poughkeepsie, because of a 1-to-2 times greater channel volume than other river segments with relatively greater populations of smelt (IP2 and IP3 to Cornwall), the NRC staff considers the CPUE metric to reflect the more biologically relevant result.

The staff finds the strength of connection between rainbow smelt and the IP2 and IP3 cooling systems is moderate for impingement and high for entrainment (Table H-16). Based on a rank-order comparison of catch statistics from FSS and BSS studies with entrainment sampling results, the proportion of rainbow smelt early life stages entrained at IP2 and IP3 is higher than would be expected from the catch statistics. YOY rainbow smelt feed on smaller fish but primarily on copepods, small crustaceans, and benthic invertebrates; thus, a low connection was determined for the impingement and entrainment of prey species. Because there is a large potential for adverse population impacts, coupled with an overall medium strength of connection, the NRC staff concluded that the impacts of the IP2 and IP3 cooling systems on this species are moderate. As described above, this assessment is caused, in part, by losses associated with impingement and entrainment. Fletcher (1990) does not report impingement mortality (Table H-5). Entrainment survival estimates are not available for this species. Because true impingement and entrainment mortality cannot be determined, the conclusion of impact for this species should be considered a conservative assessment.

Striped Bass: Small Potential for Adverse Impact

As described in Section 2 of the main text, striped bass appear to spend extended periods in the Hudson River. Based on concerns related to polychlorinated biphenyls (PCB) body burdens, the Hudson River commercial fishery was closed in 1976 (CHGEC 1999). As a result of commercial restrictions on harvesting supported by the Atlantic Striped Bass Conservation Act (1984), the fishery was declared to be in full recovery by 1995 (ASMFC 2006), and abundance levels have continued to increase in the Atlantic population. Although restrictions on both commercial and recreational fisheries have been relaxed because of the recovery of the population, the fisheries continue to be limited to State waters (within 3 nm of land), and the New York State's commercial fishery remains completely closed. While commercial landings have remained lower than the levels seen in the early 1970s, recreational landings have increased and, in 2004, made up 72 percent of the total weight harvested from the Atlantic stock (Shepherd 2006b).

Based on the above, one would expect that the population of YOY striped bass in the Hudson River would have increased from 1995 to the present. Riverwide analysis of YOY population trend data from FJS and BSS surveys (Table H-14 and Appendix I) indicate that YOY populations have increased only slightly above the environmental noise within the last few years of the studies and resulted in a small level of impact based on a WOE analysis. This trend is not evident elsewhere along the Atlantic seaboard, where YOY striped bass populations have increased since fishing restrictions were established (ASMFC 2006). Although the YOY population trends in the Hudson River do not represent a moderate or large adverse impact, the high strength of connection observed, caused by the impingement and entrainment of this species, and the loss of its prey, suggests that the IP2 and IP3 cooling systems may be inhibiting or limiting the abundance of YOY bass in the Hudson River, despite the apparent increase in adults elsewhere in the region.

H.2 Cumulative Impacts on Aquatic Resources

In addition to the potential impacts associated with the IP2 and IP3 CWIS described in Section H.3, it is possible that other natural or anthropogenic factors unrelated to the relicensing of Indian Point could influence the aquatic resources of the lower Hudson River. In this section, the NRC staff discusses and evaluates potential stressors that could contribute to the total impacts to the aquatic resources during the license renewal period. Potential stressors include other Hudson River facilities that withdraw water, the presence of zebra mussels in the freshwater portions of the river, fishing pressure associated with commercially and recreationally important species, habitat loss, interactions with other invasive species, and impacts associated with changes to water and sediment quality caused by short-term anthropogenic activities or long-term influences associated with global climate change.

Population trends should, in theory, reflect cumulative effects of all impacts on the population. Impacts attributable to the Indian Point cooling systems have already been analyzed. This section of the appendix concentrates on effects associated with the invasion of zebra mussels, using a WOE approach, as discussed in Section H.3. A qualitative assessment of effects associated with fishing pressure was also explored.

The NRC staff evaluated potential population-level impacts to RIS for the lower Hudson River (RKM 0–245, RM 0–152) (Figure 2-6 in the main text) in Section H.3.1. Riverwide data used in the analysis included the abundance index provided by the applicant and CPUE data obtained from FJS, BSS, and LRS studies. The results of this analysis were presented in Table H-14 and showed a large potential for adverse impacts for 7 of the 18 RIS caused by the CWIS.

An analysis conducted on behalf of Entergy (Barnthouse et al. 2008) used environmental risk-assessment techniques to evaluate the potential for adverse impacts to Hudson River RIS from a variety of natural and anthropogenic stressors, including the operation of the IP2 and IP3 CWIS, fishing pressure, the presence of zebra mussels, predation by striped bass, and water temperature. Barnthouse et al. (2008) concluded that the Indian Point CWIS had no effect on all seven of the RIS included in their study. Instead, the authors hypothesized that observed population declines in selected RIS were influenced by striped bass predation, mortality imposed by fishing, water temperature, and zebra mussel invasion.

Strayer et al. (2004) concluded that the abundance of juvenile American shad and white perch declined following the zebra mussel invasion. Further, the authors found that juvenile alewife abundance increased following the zebra mussel invasion. The NRC Staff's analysis follows.

Zebra Mussels

To evaluate the effects of zebra mussels, the NRC staff applied a WOE approach. It is important to note, however, that the Hudson River monitoring surveys used in these analyses were designed to evaluate the population abundance of selected species. They were not designed to evaluate competing and confounded factors affecting population abundance. Coincident measures of zebra mussel abundance through time, water quality, changes to thermal discharges, changes in fishing pressure, and predator-prey interactions would be a minimal requirement to begin to rank stressor effects on each population. These measures are not available, and so the remaining analyses should be viewed as the development of hypotheses of potential impacts associated with zebra mussels.

The NRC staff analyzed the impact of zebra mussels on RIS populations that were caught in River Segment 12 (Albany). The NRC staff analyzed the 75^{th} percentile of the weekly FJS and BSS density and CPUE data from this river segment and used this information to evaluate the population trend LOE for these species. Data for white perch, blueback herring, alewife, American shad, white catfish, spottail shiner, and striped bass were used in the analysis because all have high densities of YOY within this region. Only weeks 27 to 43 were used in the analysis for the FJS and weeks 22 to 43 for the BSS survey so that most years contained observations from the months July through October and June through October for each survey, respectively. Effects associated with changes in gear type for the FJS (1985) were also considered. Details of the analysis are presented in Appendix I.

Simple linear regression and segmented regression with a single join point were fit to the annual measure of abundance for each RIS, as described in Section H.3. If the estimated slope from the linear regression or either slope from the segmented regression, whichever was determined to be the better fitting model, was significantly less than zero, then an adverse population impact was considered detected. An assessment of adverse impact was only supported if more than 40 percent of the standardized observations were outside the bounds of ±1 standard deviation.

The strength of connection to a potential impact associated with a zebra mussel invasion was determined by the temporality of the observed change in population trends and the year associated with invasion of the zebra mussels in the Hudson River (1991) based on work by Strayer et al. (2004). For any stressor to be considered a potential cause of an impact, the stress must occur before the response (Adams 2003). For the assessment of the observed response, the year associated with a change in population trend was estimated by the join point from the segmented regression or was considered pre-1991, if the linear model was the better fit to the density and CPUE data collected from Region 12 (Albany area). If the join point was before 1991, then the strength of connection was defined as low. If the segmented regression did not converge or was not the better fitting model, the linear regression was used to suggest that there was no change in slope following invasion; thus, the strength of connection was low. If the join point from the segmented regression was after 1991, then the strength of connection was defined as high.

Based on the WOE analysis (see Appendix I for details) and the decision rules presented in Section H.3, the NRC staff determined potential moderate-to-large population impacts within

River Segment 12 (Albany) were possible for many RIS, including American shad, blueback herring, spottail shiner, white catfish, and white perch (Table H-18). A small potential for adverse population impacts was predicted for alewife and striped bass. The data tables for which the results of the strength of connection between adverse population impacts and the zebra mussel invasion are drawn are presented in Appendix I. None of the RIS evaluated had a statistically significant increase in population abundance in River Segment 12. The strength-of-connection analysis assumes that zebra mussels can affect aquatic resources indirectly by reducing potential food resources (prey) or by altering habitat (e.g. shelter). The results of the strength-of-connection analysis are presented in Table H-19 and show that a medium-to-high strength of connection was observed for all fish except white catfish.

Table H-18 Population Trends Postinvasion of Zebra Mussels in 1991 for Density and CPUE of YOY Collected from River Segment 12 (Albany)

Species	FJS Density	BSS Density	FJS CPUE	WOE	Hypothesized Level of Impact to Population Trend
Alewife	1	2	1	1.3	Small
American Shad	2	4	2	2.7	Large
Blueback Herring	2	2	2	2.0	Moderate to Large
Spottail Shiner	2	1	2	1.7	Moderate
Striped Bass	1	1	1	1.0	Small
White Catfish	1	N/A	4	2.5	Large
White Perch	2	2	2	2.0	Moderate to Large

N/A is not applicable; YOY are not present in samples.

Table H-19 Strength of Connection between Population Trends and Zebra Mussel Invasion

Species	FJS Density	BSS Density	FJS CPUE	WOE	Hypothesized Strength of Connection
Alewife	1	1	4	2.0	Medium to High
American Shad	4	1	1	2.0	Medium to High
Blueback Herring	1	4	1	2.0	Medium to High
Spottail Shiner	4	1	1	2.0	Medium to High
Striped Bass	1	1	4	2.0	Medium to High
White Catfish	1	N/A	1	1.0	Low
White Perch	1	4	1	2.0	Medium to High

N/A is not applicable; YOY are not present in samples.

The final integration of population-level and strength-of-connection LOE is presented in Table H-20. This table shows the final conclusions for both LOE—population trends and strength of connection. For an adverse impact to occur, there needs to be a measurable response in the RIS population and clear evidence that the RIS is influenced by the zebra mussel invasion. When the strength of connection is low, it is not possible to arrive at an impact level greater than small, because there is litle evidence that a relationship between the mussel invasion and population trends exists. Conversely, for an RIS with a high strength of connection

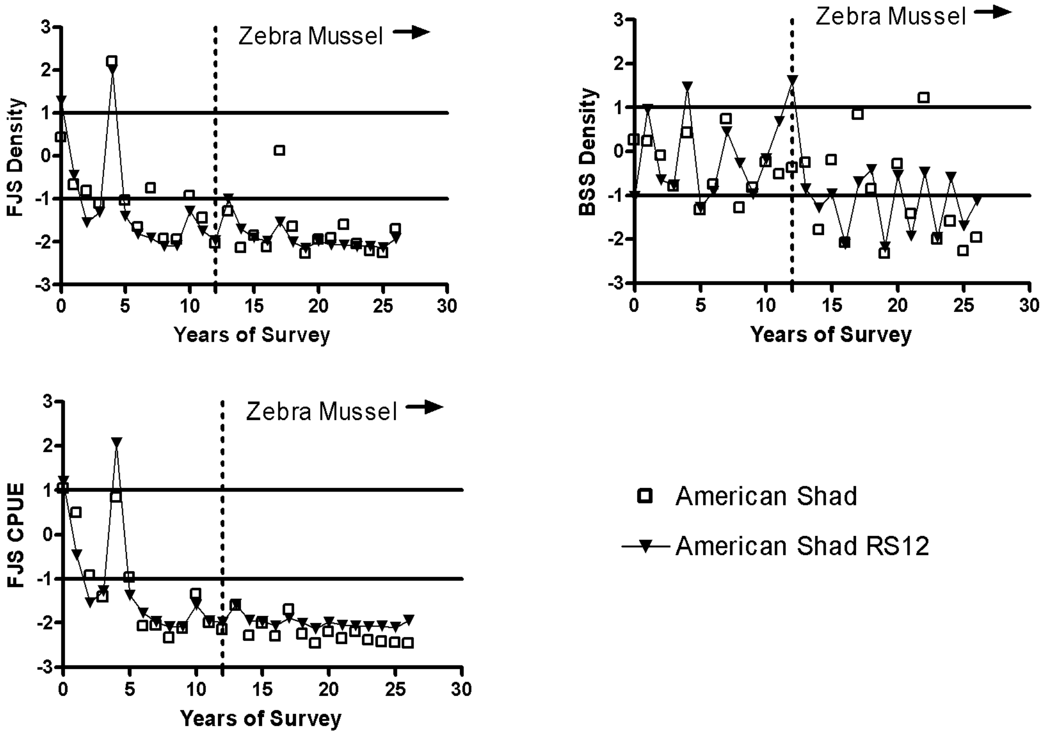
to the zebra mussel invasion but evidence of no population decline, the final determination must be small.

Based on the final WOE assessment, a small potential for adverse impacts from the zebra mussel invasion was predicted for three species (alewife, striped bass, and white catfish). Alewife and striped bass had no evidence of a population decline, even though the strength of connection was medium to high, while white catfish displayed a population decline but had a low strength of connection. A moderate or moderate-to-large impact was predicted for the remaining species (American shad, blueback herring, spottail shiner, and white perch).

Table H-20 Weight of Evidence Associated with Potential Negative Impacts on Population Trends from Zebra Mussel Invasion

Species	Hypothesized Level of Impact to Population Trends	Hypothesized Strength of Connection	Hypothesized Impact to Population Trends from Zebra Mussel
Alewife	Small	Medium to High	Small
American Shad	Large	Medium to High	Moderate to Large
Blueback Herring	Moderate to Large	Medium to High	Moderate to Large
Spottail Shiner	Moderate	Medium to High	Moderate
Striped Bass	Small	Medium to High	Small
White Catfish	Large	Low	Small
White Perch	Moderate to Large	Medium to High	Moderate to Large

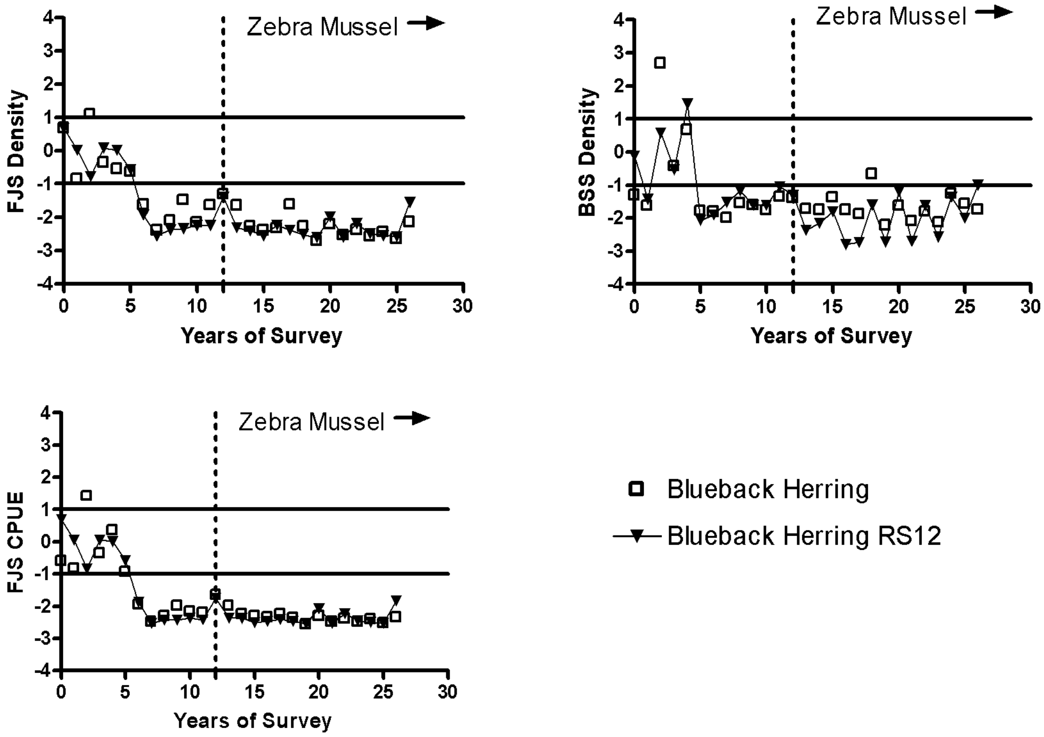
The NRC staff analysis predicted a moderate-to-large potential adverse impact on the decline in American shad associated with the zebra mussel invasion. The NRC staff WOE analysis was based on the post-1985 FJS data, since the catch efficiency of the beam trawl for YOY American shad was less than the epibenthic sled. Based on the riverwide abundance index, Strayer et al. (2004) also concluded that the abundance of American shad was affected by zebra mussels. Much of the decline in population abundance, however, was observed before the mussel invasion (Figure H-9). Unlike both the NRC staff and Strayer et al. (2004), Barnthouse et al. (2008) rejected the hypothesis that zebra mussels were a potential cause of the decline.



Source: Normandeau 2008

Figure H-9 American shad standardized population trend data for the Riverwide and River Segment 12 (RS12), Fall Juvenile, and Beach Seine Surveys (Normandeau 2008)

The NRC staff analysis predicted a moderate-to-large potential adverse impact to juvenile blueback herring abundance associated with the zebra mussel invasion. Again, unlike both the NRC staff and Strayer et al. (2004), Barnthouse et al. (2008) rejected the hypothesis that zebra mussels were a potential cause in the decline of blueback herring. The relative population response between the effect of the zebra mussel invasion and the combined riverwide impacts are presented in Figure H-10. Population trend data for River Segment 12 tend to be slightly below the riverwide observations and, for the BSS density, suggest a further decrease following the mussel invasion. This suggests to NRC Staff that the relative effects of the zebra mussel invasion may be slightly greater than the riverwide effects.

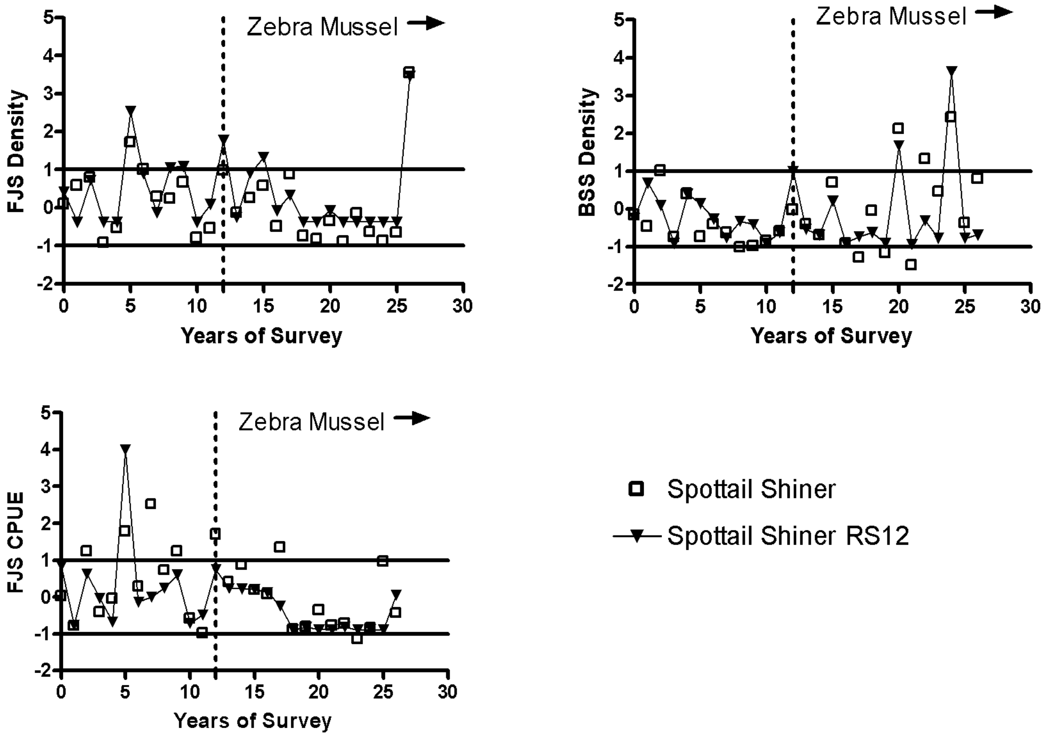


Source: Normandeau 2008

Figure H-10 Blueback herring standardized population trend data for the Riverwide and River Segment 12 (RS12), Fall Juvenile, and Beach Seine Surveys

The NRC staff analysis predicted a moderate potential adverse impact to juvenile spottail shiner abundance associated with the zebra mussel invasion. Strayer et al. (2004) concluded that there was no change in spottail shiner abundance, and Barnthouse et al. (2008) did not evaluate spottail shiner population trends. The relative population response between the effect of the zebra mussel invasion and the combined riverwide impacts is presented in Figure H-11.

The impact on white perch population trends from zebra mussels was estimated to be moderate to large. Figure H-12 presents white perch riverwide density and CPUE for River Segment 12. White perch population trends obtained from the FJS were not affected by gear changes (year 6 of the survey) and yet, an early decline in fish density and CPUE in River Segment 12 can be observed from both the FJS and the BSS. For the BSS density, riverwide and each river-segment population trend overlap. Overall, the riverwide and River Segment 12 data overlap often and show a decline from the early population abundance. This suggests to NRC Staff that a combination of stressors acting on the riverwide population is associated with a relatively greater adverse impact than the impact from the zebra mussel invasion.



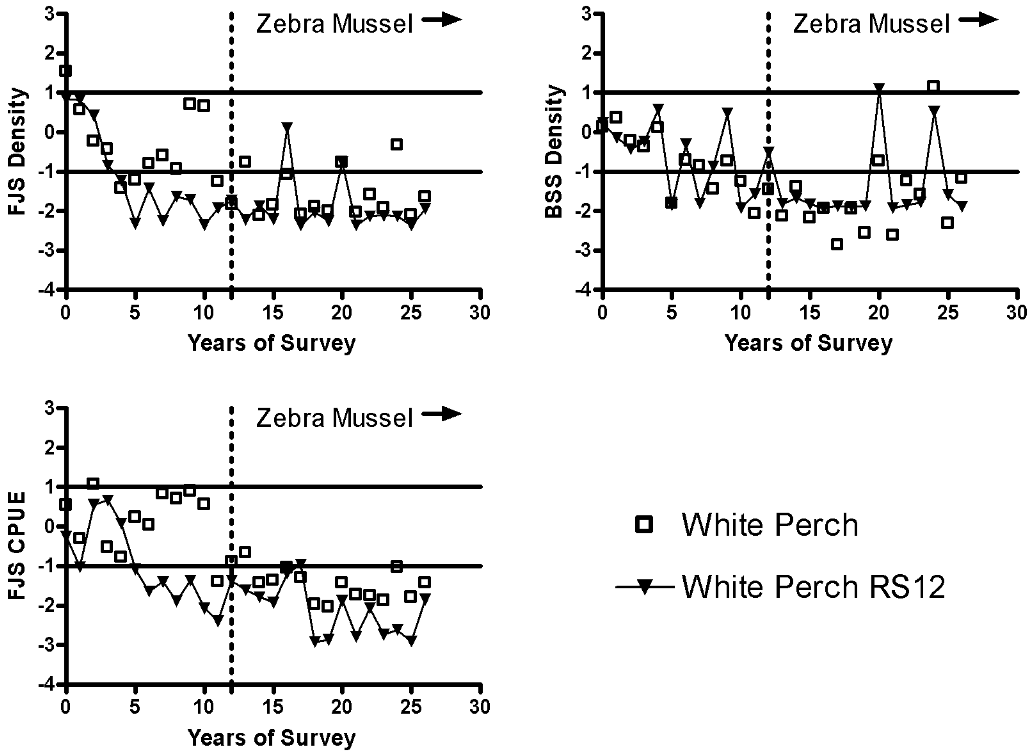
Source: Normandeau 2008

Figure H-11 Spottail Shiner standardized population trend data for the Riverwide and River Segment 12 (RS12), Fall Juvenile, and Beach Seine Surveys

Water Quality and Climate Change

Sewage Treatment System Upgrades

As discussed in Section 2.2.5, the increasing populations along the river and within the watershed resulted in an increased discharge of sewage into the Hudson River and an overall degradation of water quality. Beginning in 1906 with the creation of the Metropolitan Sewerage Commission of New York, a series of studies were conducted to formulate plans to improve water quality within the region (Brosnan and O'Shea 1996). In the freshwater portion of the lower Hudson River, the most dramatic improvements in wastewater treatment were made between 1974 and 1985, resulting in a decrease in the discharge of suspended solids by 56 percent. Improvements in the brackish portion of the river were even greater. In the New York City area, the construction and upgrading of water treatment plants reduced the discharge of untreated wastewater from 450 million gallons per day (mgd) in 1970 to less than 5 mgd in 1988 (CHGEC 1999). The discharge of raw sewage was further reduced between 1989 and 1993, caused by the implementation of additional treatment programs (Brosnan and O'Shea 1996).



Source: Normandeau 2008

Figure H-12 White perch standardized population trend data for the Riverwide and River Segment 12 (RS12), Fall Juvenile, and Beach Seine Surveys

During the 1990s, three municipal treatment plants located in the lower Hudson River converted to full secondary treatment—North River (1991), North Bergen MUA-Woodcliff (1991), and North Hudson Sewerage Authority West New York (1992). In addition, the North Hudson Sewerage Authority-Hoboken plant, located on the western bank of the Hudson River opposite Manhattan Island, went to full secondary treatment in 1994 (CHGEC 1999). Upgrades to the Yonkers Joint Treatment Plant in 1988 and the Rockland County Sewer District #1 in 1989 also resulted in improvements in water quality in the brackish portion of the Hudson River. In the mid-1990s, the Rockland County Sewer District #1 and Orangetown Sewer District plants were also upgraded. (CHGEC 1999)

Trends in Dissolved Oxygen

A review of long-term trends in dissolved oxygen (DO) and total coliform bacteria concentrations by Brosnan and O'Shea (1996) has shown that improvements to water treatment facilities have improved water quality. The authors noted that, between the 1970s and 1990s, DO concentrations in the Hudson River generally increased. The increases coincided with the

upgrading of the 170 million mgd North River plant to secondary treatment in the spring of 1991. DO, expressed as the average percent saturation, exceeded 80 percent in surface waters and 60 percent in bottom waters during summer in the early 1990s. DO minimums also increased from less than 1.5 milligrams per liter (mg/L) in the early 1970s to more than 3.0 mg/L in the 1990s, and the duration of low DO (hypoxia) events was also reduced (Brosnan and O'Shea 1996). Similar trends showing improvements in DO were noted by Abood et al. (2006) from an examination of two long-term data sets collected by NYCDEP in the lower reaches of the river. Brosnan and O'Shea (1996) also noted a strong decline in total coliform bacteria concentrations that began in the 1970s and continued into the 1990s, coinciding with sewage treatment plant upgrades.

Chemical Contaminants

As discussed in Section 2.2.5, the lower Hudson River currently appears on the EPA 303-d list as an impaired waterway, because of the presence of PCBs and the need for fishing restrictions (EPA 2004). Contamination of the sediment, water, and biota of the Hudson River estuary resulted from the manufacture of capacitors and other electronic equipment in the towns of Fort Edward and Hudson Falls, New York, from the 1940s to the 1970s. Investigations conducted by the EPA and others over the past 25 years have delineated the extent and magnitude of contamination, and numerous cleanup plans have been devised and implemented. Recently, EPA Region 2 released a "Fact Sheet" describing a remedial dredging program designed to remove over 1.5 million cubic yards of contaminated sediment covering 400 acres, extending from the Fort Edwards Dam to the Federal Dam at Troy (EPA 2008). Concentrations of PCBs in river sediments below the Troy Dam are much lower. Work summarized by Steinberg et al. (2004) suggests the sediment-bound concentrations of PCBs and dioxins have generally declined in the lower Hudson River since the 1970s and are now at or below ER-M limits.

Chemical contaminants present in the tissues of fish in the Hudson River estuary have been extensively studied for many years and resulted in the posting of consumption advisories by the States of New York and New Jersey. Current information summarized in Steinberg et al. (2004) suggests that many recreationally and important fish and shellfish still contain levels of metals, pesticides, PCBs, and dioxins above the Food and Drug Administration (FDA) guidance values for commercial sales. Tissue concentrations of mercury were of concern only for striped bass; other fish, and shellfish, including flounder, perch, eels, blue crab, and lobster, contained concentrations of mercury in their tissues well below the FDA limit of 2 parts per million (ppm) for commercial sale. Concentrations of chlordane in white perch, American eels, and the hepatopancreas (green gland) of blue crabs were also above FDA guidelines. DDT concentrations in the tissues of most recreationally and commercially valuable fish and shellfish in the estuary were below the 2 ppm FDA limit with the exception of American eel. Unfortunately, the concentrations of 2,3,7,8-TCDD (a dioxin compound) and total PCBs in fish and shellfish tissues were often above FDA guidance limits, suggesting fish and shellfish obtained from some locations within the estuary should be eaten in moderation or not at all.

The results described above suggest that, although a wide variety of contaminants still exist in sediment, water, and biota in the lower Hudson River, the overall levels appear to be decreasing because of the imposition of strict discharge controls by Federal and State regulatory agencies and improvements in wastewater treatment. These trends appear to be confirmed, based on the results of a NOAA-sponsored toxicological evaluation of the estuary in 1991, as described in Wolfe et al. (1996). There is continuing concern, however, that legacy PCB waste may still

pose a threat to invertebrate, fish, and human populations. A study by Achman et al. (1996) suggested that PCB concentrations in sediment measured at several locations in the lower Hudson River from the mouth to Haverstraw Bay are above equilibrium with overlying water and may be available for transfer within the food web. The implications of this study are that, in some locations within the lower river, the sediments could act as a source of PCBs and pose a long-term chronic threat. The authors concluded, however, that fate and transport modeling would be required to fully understand the implications of this potential contaminant source.

Based on the above information, it appears that the overall water quality in the lower Hudson River is generally improving, although the presence of legacy contaminants still presents a concern to regulatory agencies. Based on the information reviewed, the NRC staff concludes that the cumulative impact of water quality on RIS should decline if efforts continue to address point- and non-point pollution and legacy waste removal and treatment.

Climate Change

The potential cumulative effects of climate change on Hudson River RIS could result in a variety of fundamental changes to watersheds that would affect aquatic resources. The environmental factors of significance identified by Kennedy (1990) that would affect estuarine systems included sea level rise, temperature increase, salinity changes, and wind and water circulation changes. Changes in sea level could result in dramatic effects on nearshore communities, including the reduction or redistribution of submerged aquatic vegetation, changes to marsh communities, and influences to wetland areas adjacent to nearshore systems. Water temperature increases could affect spawning patterns or success, or influence the distribution of key RIS when cold-water species move poleward while warm-water species become established in new habitats. Changes to river salinity and the presence of the salt front could influence the spawning and distribution of RIS, and the range of exotic or nuisance species. Fundamental changes in precipitation could profoundly influence water circulation and change the nature of allochothonous and autochothonous inputs to the system. This could result in fundamental changes to primary production and influence the estuarine food web on many levels. Kennedy (1990) also concluded that some fisheries and aquaculture enterprises and communities might benefit from the results of climate change, while others would suffer extensive economic losses that could lead to population shifts.

The extent and magnitude of climate change impacts to the aquatic resources of the lower Hudson River are an important component of the cumulative assessment analyses. This assessment is beyond the scope of this review and will need to be explored and evaluated by others. A minimal evaluation of shifts in the distribution of RIS standardized mean density for 1979 to 1983 and for 2001 to 2005 was explored in Appendix H. Several RIS (striped bass, alewife, spottail shiner, hogchoker, and white perch) may be shifting their distribution slightly upriver while bay anchovies may be shifting their distribution seaward. This analysis attempts only to explore hypotheses about potential redistribution of fish; definitive statements cannot be made because of data limitations. Thus, the NRC staff has concluded that the cumulative effects of climate change cannot be determined.

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Appendix I

Statistical Analyses Conducted for Chapter 4 Aquatic Resources and Appendix H

Appendix I

Statistical Analyses Conducted for Chapter 4 Aquatic Resources and Appendix H

Supporting analyses and data tables are presented by section as referenced in the Aquatic Resources sections of Appendix H. Major section headings are maintained to allow mapping between appendices. This appendix includes supporting information for the U.S. Nuclear Regulatory Commission (NRC) staff assessment of impingement impacts (Appendix H, Section 1.3), the assessment of population trends (Appendix H, Section 3.1), the analysis of strength of connection (Appendix H, Section 3.2), and the cumulative impacts on aquatic resources (Appendix H, Section 4).

I.1 Impingement of Fish and Shellfish

I.1.1. NRC Staff Assessment of Impingement Impacts

Staff conducted simple linear regression over years on the number of days of operation and the combined volume of water discharged for Indian Point Nuclear Generating Station Unit Nos. 2 and 3 (IP2 and IP3) between 1975 and 1990 (Table I-1). Days of operation from 1975 to 1981 were obtained from impingement data provided by Entergy Nuclear Operations, Inc. (the applicant) (Entergy 2007b). Days of operation for the remaining years and the combined volume discharged were compiled from the annual reports for the Hudson River Ecological Study in the area of IP2 and IP3 (Con Edison 1980; Con Edison 1984, 1986–1991). The number of days of operation at IP2 and IP3 had a general increase of 8 days per year for IP2 and 5 days per year for IP3 (linear regression, $p = 0.004$ and $p = 0.286$ for IP2 and IP3, respectively). The total volume circulated at IP2 and IP3 combined also had a general increase of 26.2 10^6 cubic meters (m^3; linear regression, $p = 0.164$).

Table I-1 Number of Days of Operation at IP2 and IP3 and Combined Discharge

Year	Days of Operation		Combined Volume (millions m^3)
	IP2	IP3	
1975	307		1119
1976	176	239	1329
1977	265	259	2159
1978	234	270	2030
1979	246	227	1935
1980	263	261	1822
1981	276	297	1617
1982	304	135	1273
1983	340	48	1286
1984	238	306	1710
1985	365	266	1977
1986	285	357	1892
1987	346	265	1815
1988	357	352	2322
1989	302	301	1748
1990	365	272	1902

Source: Days of Operation: Entergy 2007b; Con Edison 1984, 1986–1991
Volume Discharged: Con Edison 1980, 1991

I.2 Combine Effects of Impingement and Entrainment

I.2.1. Assessment of Population Trends

Studies Used To Evaluate Population Trends

The Hudson River utilities conducted the Fall Juvenile Shoals Survey (FSS) from 1974 to 2005 and targeted juveniles, yearlings, and older fish. Between 1974 and 1984, a 1-square meter (m^2) Tucker trawl with a 3-millimeter (mm) mesh was used to sample the channel and a 1-m^2 epibenthic sled with a 3-mm mesh was used to sample the bottom and shoal strata. From 1985 to 2005, a 3-meter (m) beam trawl with a 38-mm mesh on all but the cod-end replaced the epibenthic sled. Size selectivity and relative catch efficiency between gear types was tested during nocturnal samplings between August and September 1984. Bay anchovy, American shad, and weakfish were sampled with less efficiency with the beam trawl (Table I-2) (NYPA 1986). Further, the number and volume of samples in the bottom and shoal strata were generally greater than 2.5 times those in the channel (Table I-3).

The Beach Seine Survey (BSS) was conducted from 1974 to 2005 and targeted young of the year (YOY) and older fish in the shore-zone (extending from the shore to a depth of 10 feet (ft)). Samples were collected from April to December but generally every other week from mid-June through early October (Table I-4). For all years, a 100-ft bag beach seine was used to collect 100 samples during each sampling period from beaches selected according to a stratified

random design. Even though the catch-per-unit-effort (CPUE) for representative important species (RIS) differed in magnitude between the BSS and FSS (Table I-5), standardizing the data (observed CPUE minus the mean CPUE and divided by the standard deviation across years) allowed a comparison of the shape of the data over time. Thus, NRC staff conducted a visual comparison of the standardized BSS and FSS data determine if a shift in gear types was affecting the observed FSS trend. When the standardized FSS data were consistently less than the standardized BSS data after 1985, the pre- and post-1985 data were evaluated separately.

Table I-2 Catch by Gear or Gear Efficiency (catch per 1000 m^2) from August to September 1984

	Young of the Year				Yearling and Older			
	3-m Beam Trawl (n = 257)		1-m^2 Epibenthic Sled (n = 322)		3-m Beam Trawl (n = 257)		1-m^2 Epibenthic Sled (n = 322)	
Species	Mean Density	Standard Error	Mean Density	Standard Error	Mean Density	Standard Error	Mean Density	Standard Error
Bay Anchovy	29.0	3.0	1261	61.9	0.6	0.1	11.2	1.2
American Shad	0.4	0.1	4.4	3.0	0.0	0.0	0.0	0.0
Bluefish	0.1	<0.1	0.3	0.1	0.0	0.0	0.0	0.0
Hogchoker	0.1	<0.1	0.1	<0.1	5.4	0.4	1.5	0.2
Striped Bass	13.3	0.8	3.4	0.4	0.2	<0.1	0.1	<0.1
White Catfish	0.0	0.0	0.0	0.0	1.6	0.2	1.0	0.1
White Perch	1.3	0.2	0.1	<0.1	22.1	1.6	6.4	1.3
Weakfish	0.7	0.1	1.9	0.3	0.0	0.0	0.0	0.0

Source: NYPA 1986

Table I-3 Changes to the Design and Gear Used During the Fall Juvenile Survey

Year	Volume (m^3)	Number of Samples	Samples per Gear			Sample Collection Dates
			Epibenthic Sled	Tucker Trawl	Beam Trawl	
1974	728083	1690	100/wk			Weekly, Aug–Dec
1975	317749	901	100/wk			Biweekly, Aug–Dec
1976	365903	881	100/wk			Biweekly, Aug–Dec
1977	368134	826	100/wk			Biweekly, Aug–Dec
1978	352420	900	100/wk			Biweekly, Aug–Dec
1979	1,006,411	2387	150/wk	50/wk		Biweekly, July–Dec
1980	771291	2103	150/wk	50/wk		Biweekly, July–Dec
1981	479591	1199	150/wk	50/wk		Biweekly, Aug–Oct
1982	400969	1000	150/wk	50/wk		Biweekly, Aug–Oct
1983	477057	1199	150/wk	50/wk		Biweekly, Aug–Oct
1984	601459	1601	150/wk	50/wk		Biweekly, July–Oct
1985	1886754	1802		~500	~1,500	Biweekly, July–Nov
1986	2,298,395	2098		549	1,549	Biweekly, July–Dec
1987	2035472	1891		495	1,396	Biweekly, July–Nov
1988	1826692	1680		440	1,240	Biweekly, July–Oct
1989	1590118	1679		439	1,240	Biweekly, July–Oct
1990	1252994	1680		439	1,241	Biweekly, July–Oct
1991	1707319	1678		440	1,238	Biweekly, July–Oct
1992	1865451	1680		440	1,240	Biweekly, July–Oct
1993	2010222	1680		440	1,240	Biweekly, July–Oct
1994	2018494	1681		440	1,241	Biweekly, July–Oct
1995	1782199	1680		440	1,240	Biweekly, July–Oct
1996	1824802	1669		484	1,185	Biweekly, July–Oct
1997	1995519	2015		826	1,189	Biweekly, July–Nov
1998	2214707	2130		825	1,305	Biweekly, July–Dec
1999	2160009	2085		823	1,262	Biweekly, July–Dec
2000	2174896	2113		816	1,297	Biweekly, July–Nov
2001	2097877	2084		818	1,266	Biweekly, July–Oct
2002	2105272	2128		821	1,307	Biweekly, July–Dec
2003	1891135	2131		825	1,306	Biweekly, July–Dec
2004	2106874	2128		823	1,305	Biweekly, July–Dec
2005	2063654	2128		824	1,304	Biweekly, July–Dec

Note: Compiled from the annual Year Class Reports for the Hudson River Estuary Monitoring Program; ASA 1999, 2001a, 2001b, 2003, 2004a, 2004b, 2005–2007; Battelle 1983; ConEd undated a, undated b, 1996; EA 1990, 1995, 1991; LMS 1989, 1991, 1996; MMES 1983; Versar 1987; TI 1977–1981; NAI 1985a, 1985b, 2007.

There were four basic combinations of sampling intensities, duration, and gear types used during the FSS (Table I-3). Likewise, there were roughly three levels of sampling intensity used during the BSS (Table I-4). Thus, for data provided on a weekly basis, only weeks 27 to 43 were used in the analysis for the FSS and weeks 22 to 43 for the BSS survey, so that most years contained observations from the months of July through October and June through October for each survey, respectively.

Table I-4 Number of Weeks Sampled Each Month During the BSS

Year	April	May	June	July	August	September	October	November	December
1974	4	4	4	5	4	5	4	4	3
1975	5	4	4	5	4	5	4	4	3
1976	5	4	4	5	4	5	4	4	2
1977	4	4	4	5	4	5	4	4	3
1978	4	4	4	5	4	5	4	4	4
1979	5	4	4	5	4	5	4	4	2
1980	5	4	4	5	4	2	2	2	1
1981	0	0	0	0	2	3	2	0	0
1982	0	0	0	0	1	3	1	0	0
1983	0	0	0	0	2	3	1	0	0
1984	0	0	0	1	2	2	2	1	0
1985	0	0	0	2	2	2	2	2	0
1986	0	0	0	2	2	2	2	2	0
1987	0	0	1	2	2	3	2	1	0
1988	0	0	1	3	2	2	2	1	0
1989	0	0	1	3	2	2	2	1	0
1990	0	0	1	3	2	2	2	0	0
1991	0	0	1	2	2	3	2	0	0
1992	0	0	1	2	2	3	2	0	0
1993	0	0	0	3	2	2	2	1	0
1994	0	0	0	3	2	2	2	1	0
1995	0	0	1	2	2	3	2	0	0
1996	0	0	1	3	2	2	2	0	0
1997	0	0	1	3	2	2	2	0	0
1998	0	0	1	3	2	2	2	0	0
1999	0	0	1	3	2	2	2	0	0
2000	0	0	1	3	2	2	2	0	0
2001	0	0	1	3	2	2	2	0	0
2002	0	0	1	3	2	2	2	0	0
2003	0	0	1	3	2	2	2	0	0
2004	0	0	1	3	2	2	2	0	0
2005	0	0	1	3	2	2	2	0	0

Source: NRC Request for Sampling Effort and Abundance Data from Three Hudson River Sampling Programs for 16 Selected Fish Species from 1974 through 2005, Normandeau Associates Inc., February 25, 2008

Metrics Used To Evaluate Population Trends

Abundance Index

The abundance index for YOY for each species was based on the catch from a selected sampling program and used by the applicant and its contractors to estimate riverwide mean RIS abundances. The selection process considered the expected location of each species in the river, based on life-history characteristics and the observed catch rates from previous sampling. The abundance index was constructed to account for the stratified random sampling design used by each of the surveys. For the Long River Survey (LRS) and the FSS, sampling within a river segment was further stratified by river depth and sampled with separate gear types. For blueback herring, alewife, bay anchovy, hogchoker, weakfish, and rainbow smelt, the YOY abundance index was based on the catch from a single gear type (Table I-5).

The construction of the LRS (L_A) and the FSS abundance index (F_A) were similar and provided an unbiased estimate of the total and mean riverwide population abundance for selected species, respectively (Cochran 1997). For the FSS and each gear type, F_A was constructed as a weighted mean of the average species density with weight given by the volume of each stratum for a given river segment. For the FSS, strata sampled were the channel, bottom, and shoal for a given river segment. Poughkeepsie and West Point river segments had the greatest channel volume, Poughkeepsie and Tappan Zee had the greatest bottom volume, and Tappan Zee had the greatest shoal volume (Table I-6). Because the river segment associated with IP2 and IP3 did not have large bottom or shoal volumes, the abundance index was not sensitive to changes in population trends within the vicinity of IP2 and IP3.

Table I-5 Sampling Program Used To Calculate the Abundance Index for YOY and Yearling Fish and the Median Catch-per-Unit-Effort Over Time

Species	Sampling Program	Riverwide FSS Median YOY Catch-per-Unit-Effort	Riverwide BSS Median YOY Catch–per-Unit-Effort
Alewife	FSS-Channel	4.35E-04	1.05
Bay Anchovy	FSS-Channel	2.61E-02	6.70
American Shad	BSS	8.12E-04	9.17
Bluefish	BSS	3.18E-05	3.36E-01
Hogchoker	FSS-Bottom	1.03E-02	2.30E-01
Blueback Herring	FSS-Channel	1.12E-02	2.86E+01
Rainbow Smelt	FSS-Channel	N/A[a]	< 0.0001
Spottail Shiner	FSS-Channel	1.10E-04	7.25
Stripped Bass	BSS	2.47E-03	6.47
Atlantic Tomcod	LRS	2.69E-03	6.70E-02
White Catfish	BSS	N/A	2.50E-02
White Perch	BSS	5.89E-03	10.4
Weakfish	FSS-Channel	N/A	5.00E-03

[a] N/A = not applicable; YOY not present in samples

Source: CHGE 1999

Table I-6 Volume of Sampling Strata by River Segment

Region	River Segment	Volume (m^3)				Area (m^2)
		Channel	Bottom	Shoal	Region	Shore Zone
Battery	0	141,809,822	48,455,129	18,747,833	209,012,784	N/A
Yonkers	1	143,452,543	59,312,978	26,654,767	229,420,288	3,389,000
Tappan Zee	2	138,000,768	62,125,705	121,684,992	321,811,465	20,446,000
Croton-Haverstraw	3	61,309,016	32,517,633	53,910,105	147,736,754	12,101,000
Indian Point	4	162,269,471	33,418,632	12,648,163	208,336,266	4,147,000
West Point	5	178,830,022	25,977,862	2,647,885	207,455,769	1,186,000
Cornwall	6	94,882,267	36,768,629	8,140,123	139,791,019	4,793,000
Poughkeepsie	7	228,975,052	63,168,132	5,990,260	298,133,444	3,193,000
Hyde Park	8	131,165,041	32,012,000	2,307,625	165,484,666	558,000
Kingston	9	93,657,021	35,479,990	12,332,868	141,469,879	3,874,000
Saugerties	10	113,143,296	42,845,077	20,307,338	176,295,711	7,900,000
Catskill	11	83,924,081	42,281,206	34,526,456	160,731,743	8,854,000
Albany	12	32,025,080	13,517,183	25,606,842	71,149,105	6,114,000

N/A – not applicable. Data from Entergy 2007b.

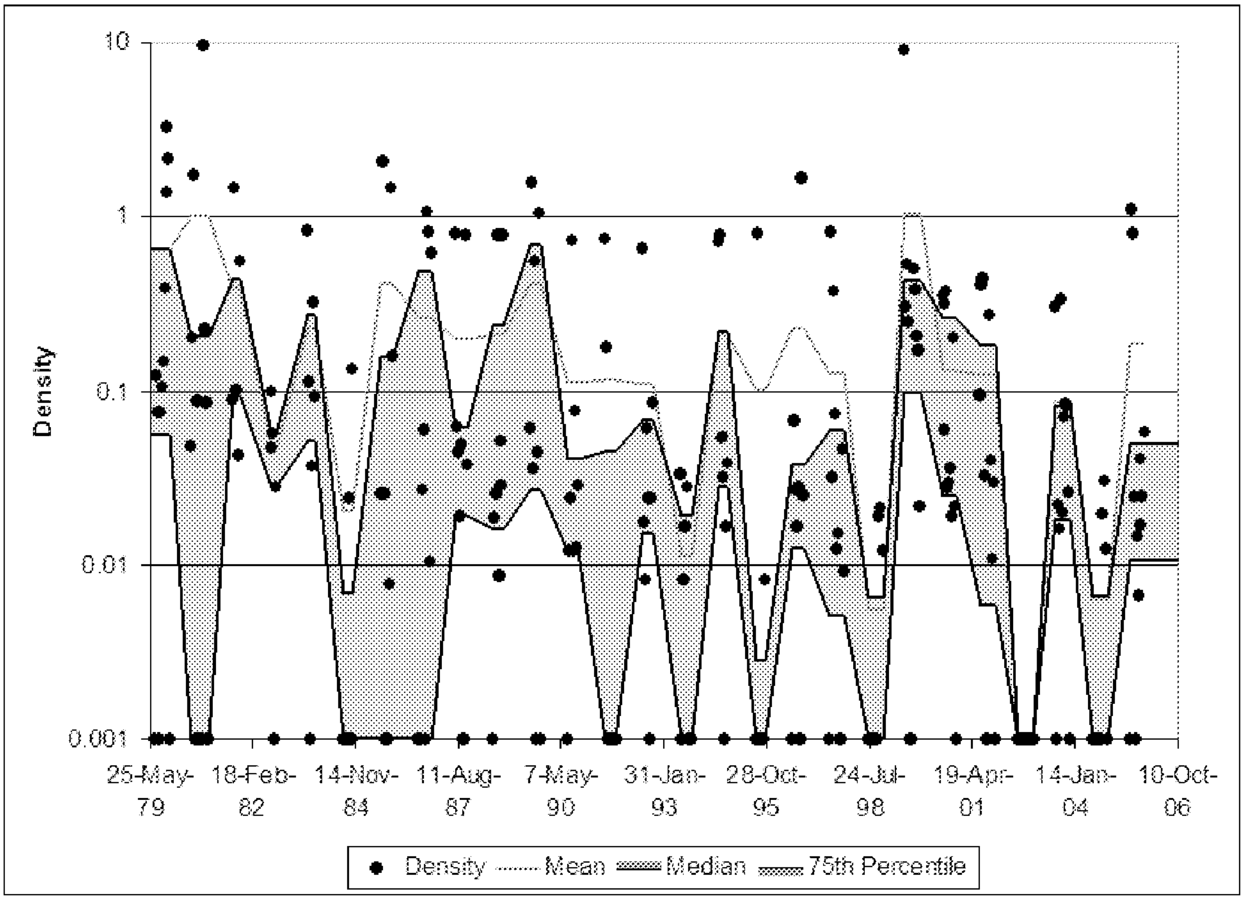
<u>Analysis of Population Impacts</u>

As discussed in Section H.3, the analysis was based on YOY fish to assess the population trends. For the river-segment analysis, the median and the 75th percentile of the densities of YOY caught within a given year in the vicinity of IP2 and IP3 (River Segment 4) were used to bound population trends for a visual representation. The median and 75th percentile are less sensitive to extreme values than the mean. Fish population sizes and the chance of catching fish were highly variable, and a few large catches can influence the mean and potentially distort a trend analysis. For example, the mean density for alewives caught during the FSS in the vicinity of IP2 and IP3 tended to be equal to or greater than the 75th percentile of the density for most years because of the relatively fewer large observations (Figure I-1). Further, seasonal and interannual differences in the salt front position may influence the pattern of trends in total or mean abundance between river segments. Evaluating the 75th percentile of the weekly data removed the influence from any given week associated with potentially extreme environmental characteristics.

River-segment data collected from 1979–2005 (n = 27 for each RIS) was standardized by subtracting the first 5-year mean and dividing by the standard deviation based on all years. Because of the large variability between years (coefficients of variation (CVs) ranging from 67 to 247 percent), a 3-year moving average was used to smooth the river-segment data before the trend analysis. Two competing models, simple linear regression and segmented regression with a single join point, were statistically fit to the smoothed and standardized 75th percentile of the annual observed densities for each taxon. The model with the smallest mean square error (MSE) was chosen as the better fitting model and used to determine the level of potential injury. Extreme outliers (values greater than 2 standard deviations from the mean) were removed from the analysis if the segmented regression was unable to converge; results with and without outliers were recorded. All data (1979–2005) from the FSS were compared to the BSS to determine if changes in the gear type affected the observed trend. When the standardized FSS

data were consistently less than the standardized BSS data after 1985, the pre- and post-1985 data were evaluated separately.

Figure I-1 Relationship among the mean, the median, and the 75th percentile of the fish density for alewives caught during the FSS in River Segment 4



Note: The value 0.001 was added to all numbers so that the log scale could be used for plotting.

For the riverwide data collected from 1979–2005 (n = 27 for each RIS), the FSS CPUE, the BSS CPUE, and the abundance index for the YOY were used to assess the population trends. Riverwide data consisted of a single number per year for a given taxon and life stage. CVs ranged from 60 percent to 154 percent for the FSS, 41 percent to 302 percent for the BSS, and 49 percent to 319 percent for the abundance index. Simple linear regression and segmented regression with a single join point were fit to the standardized data (using the first 5-year mean and the standard deviation based on all years). Extreme outliers were removed from the analysis if the segmented regression was unable to converge; results with and without outliers were recorded. The model with the smallest MSE was chosen as the best-fit model and used to determine the level of potential injury. All data (1979–2005) from the FSS were compared to the BSS to determine if changes in the gear type affected the observed trend. When the

standardized FSS data were consistently less than the standardized BSS data after 1985, NRC staff evaluated the pre- and post-1985 data separately.

The FSS density and CPUE for a given RIS can be highly correlated when nearly all of the fish are caught from a single habitat (channel, shoal, or bottom) for the majority of sampling events. For these RIS, the weight-of-evidence (WOE) analysis was conducted both with and without the FSS CPUE results. Because of the slight variation in response between the two measures of population trend, different result scores can occur. However, for all RIS, the final determination of the level of impact associated with the IP2 and IP3 cooling systems was the same by either method. Thus, the correlation between measures was ignored.

For each data set, the results of the linear and segmented regression were presented in a series of two tables and a figure if a conclusion of potential large impact to any RIS population was made. The statistics displayed in the first table included the MSE for each model; the estimate of the linear slope and associated 95 percent confidence interval; the p-value associated with the significance test of the null hypothesis that the slope (S) associated with the simple linear model equals zero; the 95 percent confidence interval (CI) of the two slopes from the segmented regression (Slope 1=S1 and Slope 2=S2); and the estimated join point. For the segmented regression, slopes were defined as significant if the CI did not include zero.

The best-fit model (defined as the model with the smaller MSE) was then characterized in a second table, based on the general trend depicted by the direction of the estimated slopes. If the slope was significantly different from 0, the trend was represented by either the statement S >0 for a positive slope or S <0 for a negative slope. If the slope was not significant, the statement depicting the lack of a trend was S = 0. This table also included the assessment of the percentage of observations outside the defined level of environmental noise, defined as ± 1 standard deviation from the mean. A percentage greater than 40 percent outside this defined level of noise was assumed to provide support for a potential impact, based on the assumption that the proportion of extreme observations was a measure of stability. A level of potential negative impact was then determined, based on the decision rules presented in Section 4.1 of the draft Supplemental Environmental Impact Statement (SEIS). If a large potential for a negative impact was concluded for any RIS, a figure of the data and the best-fit model was presented.

IP2 and IP3 River Segment 4

As stated above, there were two different gear types used during the FSS to sample the bottom and shoal habitats. From 1979 to 1984, an epibenthic sled was used, and from 1985 to 2005, a beam trawl was used. Because there were not enough annual observations from the 1979–1984 time period to conduct a segmented regression, a simple linear regression was conducted to assess the slope of the density of fish near IP2 and IP3. These data were standardized to the average of the first 2 years and divided by the standard deviation of all six observations. Only white perch had a significant negative slope (n = 6, p = 0.01; Figure I-2). Hogchoker and rainbow smelt appeared to have negative trends, but they were not significant (p= 0.15 and 0.33 respectively). Rainbow smelt and white perch had 67 percent of their observations less than -1.

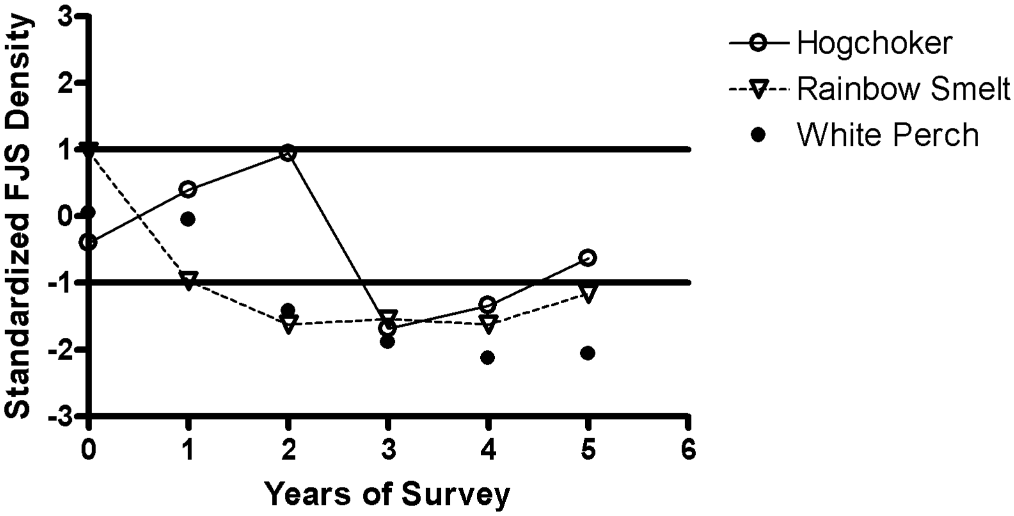
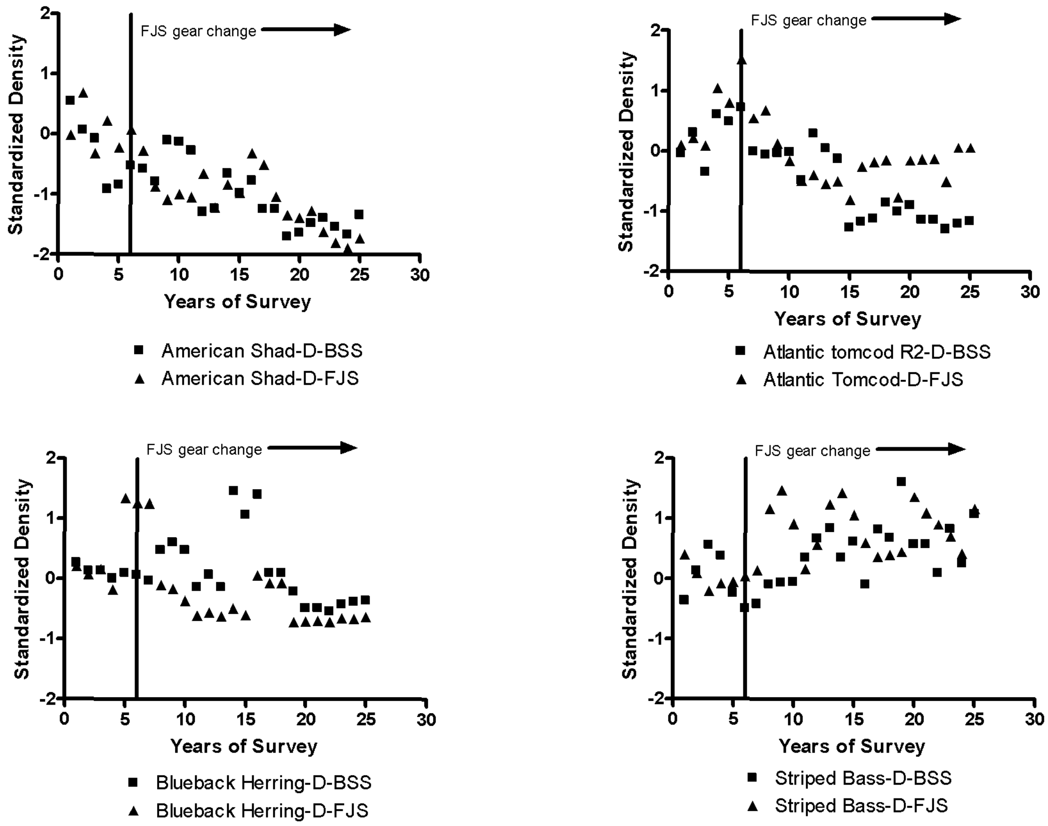


Figure I-2 River Segment 4 population trends based on the first 6 years (1979–1984) of FSS standardized density data for selected RIS

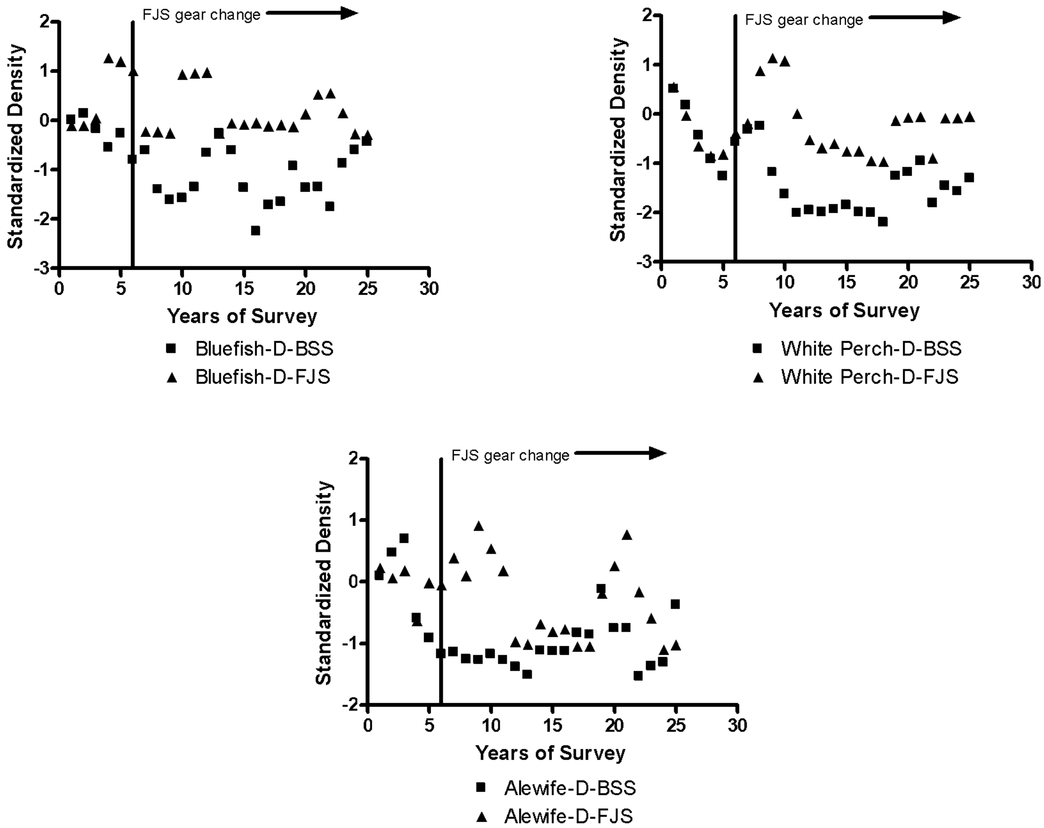
Data collected between 1985 and 2005 were temporally disconnected from the mid-1970s, when operation began at IP2 and IP3. There was a potential that fish populations responded earlier and stabilized to a lower abundance level. For this analysis, data were standardized with the average of 1985 to 1989 and the standard deviation of all data between 1985 and 2005. This analysis was used only when the observed response from all data was biologically different from the BSS population density trend and had a decline associated with the gear change.

A visual comparison of the river-segment FSS standardized density with the BSS standardized density suggested that the trends were not biologically different for American shad, Atlantic tomcod, blueback herring, and striped bass (Figure I-3). Observations from the two surveys overlap and cross over each other. The post-1985 FSS observations for bluefish, white perch, and alewife were greater than the BSS observations and did not show a decline associated with the gear change (Figure I-4). Thus, for these RIS, all of the FSS data (1979–2005) were used in the regression analysis. The FSS density data for bay anchovy and weakfish, however, did show a potential gear effect (Figure I-5), and a pre- and post-1985 analysis was conducted.



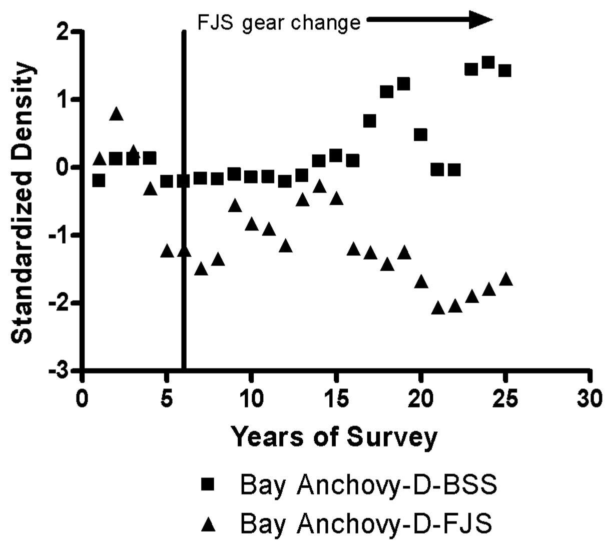
Note: All data were used in WOE analysis; R2 = River Segment 2, Yonkers

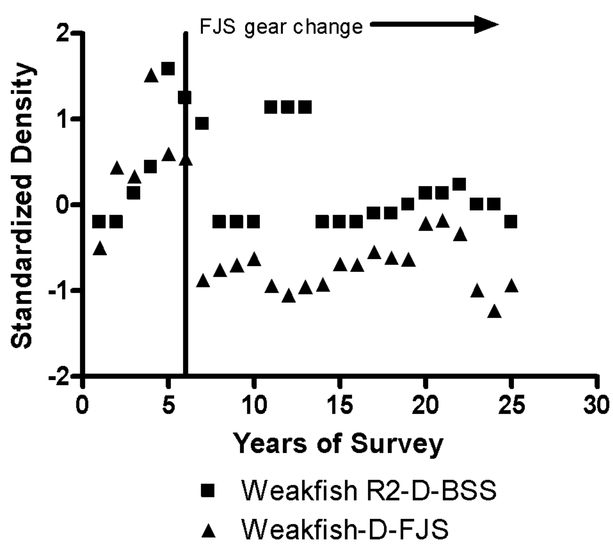
Figure I-3 River Segment 4 population trends based on the BSS and FSS standardized density (D) not considered biologically different



Note: All data were used in WOE analysis.

Figure I-4 River Segment 4 population trends based on the BSS and FSS standardized density (D) for which the FSS density is greater





Note: All years were analyzed separately for WOE analysis; R2 = River Segment 2, Yonkers

Figure I-5 River Segment 4 population trends based on the BSS and FSS standardized density (D) for which the FSS may indicate a gear difference

The following tables are the intermediate analyses for the assessment of population trends associated with fish density sampled from River Segment 4. Results of these river-segment trend analyses are compiled in Table H-13 in Section H.3 of the draft SEIS. The data used in this analysis, in order of appearance, were the standardized 75^{th} percentile of the weekly fish density for a given year collected from the FSS (Table I-7, Table I-8, and Figure I-6), BSS (Table I-9, Table I-10, and Figure I-7), and LRS for Atlantic tomcod only (Table I-11 and Table I-12).

Two FSS alewife density observations, not extreme outliers, were removed from the regression analysis to allow the segmented regression to converge (Tables I-7 and I-8). These observations corresponded to the peaks in two sporadic increases. Three FSS white catfish density observations, also not extreme outliers, were removed from the regression analysis to allow the segmented regression to converge. The results of both regression models with the observations removed were considered more conservative and were used for the trend analysis.

Table I-7 Competing Models Used To Characterize the Standardized River Segment 4 FSS Population Trends of YOY Fish Density Using a 3-Year Moving Average

	Linear Regression			Segmented Regression			
Species	**MSE**	**Slope**	**p-value**	**MSE**	**95 percent CI Slope 1**	**Join Point**	**95 percent CI Slope 2**
Alewife (All data)	0.58	-0.035 ± 0.016	0.040	Did Not Converge			
Alewife (2 values removed)	0.47	-0.041 ± 0.014	0.007	0.50	-0.070 to -0.007	2004	-3.93e+008 to 3.93e+008
Bay Anchovy 1979-1984	1.10	-0.102 ± 0.262	0.716	Not Fit			
Bay Anchovy 1985-2005	0.96	-0.058 ± 0.035	0.113	0.91	-0.174 to 0.473	1986	-0.285 to -0.002
American Shad (All data)	0.35	-0.079 ± 0.010	< 0.001	0.36	-0.106 to -0.031	1997	-0.226 to 0.008
Bluefish (All data)	0.52	-0.019 ± 0.014	0.194	0.54	-0.081 to 0.039	1996	-0.178 to 0.153
Hogchoker (All data)	0.58	-0.034 ± 0.016	0.047	0.43	0.038 to 0.268	1988	-0.150 to -0.053
Blueback Herring (All data)	0.49	-0.055 ± 0.014	0.001	0.51	-0.154 to 0.002	1992	-0.120 to 0.056
Rainbow Smelt (All data)	0.52	0.036 ± 0.028	0.220	0.35	0.041 to 0.167	1993	-0.793 to -0.119
Striped Bass (All data)	0.46	0.034 ± 0.013	0.013	0.44	-0.014 to 0.241	1988	-0.045 to 0.053
Atlantic Tomcod (All data)	0.49	-0.040 ± 0.014	0.007	0.49	-0.510 to 0.691	1983	-0.085 to -0.012
White Catfish (All data)	0.57	0.014 ± 0.016	0.37	Did Not Converge			
White Catfish (3 values removed)	0.10	0.007 ± 0.003	0.030	0.10	-0.025 to 0.070	1986	-0.006 to 0.013
White Perch (All data)	0.62	-0.014 ± 0.017	0.413	0.63	-2.43 to 1.27	1981	-0.047 to 0.035
Weakfish 1979-1984	0.88	0.328 ± 0.211	0.195	Not Fit			
Weakfish 1985-2005	1.02	0.013 ± 0.037	0.732	1.07	-11.6 to 10.1	1980	-0.071 to 0.117

CI = confidence interval

Table I-8 River Segment Assessment of the Level of Potential Negative Impact Based on the Standardized FSS Density Using a 3-Year Moving Average

Species	Best Fit	General Trend	Percent Outside Defined Level of Noise (percent)	Support for Possible Negative Impact	Level of Potential Negative Impact
Alewife (All data)	LR	S < 0	48	Yes	4
Alewife (2 values removed)	LR	S < 0	48	Yes	4
Bay Anchovy 1979–1984	LR	S = 0	50	Yes	4
Bay Anchovy 1985–2005	SR	S1 = 0 S2 < 0	43		
American Shad	LR	S < 0	56	Yes	4
Bluefish	LR	S = 0	7	No	1
Hogchoker (All data)	SR	S1 > 0 S2 < 0	15	No	2
Blueback Herring	LR	S < 0	11	No	2
Rainbow Smelt (All data)	SR	S1 > 0 S2 < 0	7	No	2
Striped Bass	SR	S1 = 0 S2 = 0	26	No	1
Atlantic Tomcod	LR	S < 0	15	No	2
White Catfish (All data)	LR	S = 0	4	No	1
White Catfish (3 values removed)	LR	S > 0	4	No	1
White Perch	LR	S = 0	19	No	1
Weakfish 1979–1984	LR	S = 0	33	No	1
Weakfish 1985–2005	LR	S = 0	29		

LR = Linear Regression; SR = Segmented Regression

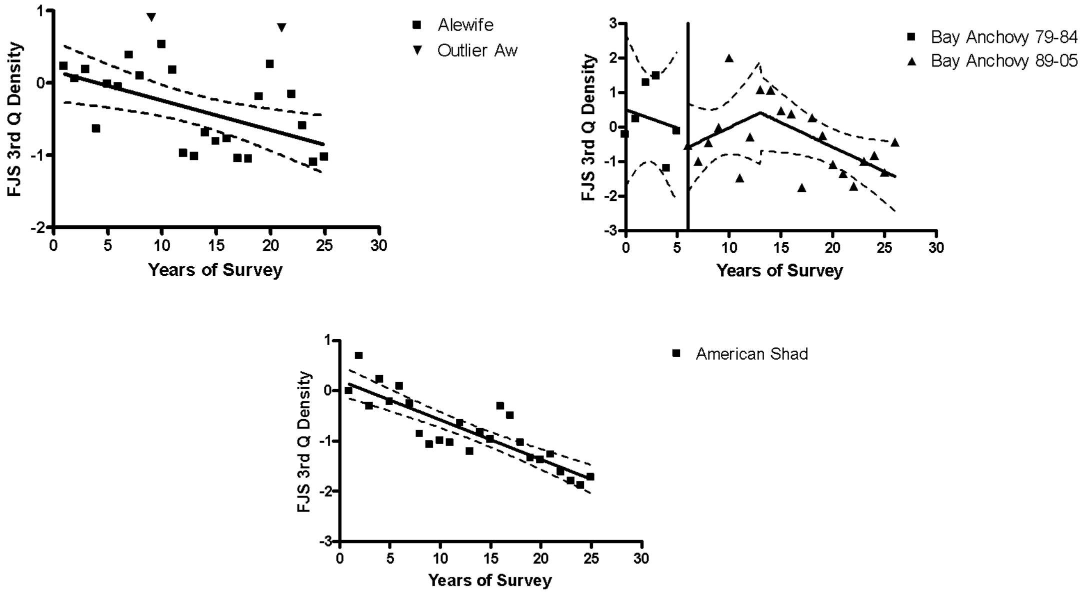


Figure I-6 River Segment 4 population trends based on the FSS standardized density assigned a large level of potential negative impact

Table I-9 Competing Models Used To Characterize the Standardized River Segment 4 BSS Population Trends of YOY Fish Density Using a 3-Year Moving Average

	Linear Regression			Segmented Regression			
Species	**MSE**	**Slope**	**p-value**	**MSE**	**95 percent CI Slope 1**	**Join Point**	**95 percent CI Slope 2**
Alewife	0.57	-0.030 ± 0.016	0.065	0.39	-0.459 to -0.156	1986	-0.010 to 0.063
Bay Anchovy	0.44	0.056 ± 0.012	0.000	0.39	-0.095 to 0.058	1991	0.055 to 0.161
American Shad	0.35	-0.069 ± 0.010	< 0.001	0.34	-0.724 to 0.270	1983	-0.083 to -0.036
Bluefish	0.58	-0.038 ± 0.016	0.027	0.48	-0.146 to -0.047	1996	-0.021 to 0.287
Hogchoker	0.52	-0.059 ± 0.014	< 0.001	0.40	-0.250 to -0.092	1991	-0.034 to 0.076
Blueback Herring	0.53	-0.024 ± 0.015	0.120	0.42	-0.005 to 0.100	1994	-0.235 to -0.042
Spottail Shiner	0.43	-0.017 ± 0.012	0.176	0.35	-0.469 to -0.004	1985	-0.014 to 0.043
Striped Bass	0.42	0.040 ± 0.012	0.002	0.43	-0.287 to 0.221	1985	0.013 to 0.087
White Perch	0.61	-0.062 ± 0.017	0.001	0.40	-0.247 to -0.122	1992	-0.007 to 0.133

Table I-10 River Segment 4 Assessment of the Level of Potential Negative Impact Based on the Standardized BSS Density Using a 3-Year Moving Average

Species	Best Fit	General Trend	Percent Outside Defined Level of Noise (percent)	Support for Possible Negative Impact	Final Decision
Alewife	SR	S1 < 0 S2 = 0	74	Yes	4
Bay Anchovy	SR	S1 = 0 S2 > 0	11	No	1
American Shad	SR	S1 = 0 S2 < 0	63	Yes	4
Bluefish	SR	S1 < 0 S2 = 0	52	Yes	4
Hogchoker	SR	S1 < 0 S2 = 0	78	Yes	4
Blueback Herring	SR	S1 = 0 S2 < 0	11	No	2
Spottail Shiner	SR	S1 < 0 S2 = 0	74	Yes	4
Striped Bass	LR	S > 0	30	No	1
White Perch	SR	S1 < 0 S2 = 0	70	Yes	4

LR = Linear Regression; SR = Segmented Regression

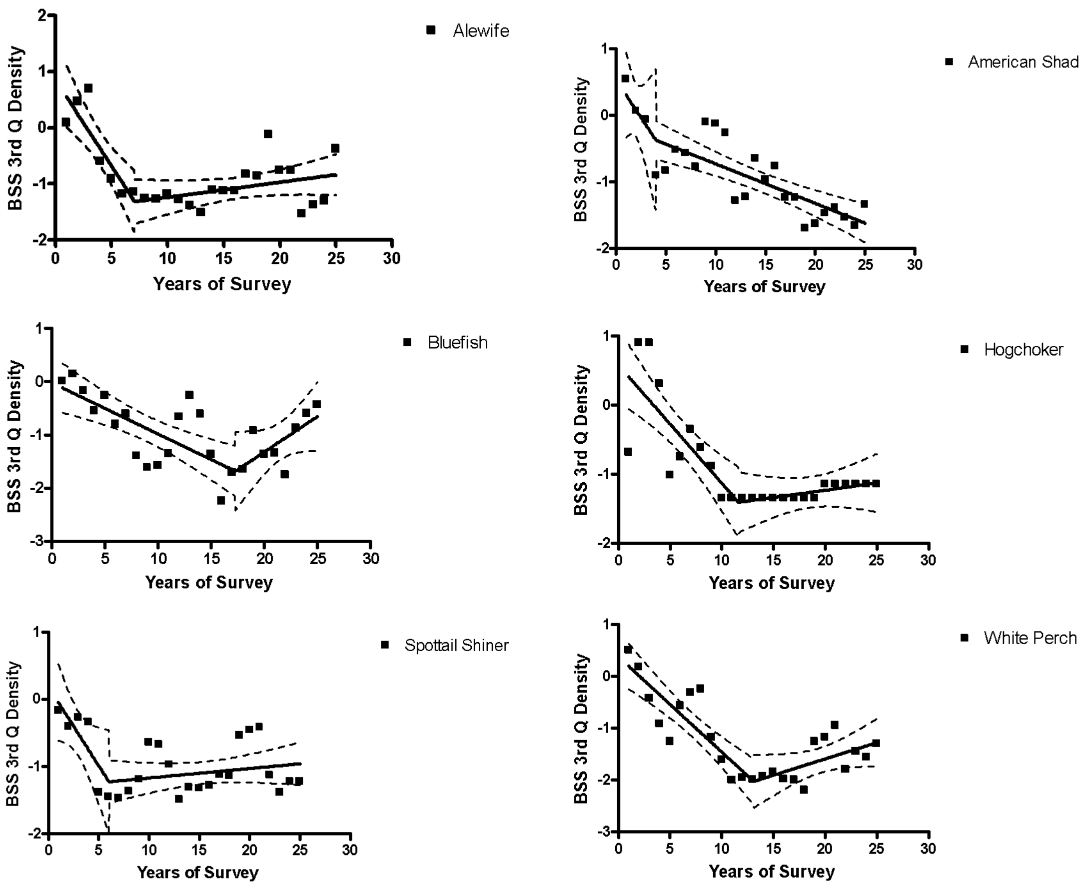


Figure I-7 River Segment 4 population trends based on the BSS standardized density assigned a large level of potential negative impact

Table I-11 Competing Models Used To Characterize the Standardized River Segment 4 LRS Population Trends of YOY Atlantic Tomcod Density Using a 3-Year Moving Average

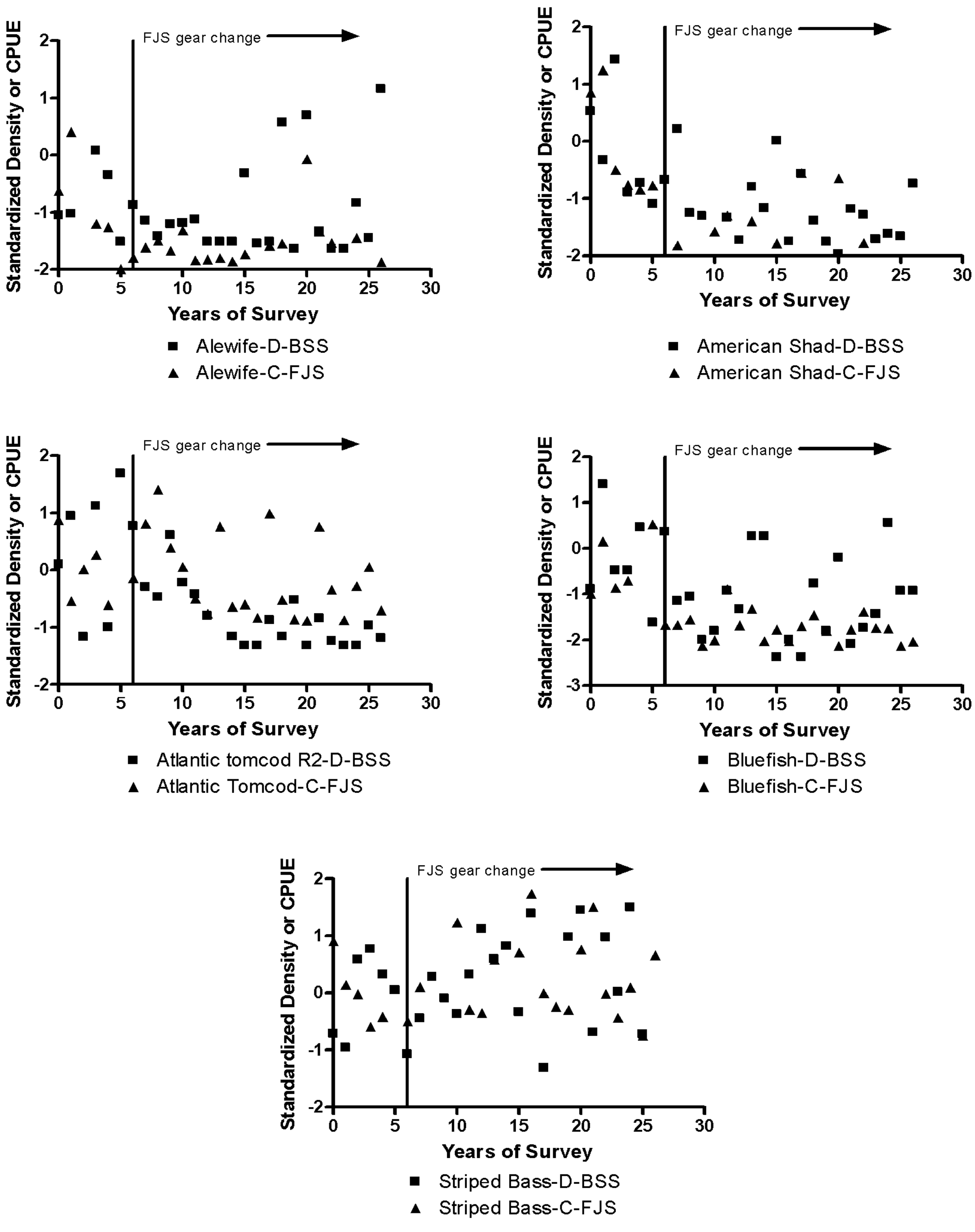
	Linear Regression			Segmented Regression			
Species	**MSE**	**Slope**	**p-value**	**MSE**	**95 percent CI Slope 1**	**Join Point**	**95 percent CI Slope 2**
Atlantic Tomcod	0.53	-0.074 ± 0.015	< 0.001	0.49	-0.187 to -0.067	1982	-0.098 to 0.124

Table I-12 River Segment 4 Assessment of the Level of Potential Negative Impact Based on the Standardized LRS Atlantic Tomcod YOY Density Using a 3-Year Moving Average

Species	Best Fit	General Trend	Percent Outside Defined Level of Noise (percent)	Support for Possible Negative Impact	Level of Potential Negative Impact
Atlantic Tomcod	SR	S1 < 0 S2 = 0	33	No	2

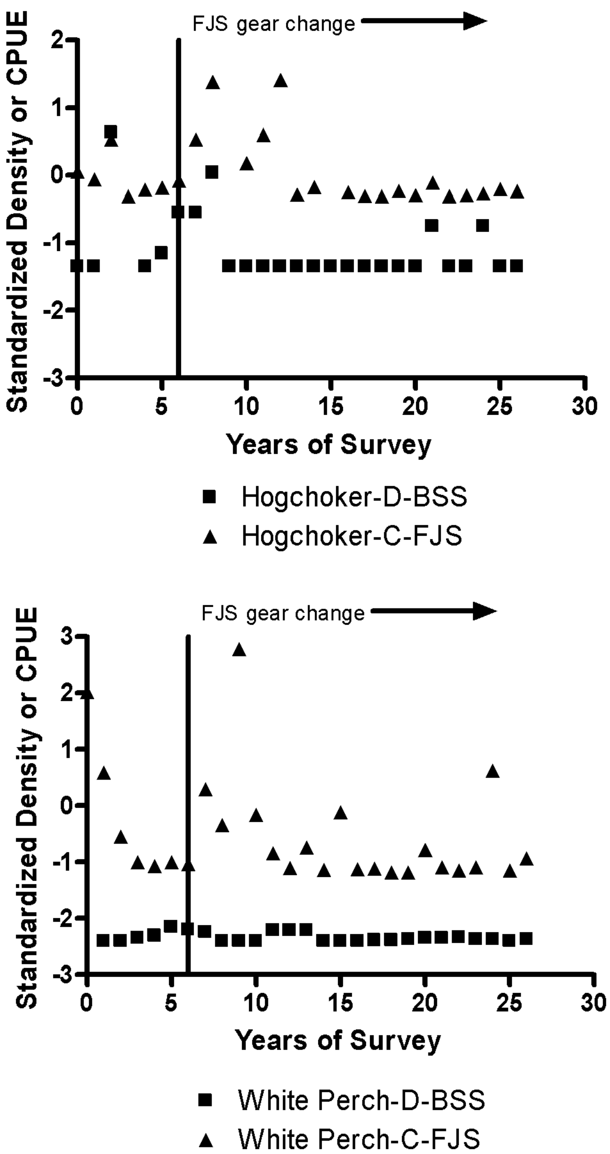
SR = Segmented Regression

A visual comparison of the river-segment FSS standardized CPUE with the BSS standardized density suggested that the trends for alewife, American shad, Atlantic tomcod, bluefish, and striped bass were not biologically different (Figure I-8). Observations from both surveys overlap and cross over each other. The post-1985 FSS CPUE observations for hogchoker and white perch were greater than the BSS observations and did not show a decline associated with the gear change (Figure I-9). Thus, for these RIS, all of the FSS CPUE data (1979–2005) were used in the regression analysis. The FSS density data for bay anchovy, blueback herring, and weakfish, however, did show a potential gear effect (Figure I-10), and a pre- and post-1985 analysis was conducted.



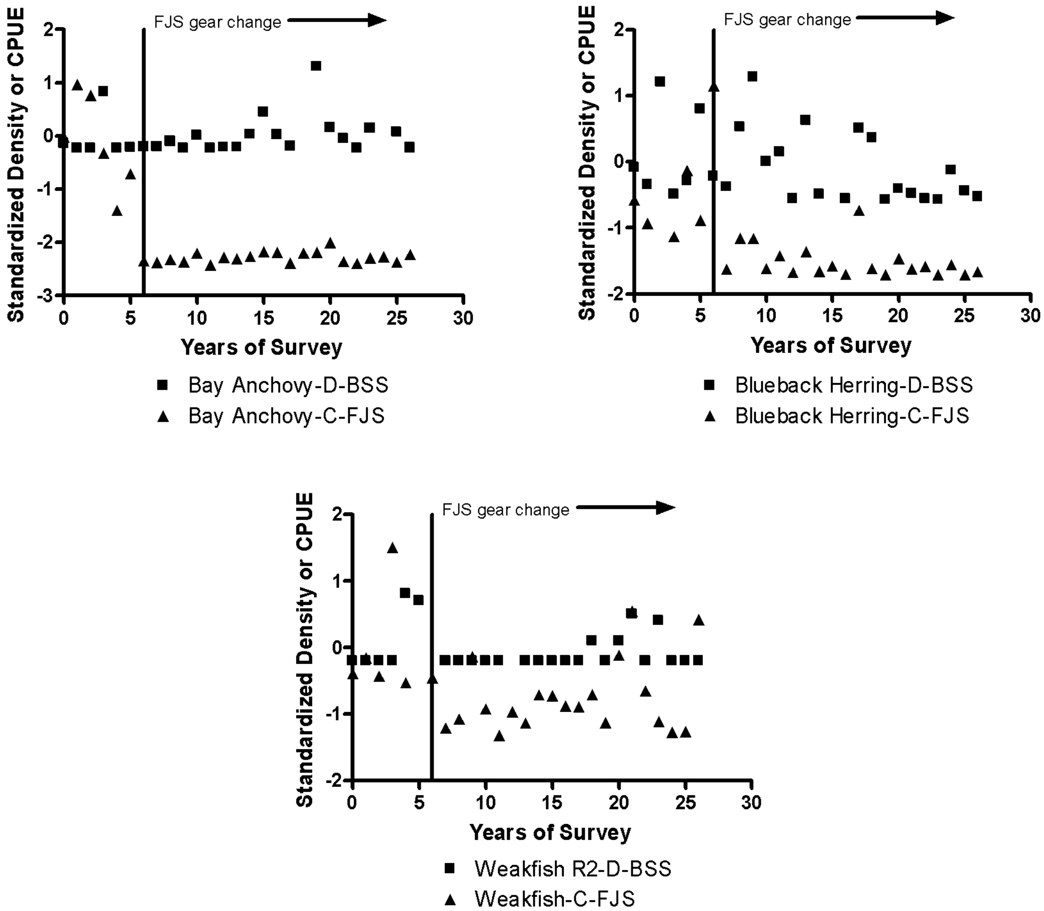
Note: All data were used in WOE analysis; R2 = River Segment 2, Yonkers.

Figure I-8 River Segment 4 population trends based on the FSS standardized CPUE (C) and BSS density (D) not considered biologically different



1 Note: All data were used in WOE analysis.

2 **Figure I-9 River Segment 4 population trends based on the FSS standardized CPUE (C)**
3 **and BSS density (D) for which the FSS density is greater**



Note: Years were analyzed separately for WOE analysis; R2 = River Segment 2, Yonkers.

Figure I-10 River Segment 4 population trends based on the FSS standardized CPUE (C) and BSS density (D) for which the FSS may indicate a gear difference

The following tables were the intermediate analyses for the assessment of population trends associated with fish CPUE sampled from River Segment 4 (IP2 and IP3). Results of these river-segment trend analyses were compiled in Table H-13 in Section H.3 of the draft SEIS (Entergy 2007). The data used in this analysis, in order of appearance, were the standardized 75th percentile of the weekly fish CPUE for a given year collected from the FSS (Table I-13, Table I-14, and Figure I-11) and LRS for Atlantic tomcod only (Table I-15and Table I-16).

Table I-13 Competing Models Used To Characterize the Standardized River Segment 4, FSS Population Trends of YOY Fish CPUE

Species	Linear Regression			Segmented Regression			
	MSE	Slope	p-value	MSE	95 percent CI Slope 1	Join Point	95 percent CI Slope 2
Alewife	0.92	-0.055 ± 0.023	0.022	0.79	-0.839 to -0.058	1984	-0.058 to 0.060
Bay Anchovy 1979–1984	0.80	-0.373 ± 0.191	0.123	Not Fit			
Bay Anchovy 1985–2005	1.00	0.034 ± 0.036	0.360	0.96	-0.022 to 0.248	1999	-0.596 to 0.172
American Shad	0.76	-0.085 ± 0.019	< 0.001	0.57	-0.717 to -0.159	1985	-0.067 to 0.018
Bluefish	0.84	-0.072 ± 0.021	0.002	0.82	-0.374 to -0.002	1988	-0.106 to 0.061
Hogchoker (All data)	1.00	-0.025 ± 0.025	0.332	0.92	-0.101 to 0.368	1988	-0.184 to 0.000
Hogchoker (2 outliers removed)	0.47	-0.021 ± 0.012	0.087	0.44	-0.049 to 0.211	1987	-0.097 to -0.008
Blueback Herring 1979–1984	1.11	-0.059 ± 0.266	0.835	Not Fit			
Blueback Herring 1985–2005	0.38	-0.022 ± 0.015	0.152	Did Not Converge			
Rainbow Smelt (All data)	0.89	-0.062 ± 0.022	0.009	0.45	-4.95 to -2.33	1980	-0.049 to 0.002
Striped Bass	1.01	-0.013 ± 0.025	0.599	1.00	-0.089 to 0.178	1993	-0.259 to 0.076
Atlantic Tomcod (All data)	0.95	-0.046 ± 0.024	0.063	0.99	-6.78 to 6.63	1980	-0.102 to 0.012
Atlantic Tomcod (1 outlier removed)	0.66	-0.028 ± 0.017	0.106	Did Not Converge			
White Perch (All data)	0.95	-0.047 ± 0.023	0.055	0.87	-3.97 to 1.12	1981	-0.071 to 0.029
White Perch (1 outlier removed)	0.72	-0.047 ± 0.024	0.038	0.51	-2.02 to -0.538	1981	-0.037 to 0.026
Weakfish 1979–1984	0.83	0.357 ± 0.199	0.148	Not Fit			
Weakfish 1985–2005 (All data)	1.00	0.035 ± 0.036	0.349	1.03	-4.66 e+007 to 4.66e+007	1986	-0.036 to 0.133
Weakfish 1985–2005 (3 values removed)	0.62	-0.003 ± 0.025	0.892	Did Not Converge			

Two extreme outliers (both values greater than 3 standard deviations from the mean) were removed from the FSS hogchoker CPUE regression analysis because of their influence on the regression (Tables I-13 and I-14). One extreme outlier (value greater than 3 standard deviations from the mean) was removed from the FSS Atlantic tomcod CPUE regression analysis, and one extreme outlier (value greater than 2 standard deviations from the mean) was

removed from the FSS white perch CPUE regression analysis. These extreme outliers had a great influence on the regression results. One value (not an extreme outlier) and two extreme outliers (both greater than 2 standard deviations from the mean) were removed from the FSS weakfish CPUE regression analysis because of the influence these data had on the regression results. The results of the regression models with the observations removed were more conservative and were used for the trend analysis.

Table I-14 River Segment 4 Assessment of the Level of Potential Negative Impact Based on the Standardized FSS CPUE

Species	Best Fit	General Trend	Percent Outside Defined Level of Noise (percent)	Support for Possible Negative Impact	Level of Potential Negative Impact
Alewife	SR	S1 < 0 S2 = 0	89	Yes	4
Bay Anchovy 1979–1984	LR	S = 0	33	No	1
Bay Anchovy 1985–2005	SR	S1 = 0 S2 = 0	33		
American Shad	SR	S1 < 0 S2 = 0	74	Yes	4
Bluefish	SR	S1 < 0 S2 = 0	78	Yes	4
Hogchoker (All data)	SR	S1 = 0 S2 = 0	15	No	1
Hogchoker (2 outliers removed)	SR	S1 = 0 S2 < 0	15	No	2
Blueback Herring 1979–1984	LR	S = 0	17	Yes	2
Blueback Herring 1985–2005	LR	S = 0	71		
Rainbow Smelt (All data)	SR	S1 < 0 S2 = 0	78	Yes	4
Striped Bass	SR	S1 = 0 S2 = 0	26	No	1
Atlantic Tomcod (All data)	LR	S = 0	7	No	1
Atlantic Tomcod (1 outlier removed)	LR	S = 0	7	No	1
White Perch (All data)	SR	S1 = 0 S2 = 0	56	Yes	2
White Perch (1 outlier removed)	SR	S1 < 0 S2 = 0	56	Yes	4
Weakfish 1979–1984	LR	S = 0	33	No	1
Weakfish 1985–2005 (All data)	LR	S = 0	24		
Weakfish 1985–2005 (3 values removed)	LR	S = 0	24		

LR = Linear Regression; SR = Segmented Regression

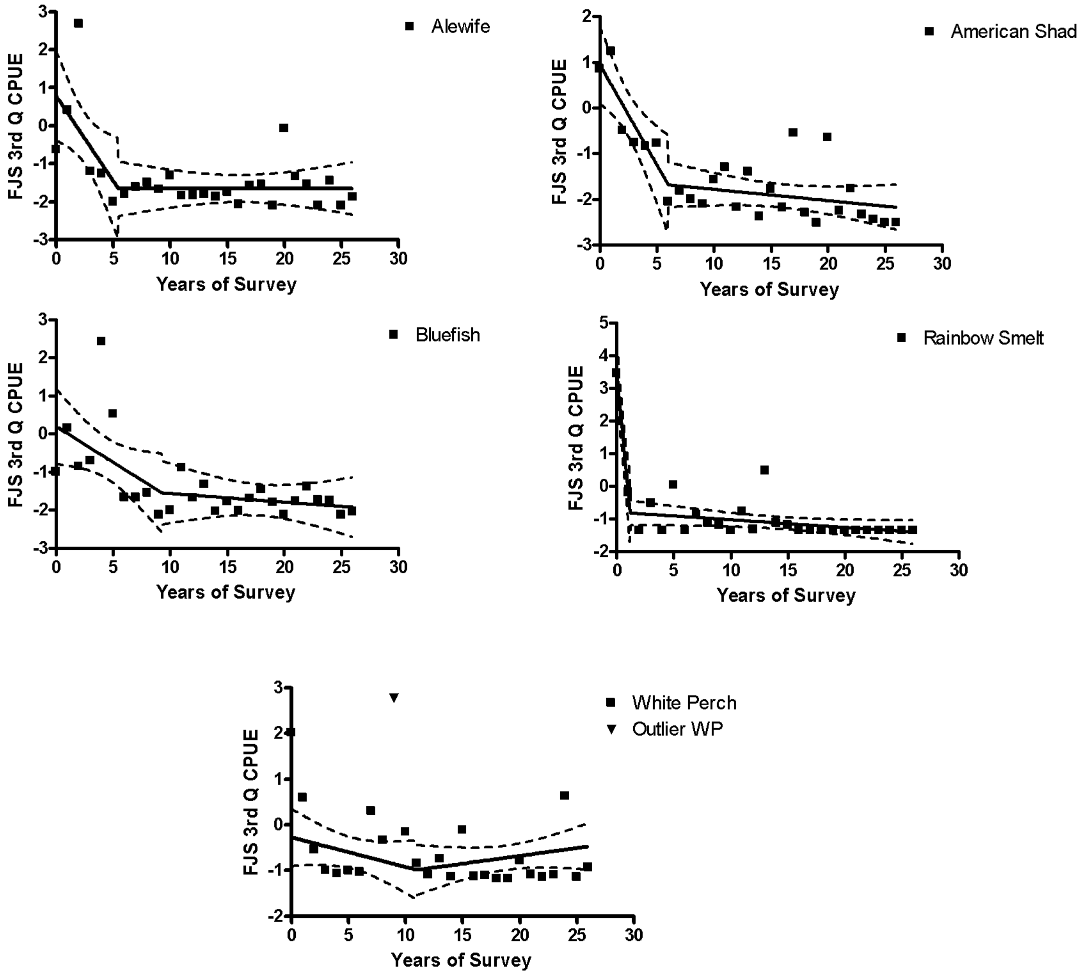


Figure I-11 River Segment 4 population trends based on the FSS standardized CPUE assigned a large level of potential negative impact

Table I-15 Competing Models Used To Characterize the Standardized River Segment 4 LRS Population Trends of YOY Atlantic Tomcod CPUE Using a 3-Year Moving Average

	Linear Regression			Segmented Regression			
Species	**MSE**	**Slope**	**p-value**	**MSE**	**95 percent CI Slope 1**	**Join Point**	**95 percent CI Slope 2**
Atlantic Tomcod	0.57	-0.069 ± 0.022	0.006	0.28	-0.873 to -0.338	1989	-0.031 to 0.034

Table I-16 River Segment 4 Assessment of the Level of Potential Negative Impact Based on the Standardized LRS Atlantic Tomcod YOY CPUE Using a 3-Year Moving Average

Species	Best Fit	General Trend	Percent Outside Defined Level of Noise (percent)	Support for Possible Negative Impact	Level of Potential Negative Impact
Atlantic Tomcod	SR	S1 < 0 S2 = 0	22	No	2

SR = Segmented Regression

The results of the two measurement metrics—density (estimated number of RIS per given volume of water provided by the applicant) and CPUE (number of RIS captured by the sampler for a given volume of water derived by the NRC staff) were combined for the assessment of population impacts potentially associated with the IP2 and IP3 cooling systems. Table I-17 presents the numeric results compiled from Tables I-8, I-10, I-12, I-14, and I-16 above and used to derive Table H-13 in Section H.3 in the draft SEIS.

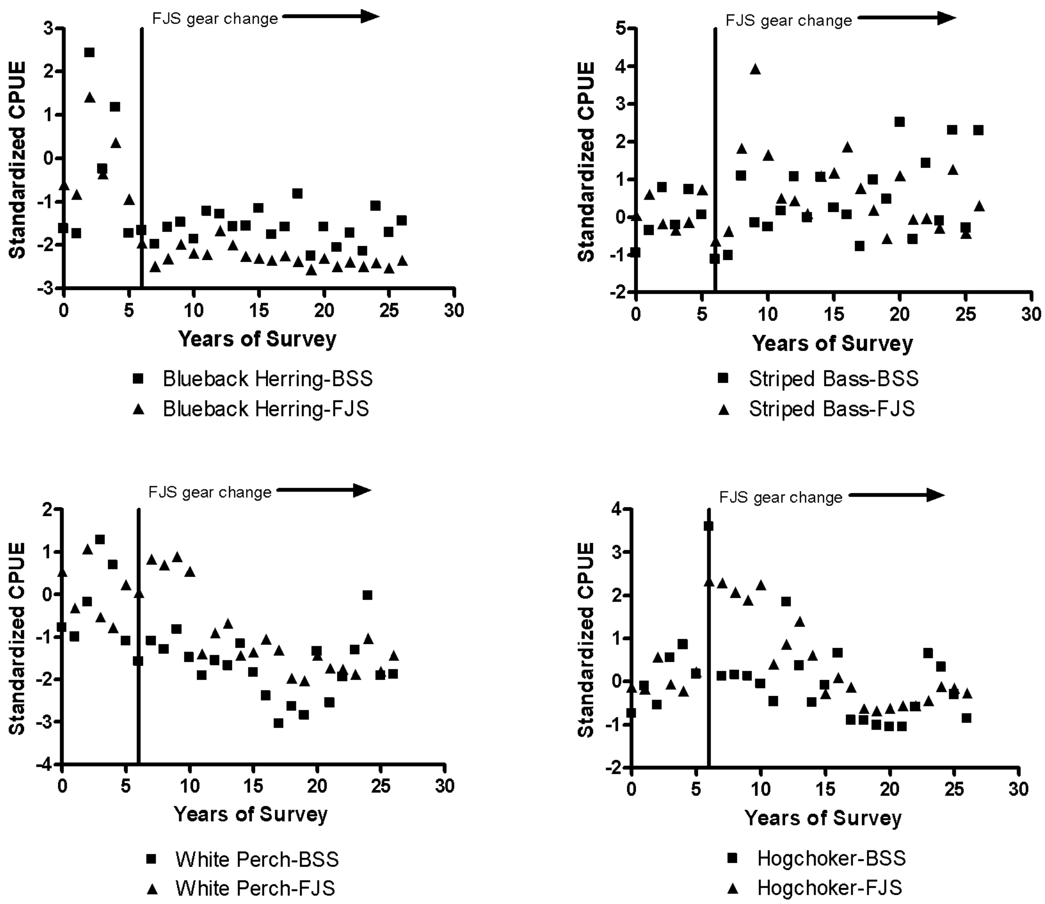
Table I-17 Assessment of Population Impacts for IP2 and IP3 River Segment 4

Species	Density			CPUE		River-Segment Assessment
	FSS	BSS	LRS	FSS	LRS	
Alewife	4	4	N/A[a]	4	N/A	4.0
Bay Anchovy	4	1	N/A	1	N/A	2.0
American Shad	4	4	N/A	4	N/A	4.0
Bluefish	1	4	N/A	4	N/A	3.0
Hogchoker	2	4	N/A	2	N/A	2.7
Atlantic Menhaden	N/A	N/A	N/A	N/A	N/A	Unknown
Blueback Herring	2	2	N/A	2	N/A	2.0
Rainbow Smelt	2	N/A	N/A	4	N/A	3.0
Shortnose Sturgeon	N/A	N/A	N/A	N/A	N/A	Unknown
Spottail Shiner	N/A	4	N/A	N/A	N/A	4.0
Atlantic Sturgeon	N/A	N/A	N/A	N/A	N/A	Unknown
Striped Bass	1	1	N/A	1	N/A	1.0
Atlantic Tomcod	2	N/A	2	1	2	1.8
White Catfish	1	N/A	N/A	N/A	N/A	1.0
White Perch	1	4	N/A	4	N/A	3.0
Weakfish	1	N/A	N/A	1	N/A	1.0
Gizzard Shad	N/A	N/A	N/A	N/A	N/A	Unknown
Blue Crab	N/A	N/A	N/A	N/A	N/A	Unknown

(a) N/A: not applicable; YOY not present in samples

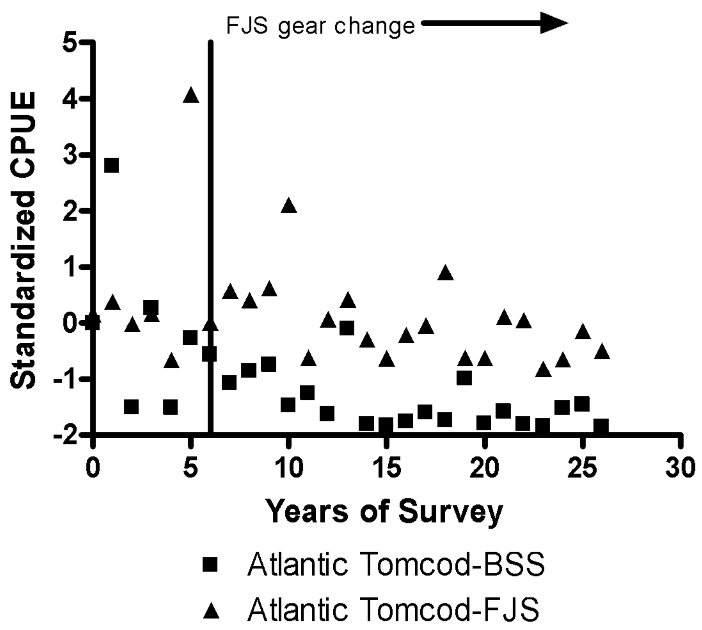
<u>Lower Hudson River</u>

A visual comparison of the riverwide FSS standardized CPUE with the BSS standardized CPUE suggested that the trends were not biologically different for blueback herring, striped bass, white perch, and hogchoker (Figure I-12). Observations from both surveys overlap and cross over each other. The post-1985 FSS observations for Atlantic tomcod were greater than the BSS observations and did not show a decline associated with the gear change (Figure I-13). For these RIS, all of the FSS data (1979–2005) were used in the regression analysis. The FSS density data for alewife, American shad, bay anchovy, and bluefish, however, did show a potential gear effect (Figure I-14), and a pre- and post-1985 analysis was conducted.



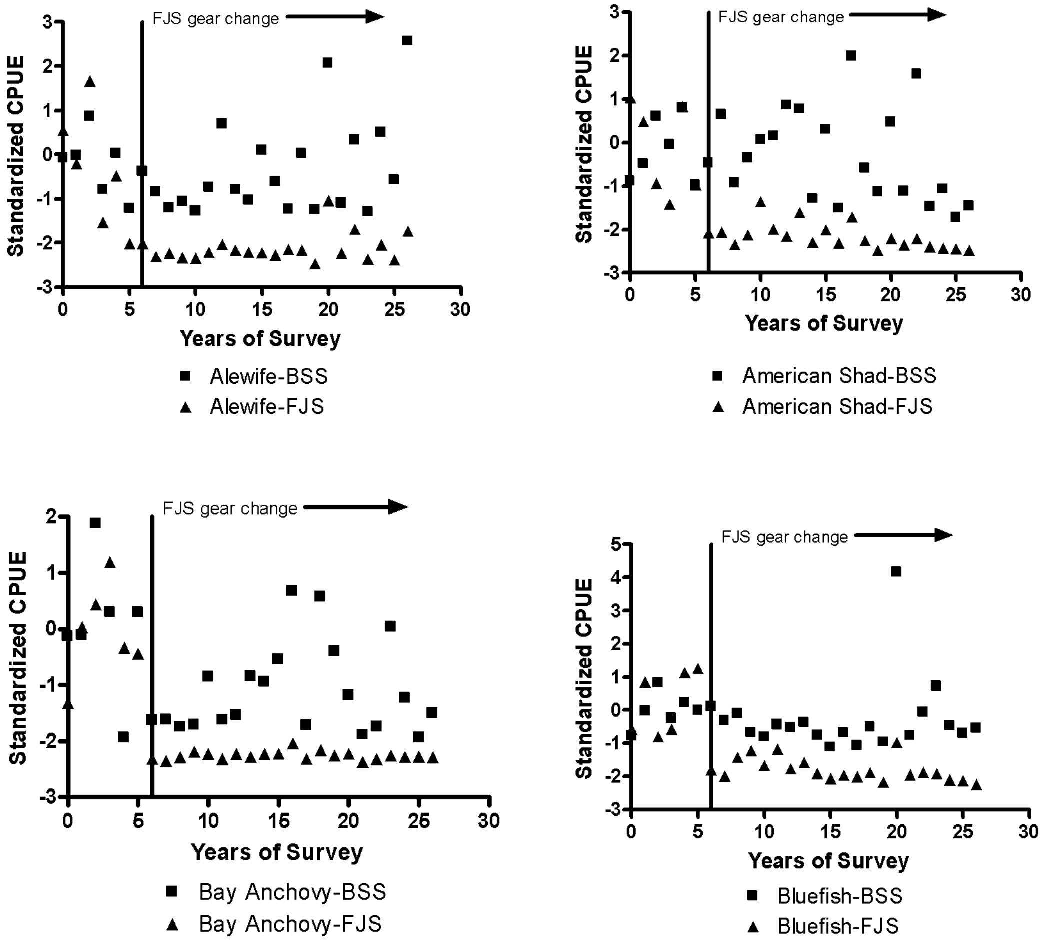
Note: All data were used in WOE analysis.

Figure I-12 Riverwide population trends based on the FSS and BSS standardized CPUE not considered biologically different



Note: All data were used in WOE analysis.

Figure I-13 Riverwide population trends based on the FSS and BSS standardized CPUE for which the FSS density is greater



Note: Years were analyzed separately for WOE analysis.

Figure I-14 Riverwide population trends based on the FSS and BSS standardized CPUE for which the FSS may indicate a gear difference

The following tables are the intermediate analyses for the riverwide assessment of population trends associated with annual fish CPUE and the abundance index. Results of these riverwide trend analyses are compiled in Table H-14 in Section H.3 of the draft SEIS. The data used in this analysis, in order of appearance, were the standardized annual fish CPUE for a given year collected from the FSS (Table I-18, Table I-19, and Figure I-15), BSS (Table I-20, Table I-21, and Figure I-16), LRS for Atlantic tomcod only (Table I-22 and Table I-23), and the annual fish abundance index (Table I-24, Table I-25, and Figure H-17).

One extreme outlier (value greater than 4 standard deviations away from the mean) was removed from the abundance index for the bluefish regression analysis (Tables I-24 and I-25).

One extreme outlier was also removed from the abundance index for both the rainbow smelt (value greater than 5 standard deviations away from the mean) regression analysis and the white catfish (value greater than 2 standard deviations away from the mean) regression analysis, because of the influence these data had on the regression results. The results of the regression models with the observations removed were more conservative and were used for the trend analysis.

Table I-18 Competing Models Used To Characterize the Standardized Riverwide FSS Population Trends of YOY Fish CPUE

Species	Linear Regression			Segmented Regression			
	MSE	Slope	p-value	MSE	95 percent CI Slope 1	Join Point	95 percent CI Slope 2
Alewife 1979–1984	0.833	-0.357 ± 0.199	0.148	Not Fit			
Alewife 1985–2005	0.628	0.025 ± 0.023	0.286	0.633	-1.90e+007 to 1.90e+007	1986	-0.015 to 0.090
Bay Anchovy 1979–1984	1.08	0.135 ± 0.259	0.629	Not Fit			
Bay Anchovy 1985–2005	0.764	-0.002 ± 0.028	0.949	0.749	-0.082 to 0.328	1993	-0.216 to 0.073
American Shad 1979–1984	0.983	-0.254 ± 0.235	0.340	Not Fit			
American Shad 1985–2005	0.873	-0.085 ± 0.031	0.015	0.831	-0.362 to 0.746	1989	-0.222 to -0.031
Bluefish 1979–1984	0.918	0.305 ± 0.219	0.236	Not Fit			
Bluefish 1985–2005	0.915	-0.073 ± 0.033	0.039	0.899	-0.778 to 1.90	1987	-0.193 to -0.021
Hogchoker	0.916	-0.055 ± 0.023	0.022	0.645	0.114 to 0.526	1986	-0.198 to -0.086
Blueback Herring	0.704	-0.091 ± 0.017	< 0.001	0.563	-0.454 to -0.153	1987	-0.079 to 0.027
Spottail Shiner (All data)	0.875	-0.035 ± 0.022	0.125	0.859	-0.295 to 0.675	1984	-0.132 to 0.003
Striped Bass	1.019	-0.003 ± 0.025	0.902	0.931	-0.085 to 0.389	1988	-0.162 to 0.025
Atlantic Tomcod	0.607	-0.028 ± 0.015	0.083	0.595	-0.089 to 0.183	1989	-0.124 to -0.002
White Perch	0.647	-0.097 ± 0.016	< 0.001	Did Not Converge			

Table I-19 Riverwide Assessment of the Level of Potential Negative Impact Based on the Standardized FSS CPUE

Species	Best Fit	General Trend	Percent Outside Defined Level of Noise (percent)	Support for Possible Negative Impact	Final Decision
Alewife 1979–1984	LR	S = 0	50	Yes	2
Alewife 1985–2005	LR	S = 0	14		
Bay Anchovy 1979–1984	LR	S = 0	33	No	1
Bay Anchovy 1985–2005	SR	S1 = 0 S2 = 0	24		
American Shad 1979–1984	LR	S = 0	50	Yes	4
American Shad 1985–2005	SR	S1 = 0 S2 < 0	52		
Bluefish 1979–1984	LR	S = 0	33	Yes	4
Bluefish 1985–2005	SR	S1 = 0 S2 < 0	48		
Hogchoker	SR	S1 > 0 S2 < 0	22	No	2
Blueback Herring	SR	S1 < 0 S2 = 0	81	Yes	4
Spottail Shiner	SR	S1 = 0 S2 = 0	26	No	1
Striped Bass	SR	S1 = 0 S2 = 0	30	No	1
Atlantic Tomcod	SR	S1 = 0 S2 < 0	7	No	2
White Perch	LR	S < 0	56	Yes	4

LR = Linear Regression; SR = Segmented Regression

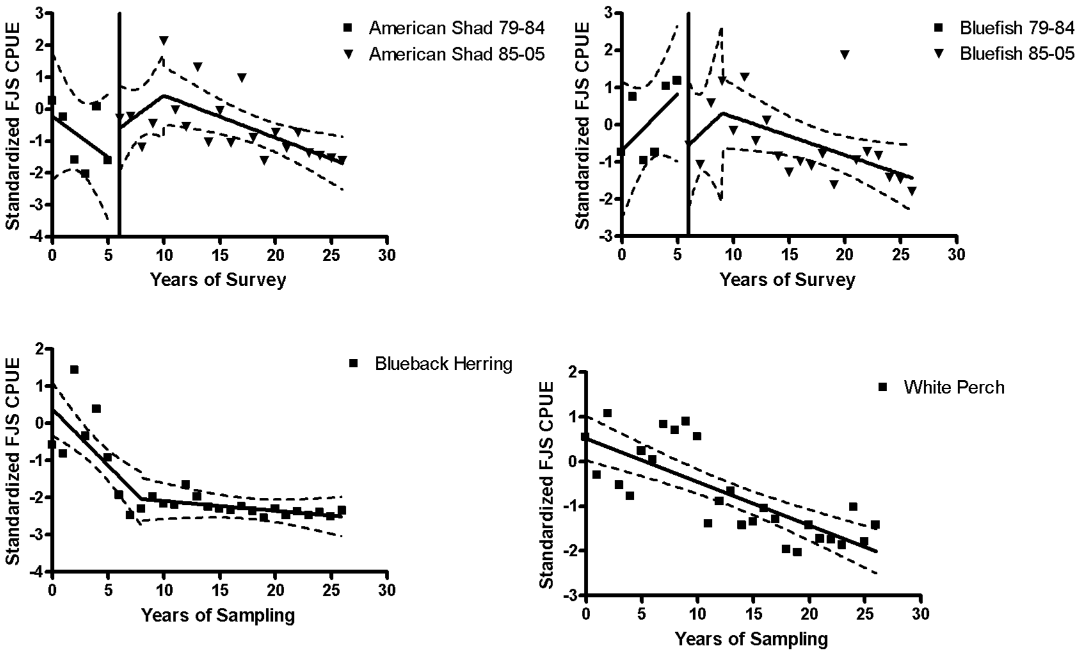


Figure I-15 Riverwide population trend based on the FSS standardized CPUE assigned a large level of potential negative impact

1 **Table I-20 Competing Models Used To Characterize the Standardized Riverwide BSS**
2 **Population Trends of YOY Fish CPUE**

	Linear Regression			Segmented Regression			
Species	**MSE**	**Slope**	**p-value**	**MSE**	**95 percent CI Slope 1**	**Join Point**	**95 percent CI Slope 2**
Alewife	0.996	0.027 ± 0.025	0.281	0.944	-0.417 to 0.087	1987	-0.001 to 0.177
Bay Anchovy	0.971	-0.038 ± 0.024	0.123	0.927	-0.631 to 0.094	1986	-0.063 to 0.085
American Shad	0.991	-0.030 ± 0.025	0.235	0.981	-0.103 to 0.198	1992	-0.240 to 0.029
Bluefish	0.478	-0.019 ± 0.012	0.121	0.439	-0.103 to -0.013	1995	-0.038 to 0.165
Hogchoker	0.969	-0.039 ± 0.024	0.113	0.913	-0.212 to 0.983	1983	-0.141 to -0.014
Blueback Herring	0.937	-0.050 ± 0.023	0.042	0.940	-0.429 to 0.091	1987	-0.101 to 0.075
Spottail Shiner	0.965	0.041 ± 0.024	0.101	0.928	-0.448 to 0.145	1987	0.012 to 0.172
Striped Bass	0.908	0.057 ± 0.022	0.017	0.941	-0.347 to 0.373	1986	-0.010 to 0.147
Atlantic Tomcod	0.802	-0.078 ± 0.020	0.001	0.787	-0.232 to -0.038	1993	-0.135 to 0.137
White Perch	0.859	-0.068 ± 0.021	0.004	0.737	-0.208 to -0.070	1997	-0.036 to 0.358
Rainbow Smelt	0.875	-0.065 ± 0.022	0.006	0.327	-1.54 to -0.939	1982	-0.022 to 0.021
White Catfish	0.642	-0.098 ± 0.016	< 0.001	0.668	-2.02 to 1.89	1980	-0.138 to -0.061
Weakfish	1.01	-0.021 ± 0.025	0.407	0.996	-0.514 to 1.33	1982	-0.111 to 0.018

Table I-21 Riverwide Assessment of the Level of Potential Negative Impact Based on the BSS CPUE

Species	Best Fit	General Trend	Percent Outside Defined Level of Noise (percent)	Support for Possible Negative Impact	Final Decision
Alewife	SR	S1 = 0 S2 = 0	41	Yes	2
Bay Anchovy	SR	S1 = 0 S2 = 0	56	Yes	2
American Shad	SR	S1 = 0 S2 = 0	37	No	1
Bluefish	SR	S1 < 0 S2 = 0	11	No	2
Hogchoker	SR	S1 = 0 S2 < 0	19	No	2
Blueback Herring	LR	S < 0	93	Yes	4
Spottail Shiner	SR	S1 = 0 S2 > 0	26	No	1
Striped Bass	LR	S > 0	33	No	1
Atlantic Tomcod	SR	S1 < 0 S2 = 0	74	Yes	4
White Perch	SR	S1 < 0 S2 = 0	81	Yes	4
Rainbow Smelt	SR	S1 < 0 S2 = 0	96	Yes	4
White Catfish	LR	S < 0	67	Yes	4
Weakfish	SR	S1 = 0 S2 = 0	11	No	1

LR = Linear Regression; SR = Segmented Regression

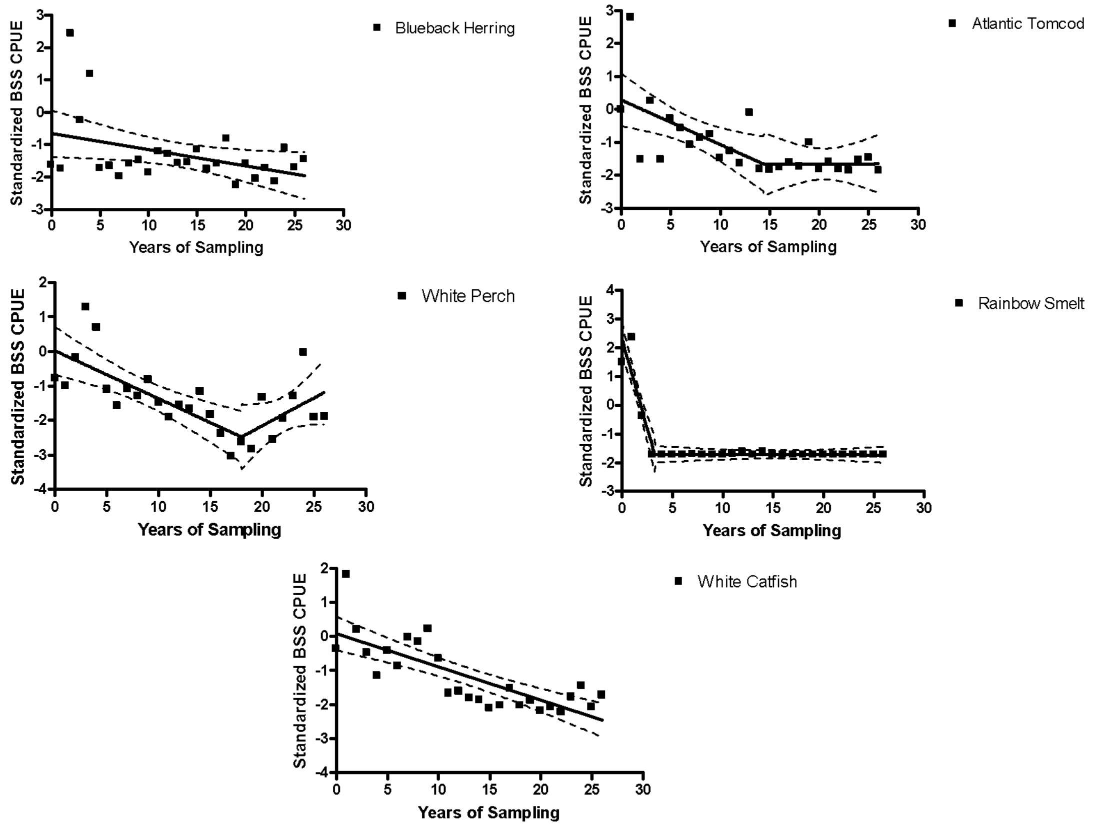


Figure I-16 Riverwide population trends based on the BSS standardized CPUE assigned a large level of potential negative impact

Table I-22 Competing Models Used To Characterize the Standardized Riverwide LRS Population Trend of YOY Atlantic Tomcod CPUE

	Linear Regression			Segmented Regression			
Species	**MSE**	**Slope**	**p-value**	**MSE**	**95 percent CI Slope 1**	**Join Point**	**95 percent CI Slope 2**
Atlantic Tomcod	1.02	-0.006 ± 0.025	0.826	0.96	-2.38 to 0.439	1980	-0.037 to 0.081

Table I-23 Riverwide Assessment of the Level of Potential Negative Impact Based on the Standardized LRS CPUE of Atlantic Tomcod

Species	Best Fit	General Trend	Percent Outside Defined Level of Noise	Support for Possible Negative Impact	Final Decision
Atlantic Tomcod	SR	S1 = 0 S2 = 0	44	Yes	2

SR = Segmented Regression

Table I-24 Competing Models Used To Characterize the Standardized Riverwide YOY Abundance Index Trends

	Linear Regression			Segmented Regression			
Species	**MSE**	**Slope**	**p-value**	**MSE**	**95 percent CI Slope 1**	**Join Point**	**95 percent CI Slope 2**
Alewife	1.00	-0.024 ± 0.025	0.334	1.03	-0.200 to 0.075	1993	-0.149 to 0.195
Bay Anchovy	0.952	-0.045 ± 0.024	0.067	0.890	-0.137 to 0.317	1988	-0.192 to -0.014
American Shad	0.924	-0.053 ± 0.023	0.028	0.934	-0.163 to 0.221	1989	-0.199 to 0.010
Bluefish (All data)	1.00	0.023 ± 0.025	0.355	1.03	-0.274 to 0.195	1989	-0.053 to 0.158
Bluefish (1 outlier removed)	0.378	0.003 ± 0.009	0.775	0.359	-0.074 to 0.015	1994	-0.014 to 0.111
Hogchoker	0.992	-0.029 ± 0.025	0.244	0.964	-0.143 to 0.349	1988	-0.179 to 0.015
Blueback Herring	0.978	-0.036 ± 0.024	0.152	0.896	-0.077 to 0.380	1988	-0.200 to -0.020
Rainbow Smelt (All data)	1.02	-0.008 ± 0.025	0.759	Did Not Converge			
Rainbow Smelt (1 outlier removed)	0.269	-0.008 ± 0.007	0.253	0.265	-0.038 to 0.104	1987	-0.047 to 0.004
Spottail Shiner	0.972	0.038 ± 0.024	0.125	0.960	-0.164 to 0.100	1993	-0.025 to 0.270
Striped Bass	0.952	0.045 ± 0.024	0.067	0.970	-0.081 to 0.114	1996	-0.126 to 0.369
Atlantic Tomcod	0.969	-0.039 ± 0.024	0.112	0.852	-0.051 to 0.323	1989	-0.223 to -0.036
White Catfish (All data)	0.854	-0.069 ± 0.021	0.003	Did Not Converge			
White Catfish (1 outlier removed)	0.495	-0.062 ± 0.012	< 0.001	Did Not Converge			
White Perch	0.964	-0.041 ± 0.024	0.096	0.795	-0.286 to -0.068	1993	-0.007 to 0.237
Weakfish	0.900	-0.059 ± 0.022	0.013	0.854	-0.329 to 0.689	1984	-0.153 to -0.028

Table I-25 Riverwide Assessment of the Level of Potential Negative Impact Based on the Abundance Index

Species	Best Fit	General Trend	Percent Outside Defined Level of Noise (percent)	Support for Possible Negative Impact	Final Decision
Alewife	LR	S = 0	33	No	1
Bay Anchovy	SR	S1 = 0 S2 < 0	30	No	2
American Shad	LR	S < 0	52	Yes	4
Bluefish (All data)	LR	S = 0	7	No	1
Bluefish (1 outlier removed)	SR	S1 = 0 S2 = 0	7	No	1
Hogchoker	SR	S1 = 0 S2 = 0	15	No	1
Blueback Herring	SR	S1 = 0 S2 < 0	19	No	2
Rainbow Smelt (All data)	LR	S = 0	4	No	1
Rainbow Smelt (1 outlier removed)	SR	S1 = 0 S2 = 0	4	No	1
Spottail Shiner	SR	S1 = 0 S2 = 0	26	No	1
Striped Bass	LR	S = 0	30	No	1
Atlantic Tomcod	SR	S1 = 0 S2 < 0	19	No	2
White Catfish (All data)	LR	S < 0	63	Yes	4
White Catfish (1 outlier removed)	LR	S < 0	63	Yes	4
White Perch	SR	S1 < 0 S2 = 0	70	Yes	4
Weakfish	SR	S1 = 0 S2 < 0	15	No	2

LR = Linear Regression; SR = Segmented Regression

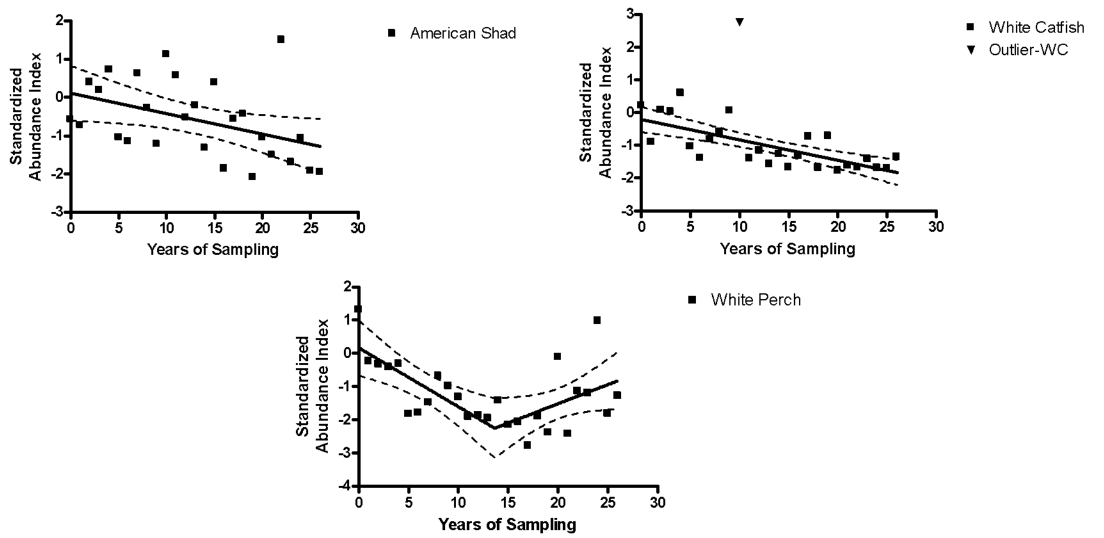


Figure I-17 Riverwide population trends based on the abundance index assigned a large level of potential negative impact

The results of the two measurement metrics—CPUE (number of RIS captured by the sampler for a given volume of water derived by the NRC staff) and the abundance index provided by the applicant—were combined for the assessment of riverwide population impacts. Table I-26 presents the numeric results compiled from Tables I-19, I-21, I-23, and I-25 above and used to derive Table H-14 in Section H.3 in the draft SEIS.

Table I-26 Assessment of Riverwide Population Impacts

Species	CPUE			Abundance Index	Riverwide Assessment
	FSS	BSS	LRS		
Alewife	2	2	N/A[a]	1	1.7
Bay Anchovy	1	2	N/A	2	1.7
American Shad	4	1	N/A	4	3.0
Bluefish	4	2	N/A	1	2.3
Hogchoker	2	2	N/A	1	1.7
Atlantic Menhaden	N/A	N/A	N/A	N/A	Unknown
Blueback Herring	4	4	N/A	2	3.3
Rainbow Smelt	N/A	4	N/A	1	2.5
Shortnose Sturgeon	N/A	N/A	N/A	N/A	Unknown
Spottail Shiner	1	1	N/A	1	1.0
Atlantic Sturgeon	N/A	N/A	N/A	N/A	Unknown
Striped Bass	1	1	N/A	1	1.0
Atlantic Tomcod	2	4	2	2	2.5
White Catfish	N/A	4	N/A	4	4.0
White Perch	4	4	N/A	4	4.0
Weakfish	N/A	1	N/A	2	1.5
Gizzard Shad	N/A	N/A	N/A	N/A	Unknown
Blue Crab	N/A	N/A	N/A	N/A	Unknown

I.2.2. Analysis of Strength of Connection

To determine whether the operation of the IP2 and IP3 cooling systems has the potential to influence RIS populations near the facilities or within the lower Hudson River, the NRC staff conducted a strength-of-connection analysis. Measurements used for this analysis include monitoring data at IP2 and IP3 from 1975–1990 that provide information on impingement and entrainment rates for RIS and prey of RIS, as well as River Segment 4 (IP2 and IP3) population-density data from the FSS and BSS.

The analysis of effects of impingement was based on the concordance of ranked proportions of the number of YOY and yearling fish of each species impinged in relation to the sum of all fish impinged and the ranked proportions of each species abundance in the river near IP2 and IP3 relative to the total abundance of the18 RIS. Likewise, the effects of entrainment were based on the concordance of ranked proportions of the estimated number entrained for all life stages for a given species in relation to the abundance of all fish entrained and the ranked proportion of each species abundance in the river near IP2 and IP3 relative to the total abundance of the RIS.

An estimate of the population abundance (S_i) for a given species in the vicinity of IP2 and IP3 was estimated as the maximum over all years (1979–1990) of the annual 75^{th} percentile of weekly density measures from all habitats. Thus, S_i for each species was the maximum annual sum of the FSS and BSS 75^{th} percentile of weekly densities from the river segment near IP2

and IP3 (Table I-27). The estimate of the total RIS community abundance (S_{RIS}) caught in the vicinity of IP2 and IP3 was the sum of the maximum densities of each species.

The density of each species impinged (Imp_i) was estimated by the 75th percentile of the annual (1975–1990) density impinged at IP2. IP2 typically had 2.8 times more fish impinged than IP3. The annual density impinged was the sum of the seasonal (January–March, April–June, July–September, October–December) densities calculated as the estimated number impinged divided by the number of samples taken (Table I-28). The estimate of the total density of RIS impinged (Imp_{RIS}) was the 75th percentile of the annual sum of all RIS densities impinged at IP2. The estimate of Imp_i / Imp_{RIS} was the ratio of the density of an individual species impinged to the total RIS density.

The density of each species entrained for a given season and year (1981–1987) was calculated as the mean number entrained divided by the number of samples taken (Table I-29). Density estimates were based on the combined entrainment from IP2 and IP3. The estimate of E_i / E_{RIS} was the maximum over years of the ratio of the density of an individual species entrained to the total RIS density.

Because of the error and bias in estimation of each of these parameters, only the ranks of each ratio were considered a reliable measure of connection. Thus, to estimate the overall strengths of connection between the IP2 and IP3 cooling systems and the RIS in the Hudson River near the facilities, the estimates of Imp_i / Imp_{RIS}, E_i / E_{RIS}, and S_i / S_{RIS} for each species were ranked from 1 (low proportion) to 18 (high proportion), and then the ratio of the ranks were compared as a measure of the strength of connection for impingement (Table I-30) and entrainment (Table I-31).

Potential food web impacts on RIS associated with the loss of prey caused by impingement or entrainment, based on the relationship presented in the conceptual model (Section 4.1.3 in the main text), were also considered. Indirect impacts on predator fish (bluefish, spottail shiner, striped bass, white perch, and weakfish) were based on the largest observed strength of connection associated with their prey. Thus, for YOY bluefish, which preys on juvenile bay anchovy and Atlantic tomcod, a loss of prey associated with impingement was estimated as 1.33 (the maximum of 0.88 for anchovy and 1.33 for tomcod) (Table I-31). The remaining YOY predator-prey relationships were YOY spottail shiner prey on YOY striped bass; YOY striped bass prey on YOY bay anchovy, hogchoker, Atlantic tomcod, and weakfish; YOY white perch prey on YOY bay anchovy; and YOY weakfish prey on YOY bay anchovy. All remaining YOY RIS eat plankton, zooplankton, benthic invertebrates, and amphipods. These prey were assumed to be unaffected by the cooling systems, and a low strength of connection was concluded. The results of this analysis are presented in Table H-16 in Section H.3 of the draft SEIS and in Table I-32.

1 **Table I-27 Sum of the FSS and BSS 75th Percentiles of the Weekly Density Caught at**
2 **River Segment 4**

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Maximum = Si
Alewife	1.01	0.55	6.94	2.86	2.36	0.21	1.31	1.28	0.36	0.93	1.42	0.87	6.94
Bay Anchovy	96.33	198.05	342.15	391.41	82.03	194.88	106.25	77.11	73.54	153.21	303.60	48.77	391.41
American Shad	5.49	4.90	19.04	8.42	7.77	7.00	6.59	13.68	5.33	4.62	23.27	5.33	23.27
Bluefish	0.52	1.23	1.03	1.06	1.66	1.30	1.41	0.52	0.63	0.20	0.30	1.64	1.66
Hogchoker	0.56	1.31	1.69	1.20	0.16	0.53	0.83	1.94	3.09	4.27	0.44	1.14	4.27
Atlantic Menhaden	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blueback Herring	10.39	3.31	38.43	3.56	8.94	24.15	24.46	5.25	17.82	29.09	8.52	10.71	38.43
Rainbow Smelt	3.12	0.63	0.00	0.12	0.00	0.65	0.00	0.97	0.58	0.39	0.00	1.36	3.12
Shortnose Sturgeon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spottail Shiner	3.20	0.20	0.60	5.80	1.19	0.25	0.20	0.75	0.20	0.73	1.80	3.10	5.80
Atlantic Sturgeon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stripped Bass	4.28	4.60	15.24	15.15	12.47	12.17	3.09	6.83	13.42	12.64	9.15	12.58	15.24
Atlantic Tomcod	2.34	1.12	4.09	3.85	0.67	11.94	1.65	5.68	2.20	2.76	2.04	1.60	11.94
White Catfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03
White Perch	16.51	14.90	18.74	15.69	7.36	8.19	10.82	22.56	13.16	10.83	2.94	4.38	22.56
Weakfish	0.90	1.72	2.21	9.21	1.36	11.11	1.76	0.76	0.45	3.17	1.42	1.00	11.11
Gizzard Shad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table I-28 Annual Density of RIS Impinged at IP2

Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Alewife	97.1	23.4	231.5	305.9	40.6	79.2	2300.1	269.4	750.0	148.3	181.1	224.8	441.7	169.7	92.5	221.6
Bay Anchovy	2394.4	304.6	1838.3	2871.8	2308.8	2677.7	47136.1	11429.7	11474.6	242.9	441.8	9285.6	2740.3	2343.0	166.1	1363.5
American Shad	26.2	38.5	52.4	421.7	129.2	331.7	8859.3	191.9	909.3	15.1	36.9	629.5	440.2	122.7	202.8	165.5
Bluefish	37.1	0.8	185.5	32.5	3.0	85.6	399.2	638.2	2599.2	7.9	47.3	762.0	1883.8	501.8	114.4	1031.6
Hogchoker	441.7	149.2	216.0	564.3	469.7	372.4	513.3	6088.4	2200.4	345.2	388.1	4253.9	3835.6	6687.7	4051.7	3071.9
Atlantic Menhaden	1.2	1.6	3.4	4.0	0.6	2.0	244.4	34.2	77.5	4.4	37.3	769.7	352.4	144.0	144.4	166.3
Blueback Herring	2902.9	4213.6	4930.9	5214.0	2157.9	290.2	5193.5	191.3	4361.3	176.9	157.8	395.3	3129.3	689.2	505.1	2424.5
Rainbow Smelt	111.9	59.8	290.7	519.7	390.2	180.4	25.2	274.0	413.3	48.9	82.5	1189.4	832.4	1868.3	50.2	140.7
Shortnose Sturgeon	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	17.6	0.0	0.0	5.0	0.0	0.0	0.0
Spottail Shiner	45.4	93.4	67.4	31.2	79.4	45.4	35.6	30.2	93.9	60.3	33.7	23.7	128.4	89.6	218.4	290.6
Atlantic Sturgeon	2.2	0.2	1.2	0.4	1.0	0.2	3.5	21.7	2.5	9.4	5.3	44.0	0.0	0.0	0.0	0.0
Stripped Bass	111.3	110.7	268.3	469.5	828.5	252.5	1439.9	341.7	1048.5	304.3	457.2	827.8	2116.3	3226.0	1021.1	1766.7
Atlantic Tomcod	1808.4	657.1	11399.8	4920.4	1294.0	5458.4	7694.2	14207.7	13612.1	294.6	1723.5	13925.4	162126.7	1414.7	400.4	14222.0
White Catfish	175.9	202.1	148.4	41.0	39.0	14.7	36.1	101.1	139.1	118.2	73.0	159.7	171.8	580.7	255.8	488.7
White Perch	4598.9	6594.8	14043.3	6720.4	25784.8	10473.8	25537.3	25264.5	12479.6	13704.1	6513.9	13729.8	31258.0	33257.3	19242.0	54654.3
Weakfish	225.6	16.5	135.5	369.4	194.0	352.8	2325.6	3487.6	19315.7	47.9	175.4	769.6	290.9	2388.5	997.6	297.9
Gizzard Shad	15.0	30.5	33.1	11.1	12.7	1.2	19.1	25.7	86.8	126.0	34.2	131.9	71.6	206.2	355.9	427.5
RIS Total	12995	12497	33846	22497	33734	20618	101762	62597	69564	15672	10389	47122	209824	53689	27818	80733

Table I-29 Annual Density of RIS Entrained at IP2 and IP3 Combined

Year	**1981**	**1981**	**1983**	**1983**	**1984**	**1984**	**1985**	**1985**	**1986**	**1986**	**1986**	**1987**	**1987**
Season	Apr–June	July–Sep	Apr–June	July–Sep	Apr–June	July–Sep	Apr–June	July–Sep	Jan–Mar	Apr–June	July–Sep	Apr–June	July–Sep
Herring Family	5.27E+08	3.80E+06	4.01E+09	1.02E+07	2.67E+09	2.03E+05	6.70E+06	--	--	7.78E+08	1.02E+05	1.25E+07	--
Blueback Herring	--	1.40E+07	3.58E+05	2.99E+07	2.49E+05	8.25E+05	--	6.22E+05	--	4.95E+04	9.93E+04	--	--
Alewife	--	--	--	5.46E+06	1.08E+05	--	--	--	--	6.61E+05	--	4.40E+04	--
American Shad	2.68E+07	4.47E+06	9.50E+06	2.36E+05	4.26E+08	2.18E+05	4.87E+05	--	--	2.12E+06	--	6.53E+04	9.60E+04
Alosa Species	1.78E+09	1.55E+07	2.99E+09	2.06E+06	4.01E+09	6.57E+05	1.54E+07	--	2.14E+06	9.90E+05	--	2.19E+04	--
Atlantic Menhaden	--	--	--	--	--	--	2.48E+06	--	--	7.99E+06	--	--	--
Anchovy Family	7.47E+08	7.50E+09	1.95E+06	9.73E+09	1.24E+08	2.11E+09	--	--	--	--	--	--	--
Bay Anchovy	1.12E+10	8.30E+10	6.51E+06	1.20E+10	1.79E+09	2.15E+10	1.79E+09	1.37E+10	--	1.01E+08	3.81E+09	4.80E+08	5.20E+09
Rainbow Smelt	--	--	2.88E+04	--	1.98E+07	3.59E+06	7.58E+05	1.54E+05	3.49E+08	5.06E+07	7.77E+06	8.59E+06	3.25E+06
Spottail Shiner	--	--	--	5.00E+05	--	2.18E+05	--	--	--	--	--	--	--
White Catfish	--	--	--	--	--	1.96E+05	--	--	5.33E+05	2.37E+04	--	--	--
Atlantic Tomcod	2.15E+08	--	5.18E+06	9.13E+05	1.32E+08	1.34E+07	1.66E+08	5.48E+05	1.84E+08	4.48E+07	--	1.48E+07	1.18E+06
White Perch	3.72E+09	7.31E+07	1.43E+09	1.33E+08	6.60E+08	1.10E+08	1.42E+08	9.95E+06	1.27E+07	6.77E+08	1.42E+07	8.81E+07	1.80E+07
Striped Bass	5.92E+09	1.22E+07	8.00E+08	1.82E+08	1.04E+09	7.58E+08	2.65E+08	7.15E+05	--	7.64E+08	7.54E+06	3.88E+08	1.67E+07
Morone Species	--	--	6.53E+08	4.27E+07	1.33E+08	3.31E+07	6.71E+07	3.29E+05	--	7.34E+07	1.02E+06	2.96E+07	9.27E+05
Perch Family	--	--	4.28E+07	--	1.29E+07	--	4.36E+04	--	--	5.34E+05	4.96E+04	4.20E+04	--
Bluefish	--	--	--	--	--	2.15E+05	--	1.07E+06	--	--	--	--	--
Weakfish	--	2.62E+08	--	2.64E+08	--	5.53E+08	1.96E+06	1.03E+08	--	--	1.44E+07	1.52E+05	2.35E+06
Hogchoker	3.32E+06	2.70E+08	5.84E+05	1.37E+08	2.82E+06	4.81E+07	3.45E+04	3.90E+07	--	2.35E+04	1.33E+07	1.30E+05	4.61E+06
Total RIS	2.42E+10	9.11E+10	9.95E+09	2.26E+10	1.10E+10	2.51E+10	2.46E+09	1.39E+10	5.48E+08	2.50E+09	3.86E+09	1.02E+09	5.25E+09

-- = Not identified in sample

Table I-30 Assessment of Impingement

Species	75th Percentile of Impingement	Imp_i / Imp_{RIS}	Rank of Impingement Ratio	Max Density Caught in River	S_i / S_{RIS} (percent)	Rank of Fish Density in River Segment 4	Rank of Impingement : Rank of Fish Density
Alewife	279	0.43 percent	7	6.94	1.30	10	0.70
Bay Anchovy	4475	6.96 percent	15	391.41	73.05	17	0.88
American Shad	426	0.66 percent	8	23.27	4.34	15	0.53
Bluefish	669	1.04 percent	10	1.66	0.31	6	1.67
Hogchoker	3890	6.05 percent	13	4.27	0.80	8	1.63
Atlantic Menhaden	150	0.23 percent	5	0.00	0.00	1	Not Calculable
Blueback Herring	4251	6.61 percent	14	38.43	7.17	16	0.88
Rainbow Smelt	440	0.68 percent	9	3.12	0.58	7	1.29
Shortnose Sturgeon	0	0.00 percent	1	0.00	0.00	1	Not Calculable
Spottail Shiner	94	0.15 percent	3	5.80	1.08	9	0.33
Atlantic Sturgeon	4	0.01 percent	2	0.00	0.00	1	Not Calculable
Striped Bass	1146	1.78 percent	11	15.24	2.84	13	0.85
Atlantic Tomcod	13690	21.28 percent	16	11.94	2.23	12	1.33
White Catfish	182	0.28 percent	6	0.03	0.01	5	1.20
White Perch	25599	39.79 percent	17	22.56	4.21	14	1.21
Weakfish	1330	2.07 percent	12	11.11	2.07	11	1.09
Gizzard Shad	127	0.20 percent	4	0.00	0.00	1	Not Calculable
Total RIS	64339			535.77			

Table I-31 Assessment of Entrainment

Species	E_i / E_{RIS}	Rank of Entrainment Proportion	S_i / S_{RIS} (percent)	Rank of Fish Density in River Segment 4	Rank of Entrainment: Rank of Fish Density
Alewife	40.28 percent	13	1.30	10	1.3
Bay Anchovy	99.10 percent	17	73.05	17	1.0
American Shad	40.28 percent	13	4.34	15	0.9
Bluefish	0.01 percent	5	0.31	6	0.8
Hogchoker	0.61 percent	8	0.80	8	1.0
Atlantic Menhaden	0.32 percent	7	0.00	1	Not Calculable
Blueback Herring	40.28 percent	13	7.17	16	0.8
Rainbow Smelt	63.72 percent	16	0.58	7	2.3
Shortnose Sturgeon	0.00 percent	1	0.00	1	Not Calculable
Spottail Shiner	0.00 percent	4	1.08	9	0.4
Atlantic Sturgeon	0.00 percent	1	0.00	1	Not Calculable
Striped Bass	37.94 percent	11	2.84	13	0.8
Atlantic Tomcod	33.47 percent	10	2.23	12	0.8
White Catfish	0.10 percent	6	0.01	5	1.2
White Perch	37.94 percent	11	4.21	14	0.8
Weakfish	2.20 percent	9	2.07	11	0.8
Gizzard Shad	0.00 percent	1	0.00	1	Not Calculable

Table I-32 Weight of Evidence for the Strength-of-Connection Line of Evidence Based on the Result Scores of Low = 1, Medium = 2, and High = 3

Measurement	Impingement Result Score		Entrainment Result Score		WOE Score[b]	Strength of Connection
	RIS	Prey	RIS	Prey		
Use and Utility[a]	1.9	2.0	1.6	2.1		
Alewife	2	1	2	1	1.5	Low to Medium
Bay Anchovy	2	1	2	1	1.5	Low to Medium
American Shad	2	1	2	1	1.5	Low to Medium
Bluefish	4	2	2	2	2.5	High
Hogchoker	4	1	2	1	2.0	Medium to High
Atlantic Menhaden	Unknown	1	Unknown	1	Unknown	Unknown
Blueback Herring	2	1	2	1	1.5	Low to Medium
Rainbow Smelt	2	1	4	1	1.9	Medium
Shortnose Sturgeon	Unknown	1	Unknown	1	Unknown	Unknown
Spottail Shiner	1	2	1	2	1.5	Low to Medium
Atlantic Sturgeon	Unknown	1	Unknown	1	Unknown	Unknown
Striped Bass	2	4	2	2	2.5	High
Atlantic Tomcod	2	1	2	1	1.5	Low to Medium
White Catfish	2	1	2	1	1.5	Low to Medium
White Perch	2	2	2	2	2.0	Medium to High
Weakfish	2	2	2	2	2.0	Medium to High
Gizzard Shad	Unknown	1	Unknown	1	Unknown	Unknown
Blue Crab	Unknown	1	Unknown	1	Unknown	Unknown

(a) Use and Utility: Low = <1.5, Medium = ≥1.5 but ≤2.0, High = >2.0
(b) WOE Score: Small = <1.5; Small-Moderate = 1.5; Moderate = >1.5 but <2.0; Moderate-Large = 2.0; Large = >2.0

I.3 Cumulative Impacts on Aquatic Resources

Zebra Mussels

For this analysis, the 75th percentile of the weekly FSS and BSS density and CPUE data from Region 12 (Albany) were used to evaluate the population trend LOE for impacts associated with a zebra mussel invasion. Data for white perch, blueback herring, alewife, American shad, white catfish, spottail shiner, and striped bass were used in the analysis because all have high densities of YOY within this region. The data were standardized based on the first 5-year mean and the standard deviation of all annual results (1979 to 2005). Only weeks 27 to 43 were used in the analysis for the FSS and weeks 22 to 43 for the BSS survey, so that most years contained observations from the months of July through October and June through October for each survey, respectively. Effects associated with changes in gear types for the FSS (1985) were also considered.

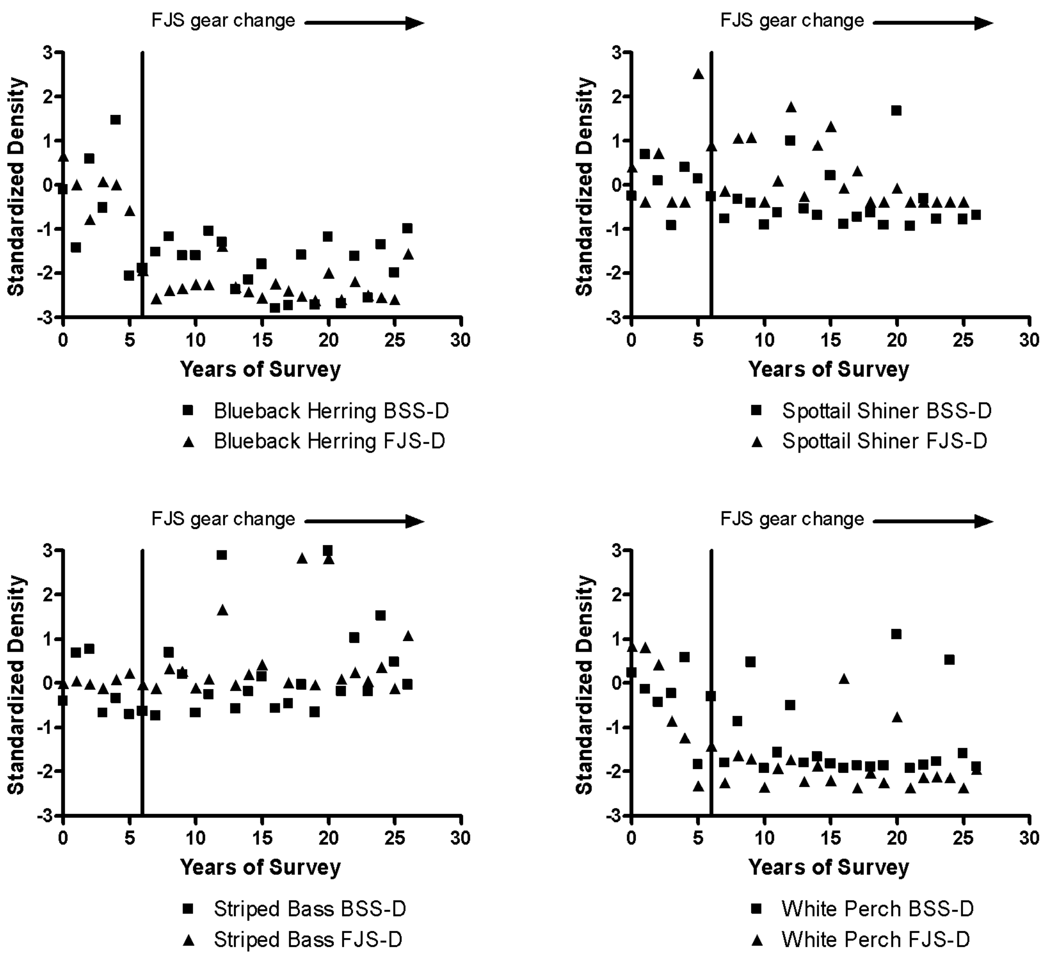
Simple linear regression and segmented regression with a single join point were fit to the annual measure of abundance for each RIS, as described in Section H.3. The model with the smallest MSE was chosen as the better fit to the data. If the best-fit model was the simple linear regression and the slope was statistically significantly less than 0 ($\alpha = 0.05$), a negative population trend was considered detected. If the slope was not significantly different from 0,

then a population trend was not considered detected. If the best-fit model was the segmented regression and either slope, S_1 or S_2, was statistically significantly less than 0 ($\alpha = 0.05$), then a negative population trend was considered detected. If both slopes S_1 and S_2 were not significantly different from 0 ($\alpha = 0.05$), then the trend was not considered detected.

An assessment of adverse impact was only supported if more than 40 percent of the standardized observations were outside the bounds of ± 1. For a normal bell-shaped distribution with a mean of 0 and a standard deviation of 1, 32 percent of the observations are outside the bounds of ± 1 standard deviation. Thus, observations outside the boundaries of ±1 standard deviation from the mean of the first 5 years were considered outside the natural variability (noise). If more than 40 percent of the standardized observations were outside this defined level of noise, then a potential for adverse impact was considered supported.

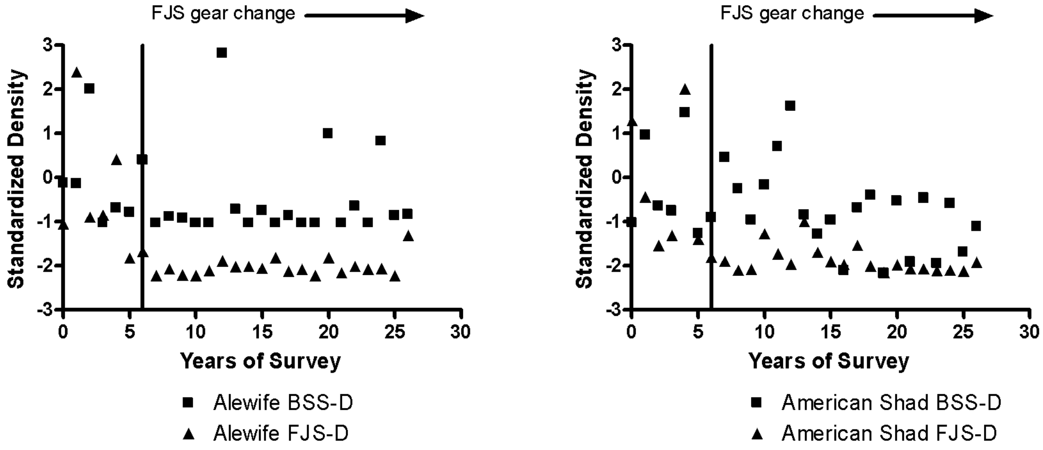
Data collected between 1985 and 2005 are not temporally disconnected from the1991 invasion of zebra mussels. However, because of earlier impacts, there is a potential that fish populations stabilized pre-1985 to a lower abundance level. If changes in gear types have affected the observed population response, only data post-1985 were used. For this analysis, data were standardized with the average of 1985 to 1989 and the standard deviation of all data between 1985 and 2005. This analysis was used only when the observed response from all data was biologically different from the BSS population density trend and had a decline associated with the gear change.

A visual comparison of the river-segment FSS standardized density with the BSS standardized density suggested that the trends for blueback herring, spottail shiner, striped bass, and white perch were not biologically different (Figure I-18). Observations from both surveys overlap and cross over each other. Thus, for these RIS, all of the FSS data (1979–2005) were used in the regression analysis. The FSS density data for alewife and American shad, however, did show a potential gear effect (Figure I-19), and a post-1985 analysis was conducted.



Note: All data were used in WOE analysis.

Figure I-18 River Segment 12 population trends based on the BSS and FSS standardized density (D) not considered biologically different



Note: Post-1985 data were analyzed for WOE analysis.

Figure I-19 River Segment 12 population trends based on the BSS and FSS standardized density (D) for which the FSS may indicate a gear difference

The following tables are the intermediate analyses for the assessment of population trends associated with fish density sampled from River Segment 12 (Albany). Results of these river-segment trend analyses are compiled in Table H-18 in Section H.4 of the draft SEIS. The data used in this analysis, in order of appearance, were the standardized 75th percentile of the weekly fish density for a given year collected from the FSS (Table I-33, Table I-34, and Figure I-20) and BSS (Table I-35, Table I-36, and Figure I-21).

Two extreme outliers (values greater than 2 standard deviations away from the mean) were removed from the FSS spottail shiner density regression analysis (Tables I-33 and I-34). Three extreme outliers were also removed from the FSS striped bass density (values greater than 2 standard deviations away from the mean) regression analysis and one extreme outlier from the FSS white catfish density (value greater than 2 standard deviations away from the mean) regression analysis because of the influence these data had on the regression results. The results of the regression models with the observations removed were more conservative and were used for the trend analysis.

One extreme outlier (value greater than 2 standard deviations away from the mean) was removed from the BSS alewife density regression analysis (Tables I-35 and I-36). One value was also removed from the BSS American shad density (value greater than 1.6 standard deviations away from the mean) regression analysis, one extreme outlier from the BSS spottail shiner density (value greater than 3 standard deviations away from the mean) regression analysis, and two extreme outliers from the BSS striped bass density (values greater than 2 standard deviations away from the mean) regression analysis because of the influence these data had on the regression results. The results of the regression models with the observations removed were more conservative and were used for the trend analysis.

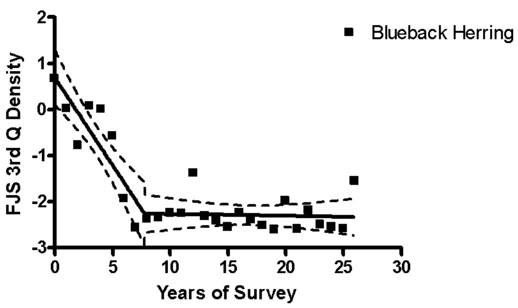
Table I-33 Competing Models Used To Characterize the Standardized River Segment 12 (Albany) Fall Juvenile Survey Population Trends of YOY Fish Density

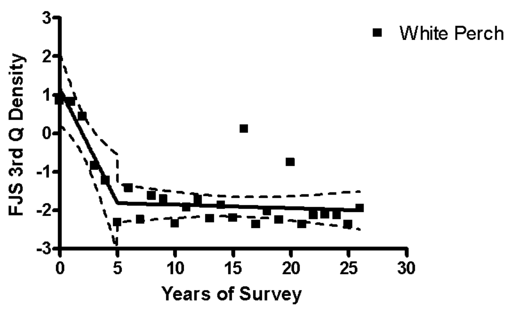
	Linear Regression			Segmented Regression			
Species	**MSE**	**Slope**	**p-value**	**MSE**	**95 percent CI Slope 1**	**Join Point**	**95 percent CI Slope 2**
Alewife (1985–2005)	1.01	0.031 ± 0.036	0.409	0.95	-5.66 to 2.00	1986	-0.028 to 0.139
American Shad (1985–2005)	0.95	-0.059 ± 0.034	0.102	0.90	-0.216 to 0.475	1992	-0.271 to -0.0001
Blueback Herring	0.73	-0.088 ± 0.018	< 0.001	0.44	-0.520 to -0.238	1987	-0.042 to 0.034
Spottail Shiner (All data)	1.02	-0.007 ± 0.025	0.777	1.05	-0.553 to 0.695	1984	-0.095 to 0.059
Spottail Shiner (2 outliers removed)	0.65	-0.025 ± 0.017	0.158	0.59	-0.041 to 0.160	1991	-0.188 to -0.010
Striped Bass (All data)	0.975	0.037 ± 0.024	0.139	0.94	0.004 to 0.155	1999	-0.568 to 0.171
Striped Bass (3 outliers removed)	0.40	0.012 ± 0.010	0.253	0.42	-1.20 to 1.30	1980	-0.014 to 0.037
White Catfish (All data)	0.982	-0.034 ± 0.024	0.171	1.00	-0.118 to 0.123	1994	-0.283 to 0.096
White Catfish (1 outlier removed)	0.88	-0.022 ± 0.022	0.327	0.92	-1.15e+006 to 1.15e+006	1979	-0.070 to 0.026
White Perch	0.84	-0.071 ± 0.021	0.002	0.58	-0.972 to -0.212	1984	-0.049 to 0.031

Table I-34 River Segment 12 (Albany) Assessment of the Level of Potential Negative Impact Based on the Standardized FSS Density

Species	Best Fit	General Trend	Percent Outside Defined Level of Noise	Support for Possible Negative Impact	Level of Potential Negative Impact
Alewife	SR	S1 = 0 S2 = 0	19 percent	No	1
American Shad	SR	S1 = 0 S2 < 0	14 percent	No	2
Blueback Herring	SR	S1 < 0 S2 = 0	78 percent	Yes	4
Spottail Shiner (All data)	LR	S = 0	22 percent	No	1
Spottail Shiner (2 outliers removed)	SR	S1 = 0 S2 < 0	22 percent	No	2
Striped Bass (All data)	SR	S1 > 0 S2 = 0	19 percent	No	1
Striped Bass (3 outliers removed)	LR	S = 0	19 percent	No	1
White Catfish (All data)	LR	S = 0	33 percent	No	1
White Catfish (1 outlier removed)	LR	S = 0	33 percent	No	1
White Perch	SR	S1 < 0 S2 = 0	78 percent	Yes	4

LR = Linear Regression; SR = Segmented Regression





Note: Design Restricted

Figure I-20 River Segment 12 (Albany) population trends based on the FSS standardized density assigned a large level of potential negative impact

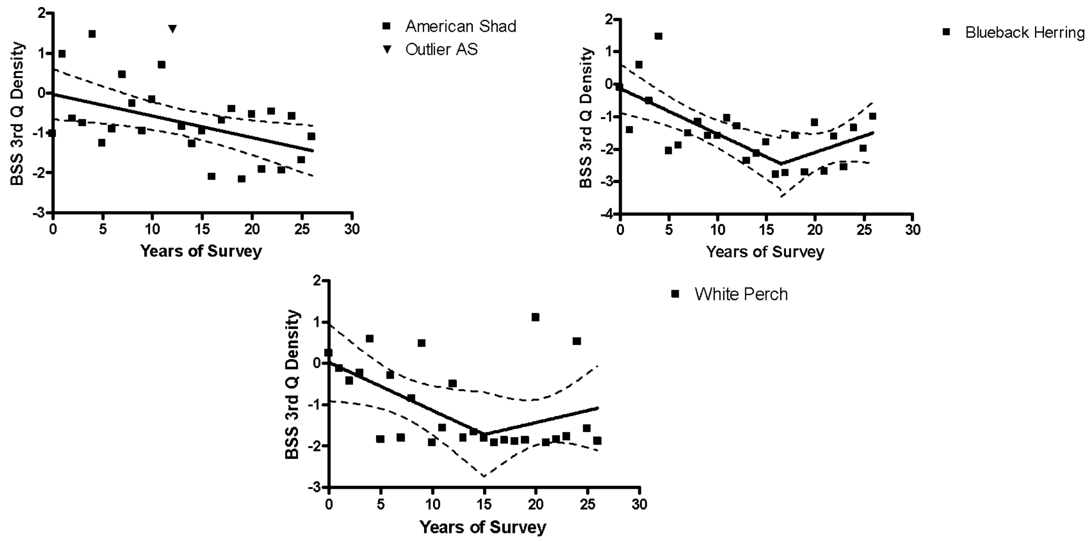
1 **Table I-35 Competing Models Used To Characterize the Standardized River Segment 12**
2 **(Albany) Beach Seine Survey Population Trends of YOY Fish Density**

	Linear Regression			Segmented Regression			
Species	**MSE**	**Slope**	**p-value**	**MSE**	**95 percent CI Slope 1**	**Join Point**	**95 percent CI Slope 2**
Alewife (All data)	1.01	-0.020 ± 0.025	0.440	1.03	-0.877 to 0.472	1984	-0.073 to 0.071
Alewife (1 outlier removed)	0.78	-0.018 ± 0.019	0.373	0.74	-0.310 to 0.027	1989	-0.039 to 0.120
American Shad (All data)	0.91	-0.056 ± 0.023	0.020	Did Not Converge			
American Shad (1 value removed)	0.81	-0.055 ± 0.020	0.012	Did Not Converge			
Blueback Herring	0.87	-0.066 ± 0.022	0.005	0.78	-0.221 to -0.060	1996	-0.078 to 0.279
Spottail Shiner (All data)	1.02	0.007 ± 0.025	0.769	1.05	-1.23 to 0.765	1982	-0.050 to 0.087
Spottail Shiner (1 outlier removed)	0.66	-0.021 ± 0.017	0.232	0.68	-1.06 to 0.704	1982	-0.059 to 0.032
Striped Bass (All data)	0.99	0.030 ± 0.025	0.226	1.02	-0.787 to 0.544	1984	-0.024 to 0.117
Striped Bass (2 outliers removed)	0.61	0.020 ± 0.015	0.211	0.59	-0.483 to 0.148	1984	-0.003 to 0.088
White Perch	0.94	-0.048 ± 0.023	0.048	0.92	-0.229 to -0.003	1994	-0.100 to 0.216

Table I-36 River Segment 12 (Albany) Assessment of the Level of Potential Negative Impact Based on the Standardized BSS Density

Species	Best Fit	General Trend	Percent Outside Defined Level of Noise (percent)	Support for Possible Negative Impact	Level of Potential Negative Impact
Alewife (All data)	LR	S = 0	44	Yes	2
Alewife (1 outlier removed)	SR	S1 = 0 S2 = 0	44	Yes	2
American Shad (All data)	LR	S < 0	41	Yes	4
American Shad (1 value removed)	LR	S < 0	41	Yes	4
Blueback Herring	SR	S1 < 0 S2 = 0	85	Yes	4
Spottail Shiner (All data)	LR	S = 0	7	No	1
Spottail Shiner (1 outlier removed)	LR	S = 0	7	No	1
Striped Bass (All data)	LR	S = 0	15	No	1
Striped Bass (2 outliers removed)	SR	S1 = 0 S2 = 0	15	No	1
White Perch	SR	S1 < 0 S2 = 0	63	Yes	4

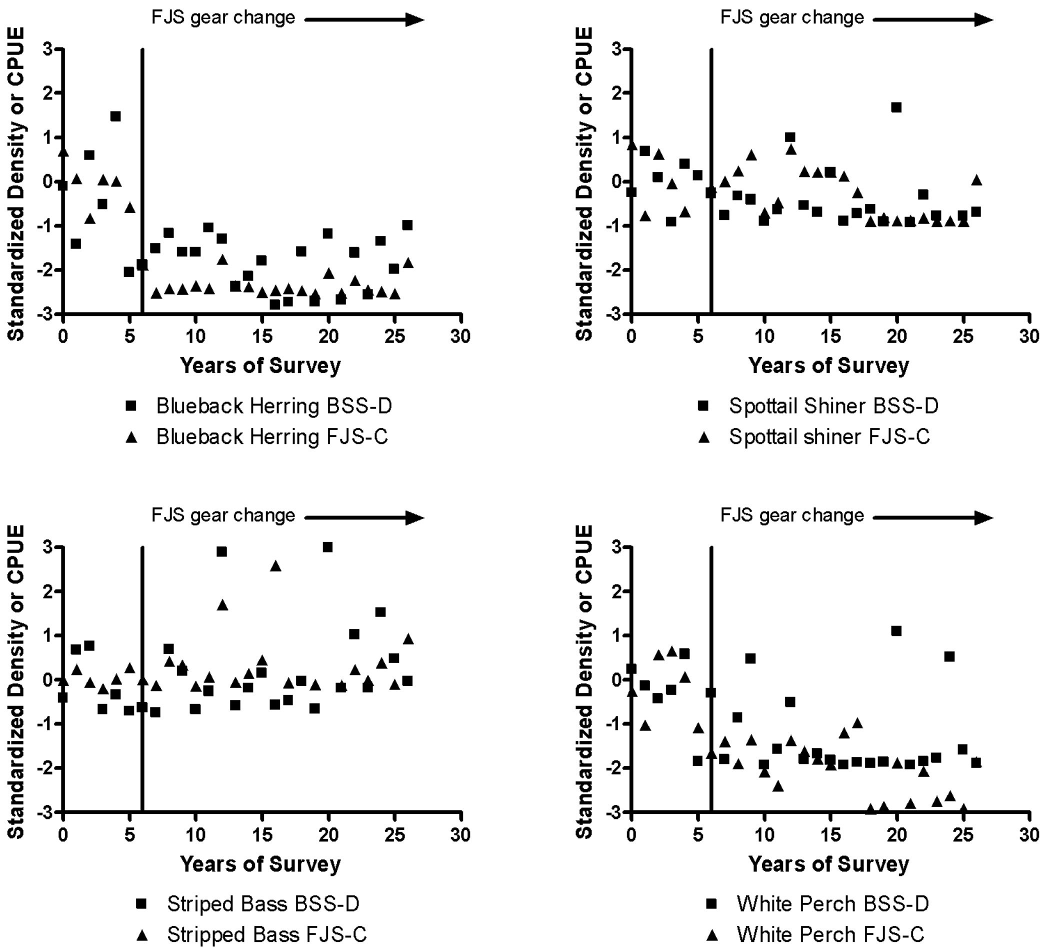
LR = Linear Regression; SR = Segmented Regression



Note: Design Restricted

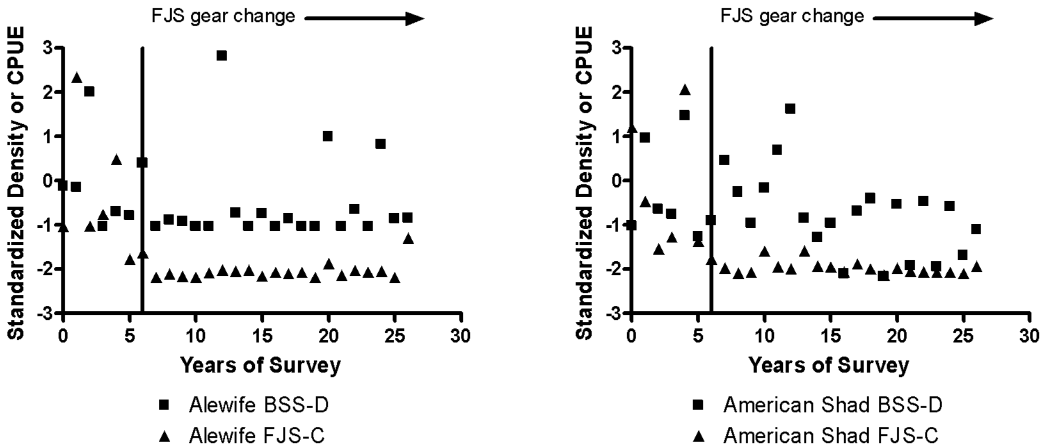
Figure I-21 River Segment 12 (Albany) population trends based on the BSS standardized density assigned a large level of potential negative impact

A visual comparison of the river-segment FSS standardized CPUE with the BSS standardized density suggested that the trends were not biologically different for blueback herring, spottail shiner, striped bass, and white perch (Figure I-22). Observations from both surveys overlap and cross over each other. Thus, for these RIS, all of the FSS data (1979–2005) were used in the regression analysis. The FSS density data for alewife and American shad, however, did show a potential gear effect (Figure I-23), and a post-1985 analysis was conducted.



Note: All data were used in WOE analysis.

Figure I-22 River Segment 12 population trends based on the FSS standardized CPUE (C) and BSS density (D) not considered biologically different



Note: Post-1985 data were analyzed for WOE analysis.

Figure I-23 River Segment 12 population trends based on the FSS standardized CPUE (C) and BSS density (D) for which the FSS may indicate a gear difference

The following tables are the intermediate analyses for the assessment of population trends associated with fish CPUE sampled from River Segment 12 (Albany). Results of these river-segment trend analyses are compiled in Table H-18 in Section H.4 of the draft SEIS. The data used in this analysis were the standardized 75th percentile of the weekly fish CPUE for a given year collected from the FSS (Table I-37, Table I-38, and Figure I-23).

One extreme outlier (value greater than 3 standard deviations away from the mean) was removed from the FSS spottail shiner CPUE regression analysis (Tables I-37 and I-38), and one extreme outlier was removed from the FSS white catfish CPUE (value greater than 2 standard deviations away from the mean) regression analysis because of the influence these data had on the regression results. The results of the regression models with the observations removed were more conservative and were used for the trend analysis.

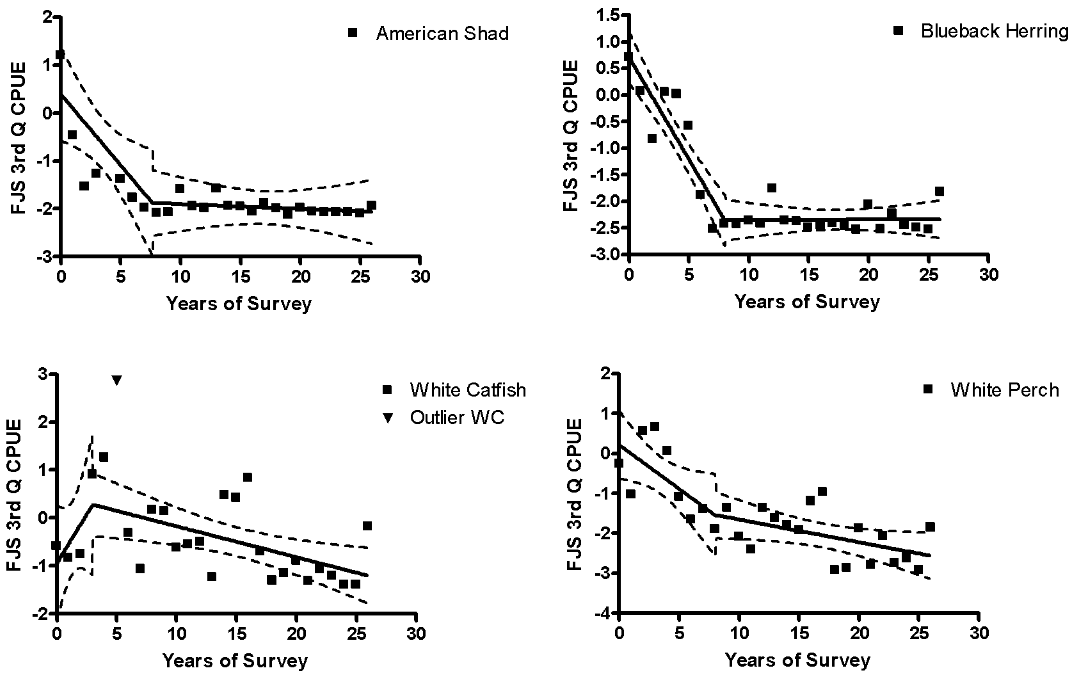
Table I-37 Competing Models Used To Characterize the Standardized River Segment 12 (Albany) Fall Juvenile Survey Population Trends of YOY Fish CPUE

	Linear Regression			Segmented Regression			
Species	**MSE**	**Slope**	**p-value**	**MSE**	**95 percent CI Slope 1**	**Join Point**	**95 percent CI Slope 2**
Alewife (1985–2005)	1.00	0.033 ± 0.036	0.371	0.96	-0.185 to 0.083	1999	-0.108 to 0.656
American Shad (1985–2005)	0.94	-0.066 ± 0.034	0.064	0.96	-0.342 to 0.385	1992	-0.247 to 0.046
Blueback Herring	0.72	-0.089 ± 0.018	< 0.001	0.38	-0.484 to -0.282	1987	-0.035 to 0.037
Spottail Shiner (All data)	0.91	-0.057 ± 0.023	0.018	Did Not Converge			
Spottail Shiner (1 outlier removed)	0.52	-0.038 ± 0.013	0.008	0.53	-2.89 to 2.14	1980	-0.066 to -0.002
Striped Bass	0.98	0.034 ± 0.024	0.168	0.95	-0.010 to 0.162	1997	-0.415 to 0.180
White Catfish (All data)	0.91	-0.056 ± 0.023	0.020	Did Not Converge			
White Catfish (1 outlier removed)	0.72	-0.042 ± 0.018	0.031	0.68	-0.325 to 1.14	1982	-0.111 to -0.018
White Perch	0.67	-0.095 ± 0.017	< 0.001	0.64	-0.391 to -0.052	1987	-0.116 to 0.003

Table I-38 River Segment 12 (Albany) Assessment of the Level of Potential Negative Impact Based on the Standardized FSS CPUE

Species	Best Fit	General Trend	Percent Outside Defined Level of Noise (percent)	Support for Possible Negative Impact	Level of Potential Negative Impact
Alewife	SR	S1 = 0 S2 = 0	10	No	1
American Shad	LR	S = 0	52	Yes	2
Blueback Herring	SR	S1 < 0 S2 = 0	78	Yes	4
Spottail Shiner (All data)	LR	S < 0	4	No	2
Spottail Shiner (1 outlier removed)	LR	S < 0	4	No	2
Striped Bass	SR	S1 = 0 S2 = 0	15	No	1
White Catfish (All data)	LR	S < 0	41	Yes	4
White Catfish (1 outlier removed)	SR	S1 = 0 S2 < 0	41	Yes	4
White Perch	SR	S1 < 0 S2 = 0	81	Yes	4

LR = Linear Regression; SR = Segmented Regression



Note: Design Restricted

Figure I-24 River Segment 12 (Albany) population trends based on the FSS standardized CPUE assigned a large level of potential negative impact

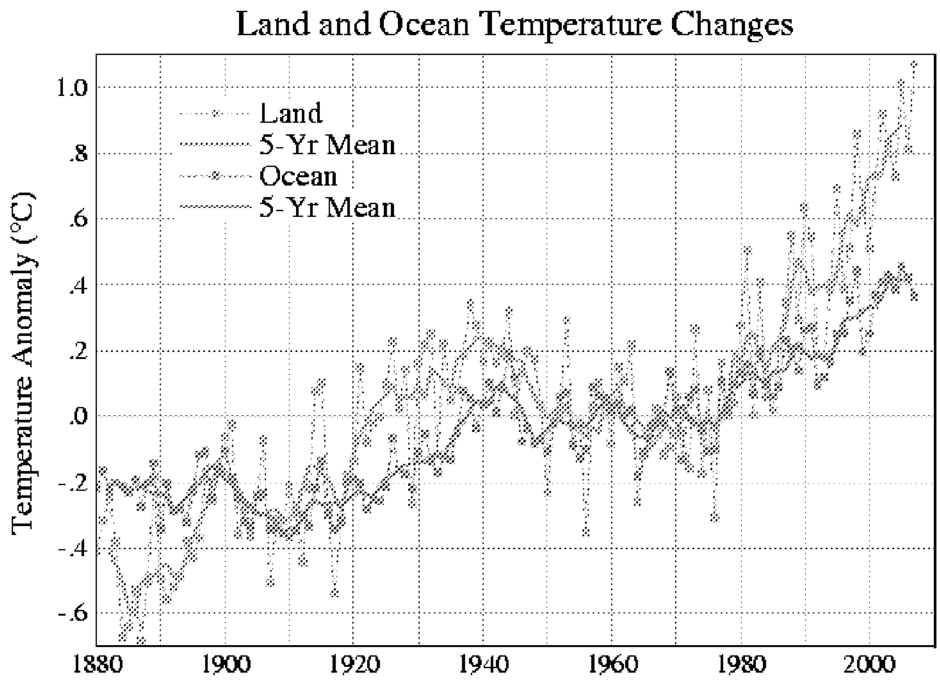
The WOE analysis for River Segment 12, Albany, for all population trend data post-1991 is presented in Table I-39. This table is a compilation of Tables I-34, I-36, and I-38 and was used to derive Table H-18 in Section H.3 in the draft SEIS.

Table I-39 River Segment 12 (Albany) Assessment of the Level of Potential Negative Impact Following Zebra Mussel Invasion in 1991 Based on the Standardized FSS and BSS Density and FSS CPUE

Species	Trend Post-1991	Percent Outside Defined Level of Noise (percent)	Support for Possible Negative Impact	Level of Potential Negative Impact Post- 1991
FSS Density				
Alewife	S2 = 0	20	No	1
American Shad	S2 < 0	13	No	2
Blueback Herring	S2 = 0	100	Yes	2
Spottail Shiner	S2 < 0	20	No	2
Stripped Bass	S = 0	33	No	1
White Catfish	S = 0	40 p	No	1
White Perch	S2 = 0	87	Yes	2
BSS Density				
Alewife	S2 = 0	47	Yes	2
American Shad	S < 0	53	Yes	4
Blueback Herring	S2 = 0	93	Yes	2
Spottail Shiner	S = 0	13	No	1
Stripped Bass	S2 = 0	27	No	1
White Perch	S2 = 0	87	Yes	2
FSS CPUE				
Alewife	S2 = 0	7	No	1
American Shad	S = 0	53	Yes	2
Blueback Herring	S2 = 0	100	Yes	2
Spottail Shiner	S < 0	0	No	2
Stripped Bass	S2 = 0	27	No	1
White Catfish	S2 < 0	53	Yes	4
White Perch	S2 = 0	93	Yes	2

<u>Water Quality and Temperature</u>

Both water quality and water temperature can act to shift RIS densities into adjacent river segments based on specific life stage needs. Water quality changes have been occurring over the past decade (Section 2.2.5 of the draft SEIS), and water temperatures have been increasing over the last 100 years (Figure I-36). An analysis of RIS distributional change within the Hudson River was conducted by comparing the first and last 5-year mean densities from the survey that was most efficient at catching a given RIS. Striped bass (Figure I-37), alewife (Figure I-38), spottail shiner (Figure I-39), hogchoker (Figure I-40), and white perch (Figure I-41) all appear to have shifted slightly upriver, while the bay anchovy has shifted slightly downriver (Figure I-42). All other RIS that could be evaluated (American shad, Atlantic tomcod, blueback herring, bluefish, and weakfish) did not show a change in their distributions. It is not possible from these data to determine what might have influenced these shifts.



Source: Hansen et al. 2006

Figure I-36 Historical trend in global land and ocean temperature

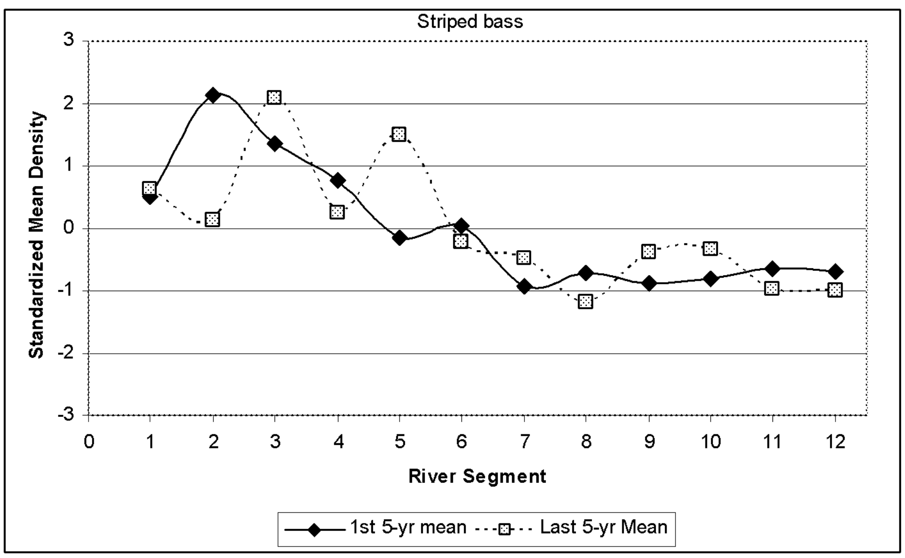


Figure I-37 Relative density of YOY striped bass from the BSS 1979–1983 and 2001–2005. data within each river segment of the Hudson River

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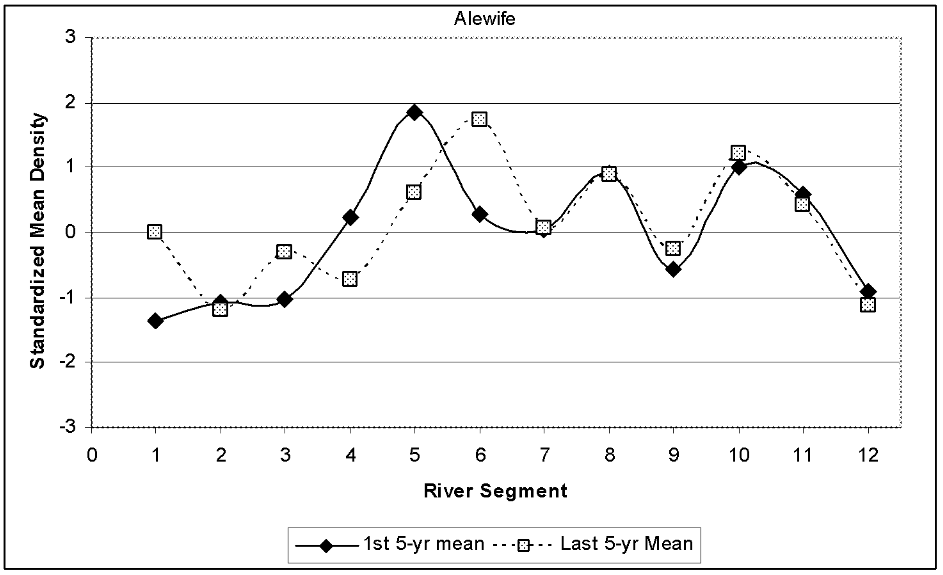

Figure I-38 Relative density of YOY alewife from the BSS 1979–1983 and 2001–2005; data within each river segment of the Hudson River

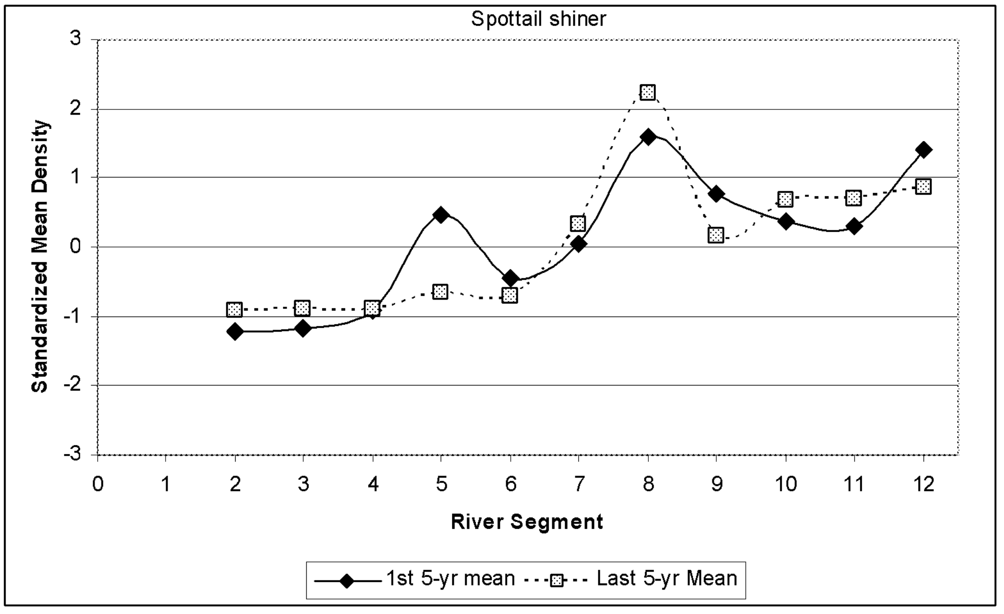

Figure I-39 Relative density of YOY spottail shiner from the BSS 1979–1983 and 2001–2005; data within each river segment of the Hudson River

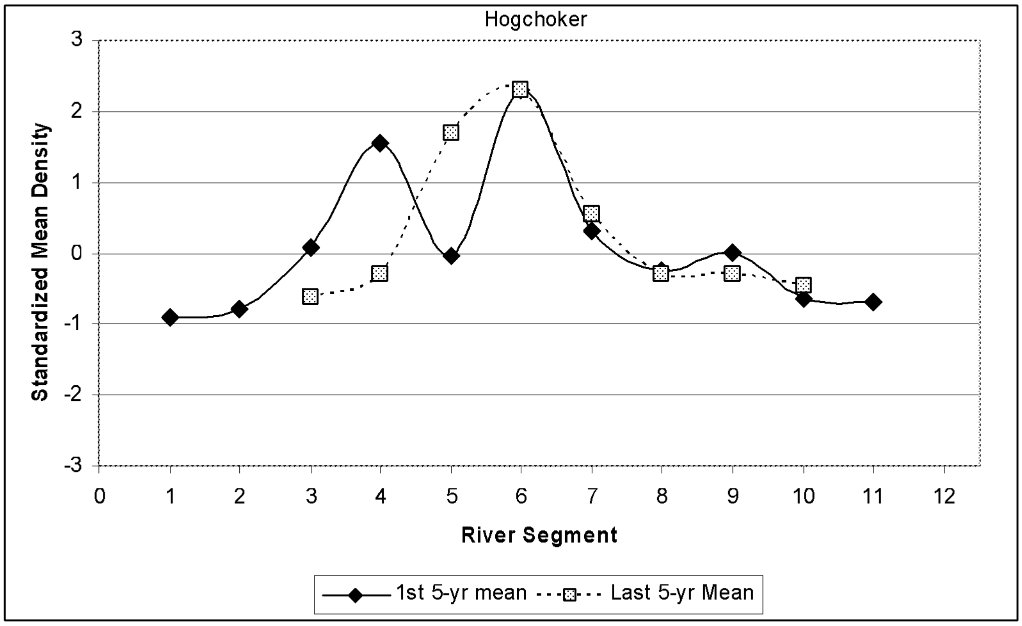

Figure I-40 Relative density of YOY hogchoker from the FSS 1979–1983 and 2001–2005; data within each river segment of the Hudson River

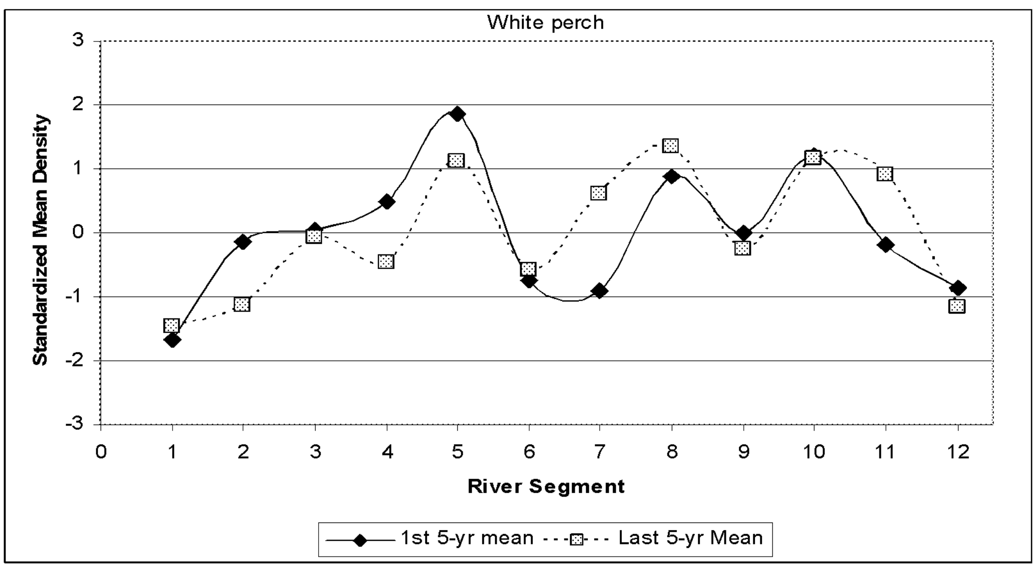

Figure I-41 Relative density of YOY white perch from the BSS 1979–1983 and 2001–2005; data within each river segment of the Hudson River

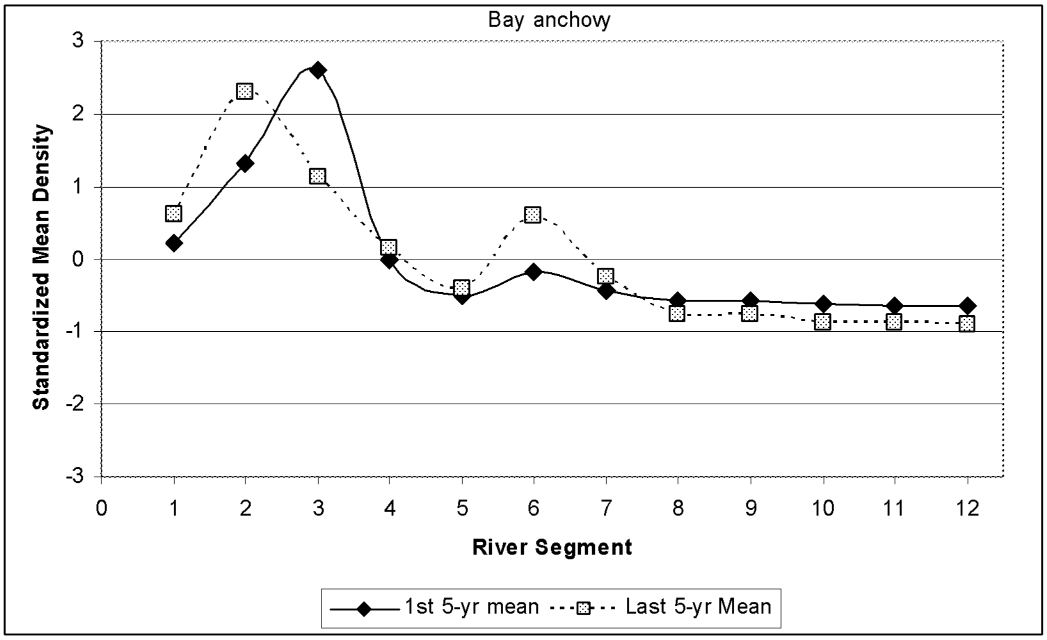

Figure I-42 Relative density of YOY bay anchovy from the FSS 1979–1983 and 2001–2005; data within each river segment of the Hudson River

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Division of License Renewal
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

9. SPONSORING ORGANIZATION - NAME AND ADDRESS *(If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.)*

Same as 8 Above

10. SUPPLEMENTARY NOTES

Docket Nos. 05000247 and 05000286

11. ABSTRACT *(200 words or less)*

This supplemental environmental impact statement (SEIS) has been prepared in response to an application submitted by Entergy Nuclear Operations, Inc. (Entergy), Entergy Nuclear Indian Point 2, LLC, and Entergy Nuclear Indian Point 3, LLC (all applicants will be jointly referred to as Entergy) to the NRC to renew the operating licenses for Indian Point Nuclear Generating Unit Nos. 2 and 3 (IP2 and IP3) for an additional 20 years under 10 CFR Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants." This draft SEIS contains the NRC staff's analysis that considers and weighs the environmental impacts of the proposed action, the environmental impacts of alternatives to the proposed action, and mitigation measures available for reducing or avoiding adverse impacts. It also includes the NRC staff's preliminary recommendation regarding the proposed action.

The NRC staff's preliminary recommendation is that the Commission determine that the adverse environmental impacts of license renewal for IP2 and IP3 are not so great that preserving the option of license renewal for energy planning decisionmakers would be unreasonable. This recommendation is based on (1) the analysis and findings in the GEIS, (2) the environmental report submitted by Entergy, (3) consultation with other Federal, State, and Local agencies; (4) the NRC staff's own independent review, and (5) the NRC staff's consideration of public comments received during the scoping process.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*	
Indian Point Nuclear Generating Unit Numbers 2 and 3 IP2 IP3 IPEC Supplement to the Generic Environmental Impact Statement DSEIS National Environmental Policy Act NEPA License Renewal GEIS NUREG-1437, Supplement 38	13. AVAILABILITY STATEMENT unlimited 14. SECURITY CLASSIFICATION *(This Page)* unclassified *(This Report)* unclassified 15. NUMBER OF PAGES 16. PRICE

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