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Entergy Nuclear Operations, Inc.; Indian Point Nuclear Generating Unit Nos. 2 and 3; Draft Supplemental Environmental Impact Statement; Request for Comment

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Organization: Morgan Lewis on behalf of Entergy Nuclear Operations, Inc.

General Comment

Entergy Nuclear Operations, Inc., the applicant in this NRC license renewal proceeding, has submitted detailed comments on NUREG-1437, Supplement 38, Vol. 5, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3, Draft Report" (Dec. 2015) ("Draft Supplement"). See Entergy Letter NL-16-021 to the NRC (including the attachments and appendices thereto). Entergy commends the NRC Staff for its work on the Draft Supplement, which reflects the NRC Staff's diligent and careful review of a large volume of data and information germane to its environmental review of the license renewal application. Entergy's comments are intended to further inform the NRC Staff's review before it finalizes its second supplement to the FSEIS for Indian Point license renewal. Entergy's comments in Attachments 1 to 5 of NL-16-021relate to the following topics and Draft Supplement sections: (1) Entergy's revised SAMA engineering project cost estimates (Section 3.0); (2) new information on entrainment and impingement impacts (Section 4.0); (3) air quality impacts, greenhouse gas emissions/climate change, and cumulative impacts (Sections 5.1, 5.13, and 5.14.1); (4) radionuclides released to groundwater (Section 5.4); and (5) the NRC Staff's evaluation and characterization of impacts to certain Federally-listed terrestrial and aquatic species (various sections of FSEIS and Draft Supplement). Attachment 6 to NL-16-021 provides some miscellaneous comments on other sections of the Draft Supplement not addressed by Attachments 1 to 5 to NL-16-021. Appendices 2A to 2G of NL-16-021 provide detailed supporting information for Entergy's comments on Draft Supplement Section 4.0 regarding aquatics species impacts.

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E-RIDS= ADM-03
Add= M. Wentzel (MJW2)

Attachments

NL-16-021 Signed

App. 2A_Rainbow Smelt Population Projection Model

App. 2B HR Rainbow Smelt Parisitology

App. 2C_Blueback Herring Distribution

App. 2D_Rainbow Smelt EMR Bias

App. 2E_Review of NRC SOC Calculations

App. 2F_AM and GS Aquatic Impact Analyses

App. 2G_Atlantic Menhaden HRBMP Data

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Fred Dacimo
Vice President
Operations License Renewal

NL-16-021

March 4, 2016

Rulemaking Docket ID NRC-2008-0672

Cindy Bladey
Chief, Rules, Announcements, and Directives Branch
Office of Administration
Mail Stop: OWFN-12-H08
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

SUBJECT: **Comments on Second Draft Supplement to Final Supplemental Environmental Impact Statement for Indian Point License Renewal**
Indian Point Nuclear Generating Unit Nos. 2 and 3
Docket Nos. 50-247 and 50-286, License Nos. DPR-26 and DPR-64

REFERENCES:

1. NUREG-1437, Supplement 38, Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3

   a. Volumes 1-3, Final Report (December 2010)
   b. Volume 4, Final Report – Supplement 1 (June 2013)
   c. Volume 5, Draft Report (Supplement 2) for Comment

2. Entergy Letter (NL-13-075) to NRC regarding "LRA Completed Engineering Project Cost Estimates for SAMAs Previously Identified as Potentially Cost-Beneficial" (May 6, 2013)

3. Entergy Letter (NL-14-030) to NRC regarding "Final Supplemental Environmental Impact Statement" (Feb. 19, 2014)

4. Entergy Nuclear Operations, Inc.; Indian Point Nuclear Generating Unit Nos. 2 and 3; Draft supplemental environmental impact statement; request for comment; 80 FR 81377 (Dec. 29. 2015)

Dear Ms. Bladey:

On December 22, 2015, the Nuclear Regulatory Commission (NRC) published in draft a second supplement (Draft Supplement) to the December 2010 Final Supplemental Environmental Impact Statement (FSEIS) prepared by the NRC Staff and its consultants for the Indian Point Nuclear Generating Unit Nos. 2 and 3 (Indian Point) License Renewal Application (LRA). See References 1.a-c. The matters addressed in the Draft Supplement include Entergy Nuclear Operations, Inc.'s (Entergy) May 6, 2013 submittal of revised engineering project cost information for certain severe accident mitigation alternatives (SAMAs) (Reference 2); Entergy's

February 19, 2014 submittal of new aquatic impacts information (Reference 3); the NRC's June 2013 revision of 10 C.F.R. Part 51, Table B-1, and the Generic Environmental Impact Statement (GEIS) for license renewal; the September 2014 amendment of 10 C.F.R. § 51.23(b) regarding the continued storage of spent nuclear fuel; and reinitiation of consultation under Section 7 of the Endangered Species Act regarding the northern long-eared bat, among other matters.

By notice published in the *Federal Register* on December 29, 2015 (80 FR 81377) (Reference 4), the NRC requested comments on the Draft Supplement by March 4, 2016. Therefore, Entergy respectfully submits the attached comments on certain portions of the Draft Supplement. Entergy commends the NRC Staff for its work on the Draft Supplement, which reflects the NRC Staff's diligent and careful review of a large volume of data and information germane to its environmental review of the LRA. Entergy's detailed comments, which are included in Attachments 1 to 5 to this letter, are intended to further inform the NRC Staff's review before it finalizes its second supplement to the FSEIS. Entergy's comments relate to the following topics and Draft Supplement sections: (1) Entergy's revised SAMA engineering project cost estimates (Section 3.0); (2) new information on entrainment and impingement impacts (Section 4.0); (3) air quality impacts, greenhouse gas emissions/climate change, and cumulative impacts (Sections 5.1, 5.13, and 5.14.1); (4) radionuclides released to groundwater (Section 5.4); and (5) the NRC Staff's evaluation and characterization of impacts to certain Federally-listed terrestrial and aquatic species (various sections of FSEIS and Draft Supplement). Attachment 6 provides some miscellaneous comments on other sections of the Draft Supplement not addressed by Attachments 1 to 5 of this letter.

Entergy appreciates the NRC Staff's efforts and respectfully requests that it implement or incorporate the attached comments when it publishes the second supplement to the FSEIS. There are no commitments identified in this submittal. If you have any questions regarding these comments, then please contact Dara Gray at (914) 254-8414.

Sincerely,

FRD/rl

Attachments:

1. Comments on Section 3.0 (Revised SAMA Engineering Project Cost Estimates)
2. Comments on Section 4.0 (New Information on Entrainment and Impingement Impacts)
3. Comments on Sections 5.1, 5.13, and 5.14.1 (Air Quality Impacts; Greenhouse Gas Emissions and Climate Change; Cumulative Impacts)
4. Comments on Section 5.4 (Radionuclides Released to Groundwater)
5. Comments Concerning NRC Staff Evaluation and Characterization of Environmental Impacts to Certain Federally-Listed Terrestrial and Aquatic Species

cc: Mr. Daniel H. Dorman, Regional Administrator, NRC Region I
Mr. Sherwin E. Turk, Special Counsel, NRC OGC
Mr. Michael Wentzel, Project Manager, NRC NRR DLR
Mr. Douglas Pickett, Senior Project Manager, NRC NRR DORL
Ms. Bridget Frymire, New York State Department of Public Service
Mr. John B. Rhodes, President and CEO NYSERDA
NRC Resident Inspector's Office

ATTACHMENT 1 TO NL-16-021

COMMENTS ON SECTION 3.0 OF THE DRAFT SUPPLEMENT

(REVISED SAMA ENGINEERING COST ESTIMATES)

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 & 3
DOCKET NOS. 50-247 AND 50-286

Entergy Comments on Section 3.0 of the Draft Supplement (Revised SAMA Engineering Project Cost Estimates)

I. Introduction

Section 3.0 of the Draft Supplement presents the NRC Staff's evaluation of the refined engineering project cost estimates for the 22 potentially cost-beneficial severe accident mitigation alternatives ("SAMAs") previously identified in the December 2010 final supplemental environmental impact statement ("FSEIS") for the Indian Point Units 2 and 3 ("IP2" and "IP3") license renewal application ("LRA").[1] As explained in its May 6, 2013 submittal to the NRC, Entergy provided the more detailed and refined engineering project cost estimates as a potential means of resolving the Atomic Safety and Licensing Board's ("ASLB") perceived concern that the original conceptual-level cost estimates included in the Indian Point SAMA analysis—which the NRC Staff found acceptable in the FSEIS—were not sufficiently "complete" for purposes of complying with the National Environmental Policy Act ("NEPA").[2]

Entergy provides its comments on Section 3.0 of the Draft Supplement below. In summary, Entergy generally agrees with the NRC Staff's technical observations and conclusions, with one critical exception. Entergy does not agree that SAMAs IP2-021 and IP2-053 should be retained for further consideration. Entergy recognizes that there are uncertainties inherent in *any* cost estimate, irrespective of the estimate's level of detail or sophistication. However, for the reasons discussed herein, Entergy respectfully disagrees with the NRC Staff's characterization of uncertainties in Entergy's refined engineering project cost estimates for SAMA implementation as being "large."

In short, the refined engineering project cost estimates were prepared by professional cost estimators with substantial nuclear engineering expertise and experience in preparing cost estimates at other nuclear power plants, including other Entergy facilities.[3] The cost estimates also were reviewed by site engineering personnel with relevant training and experience. As such, they are based on established industry and plant-specific practices and assumptions (including contingencies). They also contain a level of detail that far exceeds that recommended in NRC Staff and NRC-approved industry guidance, or contained in SAMA implementation cost estimates prepared by other license renewal applicants and approved by

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1 NUREG-1437, Supplement 38, Vols. 1-3, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3, Final Report" (Dec. 2010) ("FSEIS"); NUREG-1437, Supplement 38, Vol. 5, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3, Draft Report" (Dec. 2015) ("Draft Supplement").

2 *See* Letter from Fred Dacimo, Entergy, to NRC Document Control Desk, NL-13-075, "Subject: License Renewal Application—Completed Engineering Project Cost Estimates for SAMAs Previously Identified as Potentially Cost- Beneficial," at 2 (May 6, 2013) ("NL-13-075"); *Entergy Nuclear Operations, Inc.* (Indian Point Nuclear Generating Units 2 and 3), LBP-11-17, 74 NRC 11, 25-26 (2011), *petition for interlocutory review denied*, CLI-11-14, 74 NRC 801 (2011) (Entergy and NRC Staff petitions for review pending before the Commission).

3 *See* Letter from Fred Dacimo, Entergy, to the NRC Document Control Desk, NL-14-143, "Subject: Reply to Request for Additional Information Regarding the License Renewal Application" (Nov. 20, 2014), attach. at 1 ("November 20, 2014 RAI Responses") (ADAMS Accession No. ML14337A042).

the NRC Staff. Finally, as Section 3.0 of the Draft Supplement demonstrates, the cost estimates have undergone an unprecedented level of review by the NRC Staff, which ultimately concluded that "the approach used and the costs provided are reasonable."[4]

II. The NRC Staff's Environmental Review of the LRA, Including Its Review of the Indian Point SAMA Analysis, Is Governed by NEPA's "Rule of Reason."

The NRC Staff prepared the Draft Supplement in accordance with its obligations under NEPA and the Commission's NEPA-implementing regulations in 10 C.F.R. Part 51.[5] NEPA's requirements are intended to ensure that agencies take a "hard look" at the environmental consequences of their proposed actions.[6] The adequacy of an agency's NEPA analyses is judged by the "rule of reason."[7] Under the NEPA "rule of reason," the agency's environmental analysis need only consider environmental impacts that are reasonably foreseeable, and need not consider remote and speculative scenarios.[8] Moreover, the U.S. Supreme Court has held that NEPA does not require a "worst case" inquiry.[9] Finally, NEPA does not require agencies to resolve all uncertainties.[10] "So long as the environmental impact statement identifies areas of uncertainty, the agency has fulfilled its mission under NEPA."[11]

A license renewal SAMA analysis is a site-specific environmental mitigation analysis performed under NEPA—not a safety analysis performed under the Atomic Energy Act of 1954, as amended ("AEA").[12] Like other NEPA evaluations, a SAMA analysis is governed by the rule of reason and "alternatives must be bounded by some notion of feasibility."[13] Thus, "the proper question is not whether there are alternative choices for use in the analysis, but whether the

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4 Draft Supplement at 19.

5 *See* Draft Supplement at 1 (citing 10 C.F.R. § 51.92).

6 *Robertson v. Methow Valley Citizens Council,* 490 U.S. 332, 350 (1989) (quoting *Kleppe v. Sierra Club*, 427 U.S. 390, 410 n.21 (1976)).

7 *See Entergy Nuclear Generation Co.* (Pilgrim Nuclear Power Station), CLI-10-11, 71 NRC 287, 316 (2010); *Duke Energy Corp.* (McGuire Nuclear Station, Units 1 & 2; Catawba Nuclear Station, Units 1 & 2), CLI-02-17, 56 NRC 1, 12 (2002) (citing *Vt. Yankee Nuclear Power Corp v. NRDC,* 435 U.S. 519, 551 (1978); *Citizens Against Burlington v. Busey*, 938 F.2d 190, 195 (D.C. Cir. 1991)).

8 *See, e.g., Private Fuel Storage, L.L.C.* (Indep. Spent Fuel Storage Installation), CLI-02-25, 56 NRC 340, 348-49 (2002).

9 *Robertson,* 490 U.S. at 354-56.

10 *Entergy Nuclear Operations, Inc.* (Indian Point Nuclear Generating Units 2 & 3), LBP-13-13, 78 NRC 246, 473 (2013) (citing *Izaak Walton League of Am. v. Marsh*, 655 F.2d 346, 377 (D.C. Cir. 1981), *cert. denied*, 454 U.S. 1092 (1981)). *See also Sierra Club v. Lynn*, 502 F.2d 43, 61 (5th Cir. 1974) (holding that the mere fact that certain factors in a cost-benefit analysis are generally imprecise or unquantifiable does not render the result inadequate).

11 *Marsh*, 655 F.2d at 377.

12 *Entergy Nuclear Generation Co. & Entergy Nuclear Operations, Inc.* (Pilgrim Nuclear Power Station), CLI-12-15, 75 NRC 704, 706-07 (2012).

13 *Id.* at 724 (citations omitted).

analysis that was done is reasonable under NEPA."[14] In short, the NRC Staff meets its NEPA obligations when, based upon the available technical information, its mitigation alternatives analysis outlines relevant factors, discloses uncertainties and opposing viewpoints, and indicates particular assumptions under which the Staff ultimately concludes that specific SAMAs are potentially cost-beneficial.[15] As documented in its FSEIS, the Draft Supplement, and the discussion below, the Staff clearly has met, if not substantially exceeded, its duties under NEPA with respect to the Indian Point SAMA analysis.

Against this legal backdrop, Entergy also underscores its agreement with two key conclusions set forth in the Draft Supplement. The first is that because none of the SAMAs identified as potentially cost-beneficial relates to adequately managing the effects of aging during the period of extended operation, none of those SAMAs need be implemented as part of license renewal pursuant to 10 C.F.R. Part 54.[16] In short, the NRC Staff's Part 54 safety review does not encompass assessment of possible current licensing basis modifications to mitigate the potential environmental impacts of postulated severe accidents—an issue wholly unrelated to aging management or continuation of the current licensing basis during the period of extended operation.[17] Thus, Entergy agrees with the NRC Staff that Part 54 provides no legal basis for requiring implementation of SAMAs unrelated to aging management.

Furthermore, as noted above, Entergy originally identified the 22 SAMAs discussed in the Draft Supplement for Indian Point as part of its NEPA-mandated consideration and disclosure of possible severe accident mitigation alternatives. As construed by the U.S. Supreme Court, NEPA does not require the implementation of mitigation measures (which include SAMAs) identified by an applicant or the Staff as part of the license renewal environmental review.[18] The federal courts have consistently applied the Court's holding in *Robertson* in finding that NEPA does not require the implementation of mitigation measures.[19]

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14 *NextEra Energy Seabrook, LLC* (Seabrook Station, Unit 1), CLI-12-5, 75 NRC 301, 323 (2012). *See also Town of Winthrop v. FAA,* 535 F.3d 1, 13 (1st Cir. 2008) (stating that NEPA allows agencies "to select their own methodology as long as that methodology is reasonable.").

15 *See Duke Energy Corp.* (McGuire Nuclear Station, Units 1 & 2; Catawba Nuclear Station, Units 1 & 2), CLI-03-17, 58 NRC 419, 431 (2003); *Mass. v. NRC,* 708 F. at 78 (1st Cir. 2013) (citing *Hughes River Watershed Conservancy v. Johnson*, 165 F.3d 283, 288 (4th Cir. 1999); *Marsh v. Or. Natural Res. Council*, 490 U.S. 360, 378-85 (1989)) (obtaining opinions from agency and outside experts, giving scientific scrutiny, and offering responses to legitimate concerns as evidence of a sufficiently "hard look").

16 *See* Draft Supplement at 21-23.

17 *See Fla. Power & Light Co.* (Turkey Point Nuclear Generating Plant, Units 3 and 4), CLI-01-17, 54 NRC 3, 10 (2001) (stating that the license renewal safety review seeks to mitigate the detrimental effects of aging resulting from operation beyond the initial operating license term, and that adjudicatory hearings in individual license renewal proceedings necessarily examine only the questions the NRC's Part 54 safety rules make pertinent).

18 *See Robertson,* 490 U.S. at 350, 353 (holding that NEPA requires a "reasonably complete discussion of possible mitigation measures," but "imposes no substantive requirement that mitigation measures actually be taken.").

19 *See, e.g., Mass. v. NRC,* 708 F.3d 63, 81 n.27 (1st Cir. 2013) (citing *Robertson*, 490 U.S. at 353) (holding, in the context of post-Fukushima challenges to the adequacy of Entergy's license renewal SAMA analysis for the Pilgrim plant, that "[t]o the extent [an intervenor] seeks to impose a substantive requirement that the NRC must require certain mitigation measures under NEPA, that is foreclosed

The Commission appropriately has followed suit, as evidenced by a decision issued in this proceeding, among numerous others.[20]

The second important conclusion with which Entergy concurs is that, given the dynamic nature of the SAMA analysis, which is rooted in probabilistic risk assessment methods, it is reasonable to defer any voluntary Entergy action on a number of SAMAs until after the completion of certain other voluntary and required plant improvements designed to reduce the risk of a severe accident.[21] In other words, the additional severe accident risk reduction achieved by such improvements likely will render some of the "deferred" SAMAs no longer "potentially cost-beneficial." It makes no practical sense for Entergy (or the NRC Staff) to undertake time and resource-intensive, plant-specific analyses for issues related to severe accident mitigation that already are being considered by the NRC as part of its AEA-based post-Fukushima review, or that likely would prove to have no cost-justified, substantial safety benefit as a result of licensee implementation of new AEA-derived safety requirements emanating from that review.[22]

III. The NRC Staff's Draft Supplement Confirms the Reasonableness of Entergy's Refined SAMA Implementation Cost Estimates

As noted in the Draft Supplement, in the FSEIS, the NRC Staff found that the methods used by Entergy for the evaluation of the SAMAs were sound, and that "the treatment of SAMA benefits and costs support the general conclusion that the SAMA evaluations performed by Entergy are reasonable."[23] Section G.5 of the FSEIS describes the NRC Staff's independent review of Entergy's original SAMA implementation cost estimates.[24] Based on that review, the Staff concluded that all of Entergy's cost estimates were reasonable, generally consistent with

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by the fact that NEPA is not outcome driven"); *Cnty. of Rockland v. FAA*, 335 Fed.Appx. 52 (DC. Cir. 2009) ("NEPA does not impose [a] 'substantive requirement that a complete mitigation plan be actually formulated and adopted' before agency can act") (quoting *Robertson*, 490 U.S. at 352).

20 *See Indian Point*, CLI-11-14, 74 NRC at 813 ("NEPA is a procedural statute—although it requires a 'hard look' at mitigation measures, it does not, in and of itself, provide the statutory basis for their implementation."); *Pilgrim*, CLI-12-10, 75 NRC at 488 (stating that NEPA "neither requires nor authorizes the NRC to order implementation of mitigation measures analyzed in an environmental analysis"); *Hydro Res., Inc.* (P.O. Box 777, Crownpoint, NM 87313), CLI-06-29, 64 NRC 417, 427 (2006) ("[A] mitigation plan need not be legally enforceable, funded or even in final form to comply with NEPA's procedural requirements.") (citations and internal quotation marks omitted); *Pilgrim*, CLI-10-11, 71 NRC at 316 (a NEPA mitigation analysis "demands no fully developed plan, or detailed examination of specific measures which *will* be employed to mitigate adverse environmental effects") (citations and internal quotation marks omitted).

21 *See* Draft Supplement at 19-23.

22 *See Entergy Nuclear Generation Co. & Entergy Nuclear Operations, Inc.* (Pilgrim Nuclear Power Station), CLI-12-1, 75 NRC 39, 57 (2012) (stating that SAMAs are "supplemental" to the mitigation measures that the NRC already requires under its safety regulations for reasonable assurance of safe operation, and that "[t]here is questionable benefit to spending considerable agency resources in an attempt to fine-tune a NEPA mitigation analysis").

23 Draft Supplement at 5-6.

24 *See* FSEIS, Vol. 3, Appendix G at G-34 to G-40.

prior estimates by other licensees, and sufficient and appropriate for use in the SAMA evaluation.[25]

As documented in the Draft Supplement, the Staff's review of Entergy's refined engineering project cost estimates was meticulous and thorough, and clearly satisfies the NRC's obligations under NEPA's rule of reason. Overall, the Staff's review and conclusions further confirm the reasonableness of Entergy's SAMA analysis, including Entergy's conclusions with respect to which SAMAs are potentially cost-beneficial. Of particular note, the Staff did the following in reviewing Entergy's revised SAMA cost estimates:

- Issued requests for additional information in October 2014;
- Reviewed the description of each proposed modification and compared it against the conceptual design sketches provided by Entergy;
- Confirmed that the cost estimates included costs for design, implementation, and materials appropriate for the design modification;
- Verified the reasonableness of the costs for materials by contacting several manufacturers or vendors noted in the literature provided by Entergy;
- Reviewed the assumptions listed in the Implementation Estimate and compared those assumptions with costs stated in the Implementation Estimate Work Sheet to identify any discrepancies;
- Reviewed all line items in the Implementation Estimate Work Sheet provided by Entergy to determine whether the description, level of effort, and cost for each activity of the proposed modification were reasonable; and
- Compared similar activities from one proposed modification to those in a similar modification, including assumptions, labor hours, labor rates, and material costs across the proposed modifications.[26]

Based on its independent and thorough review of Entergy's revised cost estimates, the NRC Staff reached the following key conclusions, with which Entergy generally agrees, subject to certain clarifications made in additional comments below:

- The application of a site encumbrance premium for the purpose of accounting for site access restrictions is reasonable in light of additional burden associated with granting access to a licensed nuclear power plant versus a non-nuclear facility.
- The site encumbrance premium value used by Entergy is based on site-specific and industry experience and is similar to the term "productivity/difficulty factor" that is used in Entergy fleet administrative procedures to improve the accuracy of the cost estimate based on the location of the work being performed.
- Entergy's application of a 30-percent loader to account for the total sum of the estimated overhead costs for material loaders, capital suspense, and applied interest

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25 *See id.* at 40. *See also id.*, vol. 1, at 5-11 ("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.").

26 *See generally* Draft Supplement at 8-13.

allowance for funds used during construction is reasonable because this is a standard practice for Entergy plants that involve capital expenditures.

- Application of a factor of 1.7 to the craft labor rates for work performed inside the reactor containment building during outages is reasonable to account for time and productivity losses associated with the difficulty of working in the highly-restricted containment area (due to space limitations, environmental conditions, and radiation hazards).
- The use of actual billed craft labor rates, as inflated to 2014 dollars, for cost-estimating purposes, is a reasonable approach because the rates are known labor rates and they represent what will likely be charged for a future modification.
- The hourly rates used by Entergy for in-house engineering personnel and contract engineers are reasonable.
- Entergy's use of AACE International Class 4 and Class 5 cost estimates, which are commonly used for project planning and viability screening, is appropriate for use in a SAMA cost-benefit analysis.
- With respect to the six SAMAs identified by Entergy as no longer cost-beneficial in its May 2013 submittal—SAMAs IP2-021, IP2-022, IP2-053, IP2-056, IP3-018, and IP3-019—the Staff's review identified "some minor discrepancies or unexplained costs." However, inclusion or exclusion of the purportedly underestimated or overestimated costs would *not* alter Entergy's conclusion about the economic feasibility of the proposed modifications. In other words, such adjustments to the cost estimates would have no material impact on the SAMA analysis conclusions.
- The Staff's sensitivity analyses, as described in Section 3.1.3.3 of the Draft Supplement, indicate that accounting for uncertainties in the refined cost estimates has a minimal impact on the outcome of the SAMA analysis. Based on its sensitivity analyses, the Staff found that only SAMAs IP2-021 (Install additional pressure or leak monitoring instrumentation for inter-system loss of coolant accidents (ISLOCAs)) and IP2-053 (Keep both pressurizer power-operated relief valve ("PORV") block valves open) would become potentially cost beneficial, and SAMA IP2-062 (Provide a hard-wired connection to a safety injection ("SI") pump from alternate safe shutdown system ("ASSS") power supply) would *no longer* be potentially cost-beneficial.
- It is reasonable to defer actions regarding SAMAs IP2-009, IP2-028, IP2-044, IP2-065, IP3-007, and IP3-061 because those SAMAs would act to reduce similar risks that are being addressed by Entergy in accordance with NRC-issued Order EA-12-049, "Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (Mar. 12, 2012).
- Given the dynamic nature of a SAMA analysis, it is reasonable to defer action on SAMAs IP2-054, IP2-060, IP2-061, IP2-062, IP3-055, and IP3-062 until the risk profile for each plant is re-evaluated following the completion of both voluntary and required plant improvements designed to reduce the risk of a severe accident.

- The NRC Staff concurs with Entergy that risk reduction already has been achieved by Entergy's implementation of SAMAs IP3-052, IP3-053, IP2-GAG, and IP3-GAG, which previously were identified as being potentially cost-beneficial SAMAs.[27]

IV. Entergy Does Not Agree With The NRC Staff That the Uncertainty in Its Refined Engineering Project Cost Estimates Is "Large"

In the Draft Supplement, the NRC Staff states that "there appears to be large uncertainty in the cost estimates." That statement is based principally on the Staff's review of AACE International's Recommended Practice (RP) No. 18R-97, "Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries", which Entergy cited as providing relevant cost estimating principles and guidelines in its November 20, 2014 RAI Responses. Specifically, in assessing the degree of uncertainty associated with Entergy's refined engineering project cost estimates and performing the sensitivity analyses described in Section 3.1.3.3 of the Draft Supplement, the Staff used the lowest and highest values of certain "accuracy ranges" listed in AACE International's RP No. 18R-97.[28] As most relevant here, the Staff thus assumed that Entergy's revised cost estimates could have overestimated actual SAMA implementation costs by 100 percent—*i.e.*, by a factor of two.

Entergy does not view it as reasonable to assume that the refined cost estimates are high by a factor of two (*i.e.*, +100 percent), insofar as that assumption informs the Staff's statement that "there appears to be large uncertainty in the cost estimates."[29] Assuming that the refined cost estimates could be high by a factor of two is, in Entergy's view, akin to a worst-case assumption and thus contrary to NEPA's rule of reason. As noted in Entergy's November 20, 2014 RAI Responses, the refined engineering project cost estimates were prepared by professional cost estimators with substantial nuclear engineering expertise and experience in preparing cost estimates at other nuclear plants, including other Entergy facilities.[30] They also were reviewed by site engineering personnel with relevant training and experience.[31] As a result, the refined cost estimates are based on established industry and plant-specific practices and assumptions (including contingencies).

Furthermore, Entergy's refined cost estimates contain a level of detail that far exceeds that recommended in NRC Staff and NRC-approved industry guidance, or contained in the SAMA implementation cost estimates prepared by other license renewal applicants and approved by the NRC Staff. For example, NEI 05-01, Rev. A, which has been formally approved by the NRC Staff and is routinely used NRC license renewal applicants, states that that "the cost of each SAMA candidate should be conceptually estimated to the point where economic viability of the proposed modification can be adequately gauged, and that "the SAMA analysis is not a complete engineering project cost-benefit analysis."[32] The revised cost

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[27] *See generally* Draft Supplement at 9-23.

[28] *See id.* at 17.

[29] Draft Supplement at 14, 15.

[30] *See* November 20, 2014 RAI Responses at 1.

[31] *See id.*

[32] Nuclear Energy Institute (NEI) 05-01, Rev. A, "Severe Accident Mitigation Alternatives (SAMA) Analysis Guidance Document" at 28, 33 (Nov. 2005).

estimates reviewed by the NRC Staff in the Draft Supplement are, in fact, detailed engineering project cost estimates.

V. The Estimated SAMA Benefits to Which Entergy's Refined Engineering Project Cost Estimates Are Compared Reflect Substantial Conservatisms in the Risk-Based Portion of the SAMA Analysis That Likely Bound the Uncertainties in the Cost Estimates

It also is important to bear in mind that the "Estimated Benefit with Uncertainty" to which each refined SAMA implementation cost estimate is compared is a conservative value. In its 2010 FSEIS, the NRC Staff stated that "Entergy's bases for calculating the risk reduction for the various plant improvements . . . are reasonable and generally conservative (*i.e.*, the estimated risk reduction is higher than what would actually be realized.)"[33] The NRC Staff further noted: "The SAMA evaluations were performed using realistic assumptions with some conservatism. On balance, such calculations *overestimate the benefits and are conservative*."[34]

One of conservatisms embedded in the IPEC SAMA benefit analysis and discussed in the FSEIS involves the use of an uncertainty factor or multiplier on the already conservative risk-reduction estimates. Specifically, the SAMA analysis used two multipliers on the internal benefit quantification in order to account for (1) external events, and (2) analysis uncertainties.[35] The analysis uncertainties multiplier was based on the ratio of the 95th percentile core damage frequency ("CDF") to the mean or point estimate CDF. Any SAMAs that became cost-beneficial after the use of these two multipliers were included as cost-beneficial. Notably, the Commission has observed that, as in case of the Indian Point SAMA analysis, "[t]he final cost-benefit comparisons are based not on the baseline analysis results, *but on revised results that take into account an uncertainty factor*."[36]

The FSEIS notes other conservatisms in the risk quantification portion of the SAMA analysis. They include Entergy's use of the projected population in year 2035, which is the last year of the IP3 period of extended operation and two years after the end of the IP2 period of extended operation; a "no-evacuation" assumption, which overestimates doses incurred in the early phase of potential accidents; and the results of a sensitivity case for lost tourism and business in the base case analysis.[37]

Finally, it warrants emphasis that the IPEC SAMA analysis was prepared before the Commission ordered Entergy and other NRC licensees to implement numerous and extensive procedural and plant modifications in response to the March 2011 Fukushima accident. As discussed in Entergy's May 6, 2013 submittal to the NRC, Entergy's ongoing implementation of the Commission's numerous, ongoing Fukushima action items are intended and expected to substantially mitigate the risks of certain beyond-design-basis accidents. The fact that the IPEC SAMA analysis does not take into account these substantial safety and mitigation-related enhancements is itself a significant conservatism in the analysis. The Draft Supplement implicitly recognizes this fact in stating that "certain NRC-mandated actions, as well as the

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33 FSEIS, Vol. 3, Appendix G at G-34.

34 *Id.* at G-33 (emphasis added).

35 *See id.* at G-17, G-30, G-40 to G-42.

36 *Pilgrim*, CLI-12-1, 75 NRC at 58 (emphasis added).

37 *See* FSEIS, Vol. 3, Appendix G at G-20 to G-21, G-43, G-46.

nuclear power industry's initiatives to address the challenges faced at Fukushima Dai-ichi, are likely to have an impact on certain SAMA candidates previously found to be potentially cost beneficial."[38] It further notes that "any potential accident mitigation improvement achieved by these SAMAs may be addressed, at least in part, through the NRC's generic process reviewing all plants' current licensing bases regarding their ability to deal with beyond-design-basis events."[39]

VI. In View of the Foregoing Considerations, Entergy Recommends That SAMAs IP2-021 and IP2-053 Not Be Retained For Further Consideration

In the Draft Supplement, the Staff recommends that Entergy retain SAMAs IP2-021 and IP2-053 for further consideration because "the incremental difference by which the SAMAs are not cost beneficial, when viewed in the context of uncertainties in the cost estimates, is too small to exclude them from further consideration."[40] The Staff explains that:

- The corrected refined estimated cost for SAMA IP2-021 is approximately $4.63 million. When compared to the benefit with uncertainty of $4.41 million, the SAMA is not cost beneficial by approximately $224,000, which represents less than a 5-percent difference.
- The corrected refined cost estimate for SAMA IP2-053 is approximately $1.47 million. When compared to the benefit with uncertainty of $1.39 million, the SAMA is not cost beneficial by approximately $82,000, which represents less than a 6-percent difference.

Entergy respectfully disagrees with the NRC Staff's recommendation to retain SAMAs IP2-021 and IP2-053 for further evaluation for several reasons. First, as noted above, the Staff's recommendation to retain SAMAs IP2-021 and IP2-053 for further consideration is based on the notion that there is "large uncertainty" in the refined cost estimates—possibly on the order of +100 percent. For the reasons stated in Section IV, *supra*, Entergy disagrees with that characterization. The refined engineering cost estimates were prepared by a contractor with significant nuclear engineering expertise and experience in preparing such cost estimates, and also were reviewed by qualified site engineering personnel. Indeed, the NRC Staff itself has reviewed the cost estimates in detail and found both the approach used and the costs provided to be reasonable.

Second, as stated in the AACE International guidance, the Expected Accuracy Range "depend[s] on the technological complexity, appropriate reference information, and the inclusion of an appropriate contingency determination." Consideration of these factors relative to the two SAMAs in question—IP2-021 and IP2-053—leads Entergy to conclude that it is highly unlikely that refined cost estimates overestimate the cost of implementing those two SAMAs at IPEC. Therefore, the 5 to 6 percent "incremental difference by which the SAMAs are not cost beneficial" cited by the NRC Staff does not, in Entergy's view, warrant retention of the SAMAs for further evaluation on a voluntary basis by Entergy.

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38 Draft Supplement at 20.

39 *Id.*

40 *Id.* at 19.

Specifically, SAMA IP2-021 involves the installation of pressure transmitters at nine inter-system ISLOCA paths to measure pressure changes within an isolation boundary and to transmit the information to a location outside containment for remote display and monitoring. The complexity of the required technology is typical of other systems used at Indian Point (*e.g.*, pressure transmitters, valve manifolds, recorders). In addition, the cost estimate includes typical vendor transmitter and recorder Product specification sheets as well as piping single line diagrams and system block diagrams. Considering the details of the estimate prepared by Entergy's experienced vendor, it is highly unlikely that the actual cost estimate for IP2-021 would decrease by 100 percent upon further refinement. In fact, it is more likely that there are other project considerations that were *not* included, and that would increase the cost estimate. For example, the estimate says the recorder will be located in the control building on the 33' elevation. For the operators to more expeditiously determine that there is an Inter-System LOCA, the recorder also could be located in the control room. To locate the recorder in the control room, there would be many design considerations that must be met, such as penetration and resealing of the fire barrier for cables, Human Factor evaluation to ensure proper location of the recorder(s), panel mounting of the recorder, cable separation requirements, etc.

SAMA IP2-053 involves undoing a previous modification to two PORV block valves, and modifying the control circuit of the two PORV block valves to keep the valves open during normal plant operations. The complexity of the technology associated with this possible plant modification is typical of what currently is used at Indian Point, insofar as it involves reinstating previous circuitry. The portion that is not as clearly defined is the 10 C.F.R. Part 50, Appendix R (fire protection) evaluation that would be necessary to implement SAMA IP2-053. The current estimate includes $250,000 to perform this evaluation, which may be on the low side in light of potential technical and regulatory considerations related to Hot Shorts and cable separation issues. Again, given the level of detail included in the current estimate, it is unlikely that the actual cost would decrease by a factor of two (*i.e.*, 100 percent). As in the case of IP2-021, it is more likely that there are other project considerations (*e.g.*, status/condition of the original wiring, changes to plant computers, training of Licensed Operators) and associated costs that would increase the estimate.

Third, the refined SAMA implementation cost estimates were compared to the estimated "Benefit with Uncertainty" for each of those SAMAs. As discussed in Section V, *supra*, the Benefit with Uncertainty value reflects various conservatisms, such that the the estimated risk reduction is higher than what would actually be realized by the implementation of the SAMA. Therefore, for this additional reason, Entergy does not view the 5 to 6 percent margin between the Benefit with Uncertainty and the Corrected Estimated Cost (2014), as shown in Table 3-1 of the Draft Supplement, as warranting further consideration of SAMAs IP2-021 and IP2-053. Those SAMAs should, in fact, be excluded as no longer potentially cost-beneficial based on the current benefit and cost values provided in the table.

Finally, as the NRC Staff notes, when any SAMA that was previously determined to be potentially cost-beneficial is implemented, the risk profile from which the SAMA analysis is derived will necessarily change. Therefore, after the initial SAMA analysis is completed, decisions to implement potentially cost-beneficial SAMAs should be viewed as a dynamic process. Entergy's previous implementation of four of the potentially cost-beneficial SAMAs, and its implementation of plant improvements required by NRC Order EA-12-049 will lower the IP2 and IP3 plant risk profiles and, therefore, will tend to lower the benefits associated with any other potentially cost-beneficial SAMAs—including IP2-021 and IP2-053. That is, many of the 22 potentially cost-beneficial SAMA candidates act on the same accident sequences. Therefore,

as alternatives for mitigating the dominant accident sequences are implemented, the baseline risk, as recalculated, is reduced. This reduces the likelihood that other SAMA candidates acting on the same accident sequences will remain, or become, potentially cost-beneficial. This fact further supports Entergy's position that those two SAMAs should be excluded from further voluntary consideration by Entergy.

VII. Although Entergy Agrees That the "Minor Discrepancies or Unexplained Costs" Identified in the Draft Supplement Do Not Alter Entergy's Conclusions About the Economic Viability of Any Proposed SAMA, Some Clarifications Are Warranted

With respect to the six SAMAs identified by Entergy as being no longer cost-beneficial based on the refined engineering project cost estimates, the Staff noted that certain, limited aspects of those cost estimates "appeared to be errors, overestimations, or could not be readily understood." Upon further review and assessment, however, the Staff concluded in Section 3.1.3.1 of the Draft Supplement that none of those issues affected Entergy's conclusions regarding the economic viability of the relevant SAMAs.

Entergy agrees that none of the issues identified by the Staff in Section 3.1.3.1 has any effect on the SAMA cost-benefit analysis conclusions. In fact, the table provided below, which provides some clarifications in response to the Staff's statements in Section 3.1.3.1, confirms that any increases or decreases in the cost estimates associated with the minor issues identified by the NRC Staff are less than 1.0 percent and thus are negligible in effect, especially when one considers of the overall scope and complexity of the cost estimates. For the reasons discussed throughout these comments, Entergy has full confidence in the quality and acceptability of the refined cost estimates, particularly in view of the Staff's detailed review of the estimates, the purpose for which they are being used, and the NEPA reasonableness standard that applies to the estimates.

Draft Supplement Page	Relevant SAMA	NRC Staff Observations	Entergy Response/Comments
14	IP2-021	a) On the Implementation Estimate Work Sheet for the QA/QC verification item, a cost of $15,000 is listed, but there is also a cost of $15,000 for a subcontractor. It is not clear what this additional $15,000 subcontractor cost is for. The similar SAMA for IP3 (IP3-019) does not include an additional subcontractor cost. b) On page 1 of the Implementation Estimate Work Sheet, Item 1 of the non-outage work appears to be a labor-only item, the cost being $2,466. However, a cost of $2,466 is also included as a material cost. In comparison, for SAMA IP2-009, the same item ("Gather material and stage tools and materials") is only a labor cost; there is no materials cost for that line item. c) For the fire watch (during the outage), the FCTR (factor) is only 1.0, not 1.7.Because the work is being performed inside containment, a factor of 1.7 should have been used.	a) For IP2-021, the additional $15,000 Subcontractor cost represents the cost of outside vendor to perform the commercial grade dedication required to qualify the Yokogawa Recorder for use in this application. For IP3-019, the $15,000 cost was inadvertently omitted and should be added to the Estimated Work Sheet for the QA/QC verification line item. The omission of this cost from SAMA IP3-019 estimate results in an insignificant increase to the cost estimate. b) The $2,466 material cost listed on line Item 1 for SAMA IP2-021 was inadvertently included and therefore should be changed to $0. Removing the $2,466 material cost from the estimate results in an insignificant decrease to the cost estimate. c) The 1.0 factor used in the estimate for the fire watch time while working in containment is correct. The 1.7 factor does not apply to the fire watch time because the fire watch individual is not involved with the productivity performance of the modification installation activity. The hours used in the estimate for fire watch support are the total hours needed for fire watch.

Draft Supplement Page	Relevant SAMA	NRC Staff Observations	Entergy Response/Comments
14	IP2-022	a) For qualification testing of the valve, the largest and more costly valve is used. b) A cost range for the valves was given; however, in the cost estimate, the highest cost for each valve is used. c) On the Implementation Estimate, Item 2 assumes that non-outage work will occur in 2011, yet the labor rates for the non-outage work are presumably for 2014 because the labor rates are not different from those used for outage work, which is assumed to occur in 2014. d) There are hourly charges for nondestructive evaluation profile of the welds for the valves; however, there is also a subcontractor charge for non-destructive evaluation of $70,000.	a) The size or cost of the valve does not impact the cost of the qualification testing. b) The highest value of the cost range is used to account for potential uncertainties in the estimated cost range. c) See items 13 on the Description page for SAMA IP2-022 for assumption of labor dollars used. Item 13 states "Labor dollars in this estimate are projected 2014 costs based on current 2012 craft billing rates at Indian Point. The projected costs provide for anticipated billing rate increases for 3% per year. The assumption stated in Items 2 on the Description page was from an earlier version of the estimate and could have been modified to indicate that the non-outage work will be projected to 2014 costs, as stated in item 13 on the description page. d) The hourly charges for the "NDE Profile" of the welds for the valves are the charges for a pipefitter to prepare the weld area for the NDE Profile. The $70,000 subcontractor charge for non-destructive evaluation is the cost of hiring NDE qualified subcontractor to perform the NDE Profile. Both charges are correct.
15	IP2-053 and	a) Regarding IP2-053, Item 7 of the Implementation Estimate assumes that a 10 CFR Part	a) $250,000 was included after further consideration of the effort required to perform the

Draft Supplement Page	Relevant SAMA	NRC Staff Observations	Entergy Response/Comments
	IP3-053	50, Appendix R, evaluation will cost $250,000 and will be performed by a contract person; however, in response to RAI 5I (Entergy 2008a), although Entergy acknowledged that a change to the fire protection program would be needed, it did not initially include $250,000 for the evaluation. b) Regarding IP2-053, 1,700 hours of contractor design support are estimated. This seems high for what appears to be a relatively straightforward design (*i.e.*, undo the previous modification). c) The NRC Staff notes that for an IP3 SAMA (IP3-053), which also involves a 10 CFR Part 50, Appendix R, evaluation, Entergy proposed the same cost of $250,000 for the evaluation. As an aside, the NRC Staff notes that even though Entergy stated in the assumptions for IP3-053 that a cost of $250,000 is included for the 10 CFR Part 50, Appendix R, evaluation, the actual cost estimate did not include the $250,000 cost. d) For IP2-053, and with regard to the seemingly large contractor design support effort to "un-install the modification" and "restore the original design" (Entergy 2014a), the NRC Staff notes that contractor design support efforts for other proposed modifications that are "new" are on the order of 1,000 to 1,700 hours and that several are even less. A reduction in	10 CFR Part 50, Appendix R evaluation. b) The 1700 man-hours estimate includes preparing Engineering Change (EC) Package in accordance to Entergy's procedure EN-DC-115, Engineering Change Process (EC). The process includes providing the required evaluation, analysis, calculations, design basis documentation and review and approval required for: (1) Un-installing the existing modification, (2) restoring original design, including restoring wiring to original configuration PORV Block Valve control circuits that will restore each valve's original isolation function, and (3) revising procedures to reflect original configuration. The 1700 man-hours is based on 3 men for approximately 3.5 months and is considered to be a reasonable estimate for the effort required to implement the EC. c) Although the assumption section for the cost estimate for IP3-053 indicates that a cost of $250,000 is included for Appendix R evaluation, the $250,000 for Appendix R evaluation is not applicable to SAMA IP3-053. The modification associated with SAMA IP3-053 does not result in a change to 10CFR50 Appendix R. Item 7 of the assumptions listed in the "Description" page was

Draft Supplement Page	Relevant SAMA	NRC Staff Observations	Entergy Response/Comments
		the contractor design support effort of 325 hours would reduce the total cost estimate to a value that would make the modification potentially cost beneficial.	copied in error from SAMA IP2-053. d) See item b) above.
16	IP2-056	a) On the Implementation Estimate, Items 2 and 3 assume that the non-outage and outage work will be completed in 2012. However, the labor rates are presumably for 2014 because the labor rates used are not different from those used for other SAMAs for which work was assumed to be conducted during 2014. b) A cost for a decontamination contractor ($10,000) has been included; however, a cost for radwaste has not been included. Although it is not clear whether radioactive waste will be generated as part of this modification, it is also not clear why a decontamination contractor is needed for this modification. The NRC Staff notes that a decontamination contractor is proposed only for this SAMA and SAMA IP2-022, which does involve the replacement of existing valves.	a) See Item 11 on the Description page for SAMA IP2-056 for assumption of labor dollars used. Item 11 states "Labor dollars in this estimate are projected 2014 costs based on current 2012 craft billing rates at Indian Point. The projected costs provide for anticipated billing rate increases for 3% per year." The assumptions stated in Items 2 & 3 on the Description page were from an earlier version of the estimate and could have been modified to indicate that the estimate is projected to 2014 costs, as stated in item 11 on the description page. b) The estimated cost of $10,000 for decontamination contractor includes the shipping cost for the small amount of radwaste generated from the installation.
16	IP3-018	a) The original cost estimate was $12 million (Entergy 2009b). The refined cost estimate is $35.7 million, which exceeds the estimated benefit with uncertainty of $14.6 million by $21 million (Entergy 2013b). This proposed modification is extensive, and the costs associated with it are large and	a) The proposed modification is extensive, and the cost may be slightly underestimated. However, based on the maturity of the scope information and deterministic approach used to create the estimate, the uncertainty in the cost estimate (with contingency) is expected to

Draft Supplement Page	Relevant SAMA	NRC Staff Observations	Entergy Response/Comments
		most likely underestimated. Even with large uncertainty in the cost estimate, as discussed in Section 3.1.3.4, the NRC Staff does not believe that Entergy's conclusion about the economic feasibility of this modification will be altered.	be small.
16-17	IP3-019	a) On page 1 of the Estimate Worksheet, Item 1 of the non-outage work appears to be a labor-only item, the cost being $2,466. However, a cost of $18,000 is also included as a material cost. For SAMA IP2-021, the material cost is $2,466. It is not clear what comprises these material costs. b) There is not a materials cost for "testing," but there is one in IP2-021, which is the similar SAMA for IP2. c) For the fire watch (during the outage), the FCTR (factor) is only 1.0, not 1.7.Because the work is being performed inside containment, a factor of 1.7 should have been used.	a) The $2,466 labor cost listed on page 1, line Item 1, of the Estimated Worksheet for SAMA IP3-019 is correct. The $18,000 for the material cost in line Item 1 is incorrect and should be changed to $0. Removing the $18,000 material cost from the estimate results in an insignificant increase in the cost estimate. b) There should not be any material cost for "testing" for either SAMA IP2-021 or SAMA IP3-019. The $5000 cost was inadvertently included and should be removed from the cost estimate of SAMA IP2-021. The resulting decrease in the estimate is insignificant. c) The 1.7 factor does not apply because the fire watch individual is not involved with the performance of the modification installation activity and doesn't impact productivity or time loss associated with the installation of the modification.

ATTACHMENT 2 TO NL-16-021

COMMENTS ON SECTION 4.0 OF THE DRAFT SUPPLEMENT

(NEW INFORMATION ON ENTRAINMENT AND IMPINGEMENT IMPACTS)

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 & 3
DOCKET NOS. 50-247 AND 50-286

Entergy Comments on Section 4.0 of the Draft Supplement (New Information for Entrainment and Impingement Impacts)

I. Introduction

Entergy Nuclear Operations, Inc. ("Entergy") submits these comments to address the Nuclear Regulatory Commission ("NRC") Staff's analysis of potential aquatic impacts in Section 4.0 of the Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 38, Volume 5, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3 ("Draft Supplement").[1] That analysis concerns potential impacts to aquatic species resulting from their presumed impingement and entrainment mortality attributed to continued operation of the existing cooling water intake structures at Indian Point Units 2 and 3 ("IP2" and "IP3") during the license renewal term.

Entergy appreciates that the NRC Staff has reviewed what it determined are relevant species, and concluded that potential impacts of impingement and entrainment associated with Indian Point operations are "SMALL" for 10 species (Alewife, American Shad, Atlantic Tomcod, Bay Anchovy, Bluefish, Spottail Shiner, Striped Bass, Weakfish, White Catfish and White Perch) and MODERATE for one species (Hogchoker). Entergy concurs with these NRC Staff findings.

These comments focus on what Entergy respectfully submits are anomalous intermediate, species-specific findings of "LARGE" potential impacts for two species, the Rainbow Smelt and Blueback Herring. As detailed below, the NRC Staff's intermediate findings with respect to these two species are not in accordance with the "best available information" consistent with NEPA.[2] This is because the NRC Staff's findings do not reasonably take into account key elements of the life histories (including early life stage distribution patterns) of these species in the Hudson River which renders them not usually susceptible to impingement and entrainment mortality, as well as specific studies of these species identifying the bases for

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1 Entergy incorporates, but does not herein reiterate, its prior comments regarding the potential aquatic impacts of the proposed action—that is, the renewal of the NRC operating licenses of Indian Point Units 2 and 3. *See* March 29, 2011 letter from F. Dacimo, Entergy, to B. Holian, Division Director, NRC (ADAMS Accession No. ML110980073) and attached report, AKRF, Inc., 2011, *Technical Review of FSEIS for Indian Point Nuclear Generating 17 Unit Nos. 2 and 3; Sections 4.1.1–4.1.3 and Appendices H and I.* (ADAMS Accession No. ML110980163.); *see also* February 19, 2014, Letter from F. Dacimo, Entergy, to the NRC Document Control Desk (ADAMS Accession No. ML14063A528) and attached report, AKRF, Inc., 2014, *Update of Aquatic Impact Analyses Presented in NRC's FSEIS (December 2010) Regarding Potential Impacts of Operation of Indian Point Units 2 and 3.* (ADAMS Accession No. ML14063A529).

2 *Luminant Generation Co. LLC* (Comanche Peak Nuclear Power Plant, Units 2 and 3), CLI-12-7, 75 NRC 379, 391-92 (2012) (citations omitted) ("[W]e observe that an application-specific NEPA review represents a "snapshot" in time. NEPA requires that we conduct our environmental review with the best information available today."); *see also Delaware Riverkeeper Network v. FERC*, 753 F.3d 1304, 1313 (D.C. Cir. 2014) (quoting *Motor Vehicle Mfrs. Ass'n of the U.S., Inc. v. State Farm Mut. Auto. Ins.*, 463 U.S. 29, 43 (1983)) (to satisfy NEPA, agencies must comply with "principles of reasoned decisionmaking", and to do so they must "examine the relevant data and articulate a satisfactory explanation for its action including a rational connection between the facts found and the choice made").

certain trends that have been incorrectly attributed to Indian Point (*i.e.*, the catastrophic loss of Rainbow Smelt in the mid-1990s due to infection with a microsporidian parasite).

Accordingly, below, a team of leading national biologists consisting of Dr. Lawrence W. Barnthouse of LWB Environmental Services, Inc., Dr. Douglas G. Heimbuch of AKRF, Dr. John R. Young of ASA Analysis and Communications, Inc., and Dr. Mark M. Mattson of Normandeau Associates, Inc. (collectively, the "Biological Team") provides additional, highly detailed, species-specific information—based on multiple published, peer-reviewed resources and an analysis of the extensive Hudson River aquatic species dataset, as well as with the benefit of its nearly 150 collective years of Hudson River ecological expertise—to better illustrate for NRC Staff the extent to which the "LARGE" findings for Rainbow Smelt and Blueback Herring are anomalous and inconsistent with the "best information available." In the process, the Biological Team also identifies certain application errors in the NRC Staff's methodology relative to these species that has compounded these anomalies, thereby allowing conclusions that, if maintained, would be considered irrational.

II. The Best Available Scientific Data Support an Intermediate, Species-Specific Finding of "SMALL" Impact to the Rainbow Smelt

A. Hudson River Biological Monitoring Program Longitudinal River Survey Data Show No Downward Trend in the Rainbow Smelt Population During the First Twenty Years of Indian Point Operations, with a Clear Catastrophic Disappearance Unrelated to Indian Point in 1996

By way of review of NRC Staff's methodology, the Draft Supplement's suggested weight of evidence approach combines the results of two lines of evidence ("LOE"): (1) a population trend LOE intended to assess the stability of each species; and (2) a strength of connection ("SOC") LOE intended to represent the ability of impingement and entrainment at Indian Point to produce noticeable changes in fish population trends.[3] For the population trend LOE, the NRC Staff used a "simple linear regression of annual population measurements over years to assign the level of adverse impact."[4] Populations with slopes not significantly different from zero receive a score of 1.0, and populations with negative slopes significantly different from zero receive a score of 4.0.[5] The source of the population data is the widely touted, frequently cited, robust and extensive Hudson River Biological Monitoring Program ("HRBMP"), which provides annual measurements of the Hudson River estuary for every year from 1974 through, as reflected in the update submitted to NRC in response to its September 24, 2014 Request for Additional Information, 2011.

For Rainbow Smelt, the NRC Staff analyzed HRBMP data for the period from 1985 through 2011, and found a statistically significant decreasing population, both River-wide and in the portion of the River adjacent to Indian Point, known as Region 4 in the HRBMP (referred to by NRC Staff as River Segment 4). The NRC Staff therefore assigned Rainbow Smelt an

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3 *See* Draft Supplement, Appendix A at A-9, A-11.

4 *Id.* at A-20.

5 *Id.*

overall score of 4.0 for the population trend LOE.[6] The NRC Staff also recognized that its population trend conclusion was dictated by the fact that, as is undisputed, Rainbow Smelt effectively disappeared from the Hudson River in 1996.[7] As explained below, the NRC Staff effectively assumed that a catastrophic loss of a population is the same as a declining trend of the sort that would occur as a result of continuous cooling water withdrawals by a nuclear station presumed to have an impact. In fact, however, the suddenness, magnitude and timing of the catastrophic decline of Rainbow Smelt are not consistent with presumed impingement and entrainment mortality. Thus, the data warranted careful investigation to ensure that a purported trend-based conclusion captures the biological reality, as established by the best available data and scientific analysis in a manner consistent with NEPA.[8] This additional investigation is particularly important to avoid an anomalous SOC LOE finding of potential impact.

As background and further explanation, IP2 and IP3 commenced commercial operation in 1973 and 1975, respectively. If their operation had the ability to significantly impact the abundance of Hudson River Rainbow Smelt in a manner that could result in the disappearance of a population at the height of its measured abundance in less than a handful of years (as a "high" SOC finding suggests), then a decline in that population over the first two decades of that operation would have occurred. In fact, no such decline occurred. Rather, as explained below, the available data show that there was no downward trend in Rainbow Smelt abundance during the first 22 years of Indian Point's operation—that is, before the sudden collapse of the Rainbow Smelt population in the Hudson River in the mid-1990's.

Specifically, Appendix 2A to these comments contains two graphs depicting River-wide abundance of larval Rainbow Smelt based on data collected from 1974 through 2011 as part of the HRBMP's Longitudinal River Survey ("LRS").[9] Figures 1 and 2 in Appendix 2A depict average annual River-wide abundance of Rainbow Smelt larvae from week 17 to week 27 (*i.e.*, the period when these life stages are present in LRS samples), presented on a log10 scale to account for large differences in abundance among years. Figure 1 presents the results of an ordinary least squares ("OLS") linear regression of the annual averages for the years 1974 (the first full year of Unit 2 operation) through 1995, the last year in which Rainbow Smelt were present in the Hudson River in significant numbers. Figure 2 depicts the same data for larvae, but with an OLS linear regression performed using log10-transformed estimates of average River-wide abundance (consistent with the log10 axis of the graphs).

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6 *See id.* at A-27 to A-29 (Tables A-12, A-13, A-14).

7 *See, e.g.*, Draft Supplement at 31 ("[t]he Hudson River population appears to have been extirpated in the mid-1990s"), 33 (acknowledging that Rainbow Smelt "has been extirpated"; Draft Supplement, Appendix A at A-37 to A-38 (stating that the once abundant Rainbow Smelt "has undergone an abrupt population decline in the Hudson River since 1994" and that "post-yolk sac larvae essentially disappeared from LRS samples after 1995" while "YOY [young of the year] were last captured in the LRS, FSS, and BSS in 1995, 1998 (one fish), and 1993, respectively.").

8 *See, e.g., Motor Vehicle Mfrs. Ass'n,* 463 U.S. at 43; *see also Delaware Riverkeeper Network,* 753 F.3d at 1313.

9 The Appendices to these and other Entergy comments follow the last attachment to this submittal. The Appendices to this Attachment (Attachment 2) are designated Appendix 2A, 2B, etc.

In both figures, the graphs show a slightly positive slope (one that is not significantly different from zero) for the 1974 to 1995 period, after which Rainbow Smelt Larvae essentially disappear from the Hudson River—an obvious sign of a catastrophic collapse. This is consistent with the findings in Daniels *et al.* (2005), which analyzed the same data to conclude that all other life stages of this species (*i.e.*, eggs, yolk sac larvae, young-of-the-year ("YOY"), older) show a similar pattern of persistence and then a sudden disappearance.[10] Thus, as depicted in Appendix 2A to these comments and Figure 5 of Daniels *et al.* (2005), following two decades of non-declining population abundance, there was a catastrophic loss of Rainbow Smelt from the Hudson River in 1996. Larval abundance dropped from a measured high over the prior two decades of about 96.6 million in 1994, to about 5.1 million in 1995, to zero (0) in 1996. In sum, the demonstrated persistence of the Rainbow Smelt population for the first 22 years of Indian Point operation, followed by the sudden disappearance of Rainbow Smelt from the River beginning in 1996, reflects a sudden collapse—not a declining trend—in the Rainbow Smelt population.[11]

To put in perspective the suddenness and magnitude of the collapse of the Hudson River Rainbow Smelt population, the Biological Team developed and ran an illustrative Rainbow Smelt population projection model. This model illustrates the common-sense biological implications of recruitment failures in the mid-1990s, showing that five consecutive years of recruitment failure (*i.e.*, failure of year classes to contribute to spawning) would cause the catastrophic collapse of the population actually seen in the Hudson River.[12] In other words, if the Hudson River Rainbow Smelt were to have experienced recruitment failure from 1991 through 1995, the model predicts a complete population collapse as occurred in 1996.[13] The similarity between the modeled collapse following five years of recruitment failure and the actual

[10] *See* Daniels *et al.* (2005) at 481; *see also* Draft Supplement, Appendix A at A-38 (*citing* Daniels *et al.*). Full citations to Daniels *et al.* (2005) and other technical papers cited herein are provided in the List of References provided at the end of this attachment.

[11] As a related matter, investigation of the sudden Rainbow Smelt collapse also is important to avoid an anomalous "high" SOC finding. As noted above, because Indian Point Units 2 and 3 commenced commercial operation in 1973 and 1975, respectively, it is reasonable to expect that Indian Point's operations, if they had the ability to significantly impact the abundance of Hudson River Rainbow Smelt (as a "high" SOC finding communicates), would affect the population over the first two decades of its operation. The data, however, show there was no downward trend in Rainbow Smelt abundance during the first 22 years of Indian Point's operation, *i.e.*, before the smelt suddenly disappeared from the Hudson River. Specifically, the LRS data presented in Appendix 2A confirm that Indian Point operations did not cause a downward or declining trend in Rainbow Smelt abundance in the Hudson River from 1974 through 1995. The absence of a trend in the Rainbow Smelt population for the first 22 years of Indian Point operations warrants consideration of whether the sudden disappearance of Rainbow Smelt from the River beginning in 1996 is reasonably related to Indian Point operations.

[12] *See* Appendix 2A at 2-6. Moreover, from a population dynamics perspective, for any species in which: (1) age 0 organisms do not reproduce; and (2) no organisms live past age 5, five successive complete year class failures are sufficient to cause a population collapse. The AKRF Smelt population model is therefore consistent with theory, and in addition predicts the numbers of age 0 fish produced each year prior to its collapse; these values can be compared to observed data from the HRBMP.

[13] The model assumes, as is the case, that no major operational changes occurred during this time period.

collapse of the Hudson River Rainbow Smelt population is evident in a comparison of Figures 1 and 5 in Appendix 2A.

To understand the specific nature and magnitude of the events precipitating the collapse of the Rainbow Smelt population, the Biological Team considered the conditions or events that could result in this sort of catastrophic collapse. Specific consideration was given to a spore-forming, intracellular parasite, the microsporidian *Glugea hertwigi* (hereinafter "*Glugea*"), that is known to particularly infect Rainbow Smelt.[14] In general, microsporidians induce hypertrophy (*i.e.*, enlargement) of infected host cells, causing the formation of grossly visible cysts called "xenomas" in multiple tissues, including muscles, skin, the digestive tract, nerves, and gonads.[15] Rainbow Smelt are infected with *Glugea* either by direct ingestion of spores suspended in ambient water or by ingestion of filter-feeding zooplankton prey in which spores have been concentrated.[16] Upon infection, *Glugea* localizes primarily in the Rainbow Smelt digestive tract, and secondarily in the ovaries of females, producing characteristic xenomas in both locations.[17] *Glugea* is a progressive infestation *i.e.*, once infected, the severity of infection increases as fish age and results in decreased fecundity and in mortality of infected individuals.[18] As a result, larger, older fish are more likely to experience infection levels that compromise reproductive success and accelerate morbidity and mortality.[19]

Indeed, beginning in the 1970s, widespread infection within various northeastern populations was determined to be responsible for sudden Rainbow Smelt die-offs.[20] Specifically within New York State, massive die offs of YOY Rainbow Smelt in eastern Lake Erie in the fall of 1969, and of adult Rainbow Smelt in May 1971, were attributed to rates of *Glugea* infection ranging from 74% to 90%.[21] Further, such die-offs have been reported in a variety of environments, including estuarine environments comparable to the Hudson River.[22] Indeed, the current peer-reviewed, published scientific literature indicates that *Glugea* infection rates as low as 23% can result in Rainbow Smelt population declines, with higher infection rates causing large, often sudden die-offs or population collapses.[23]

In view of the best available scientific evidence described above and consistent with the framework reflected in the Rainbow Smelt population projection model, the Biological Team assessed the presence of *Glugea* in Hudson River Rainbow Smelt prior to that population's

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14 *See, e.g.,* Haley (1957); Sindermann (1970); Nepszy and Dechtiar (1972); Scarborough and Weidner (1979); Buckley and Moran (1989).

15 *See, e.g.,* Sindermann (1970); Scarborough and Weidner (1979).

16 *See* Scarborough and Weidner (1979).

17 *See, e.g.,* Scarborough and Weidner (1979);); Sindeman (1970).

18 *Id.*; *see also* Noga (2010).

19 *Id.*

20 *See, e.g.,* Haley (1957); Chen and Power (1972); Nepszy and Dechtiar (1972); Nepszy and Dechtiar (1978); Nepszy *et al.* (1978).

21 *See, e.g.,* Nepszy and Dechtiar (1972); Nepszy and Dechtiar (1978); Nepszy *et al.* (1978).

22 *See, e.g.,* Haley (1957).

23 *Id.*

collapse, utilizing its unique cache of preserved, archived HRBMP (LRS) samples containing Rainbow Smelt for the five years preceding the 1996 collapse, *i.e.*, the years 1991 through 1995. Appendix 2B to these comments reports the results of that investigation. Because of the progressive nature of the infestation, in three years—1992, 1994 and 1995—the Biological Team focused on the oldest and largest Rainbow Smelt YOY present in those samples, and examined a total of 232 YOY for grossly visible signs of *Glugea* infection, *i.e.*, xenomas.[24] In 1991 and 1993, as discussed further below, the Biological Team examined a wider range of life stages for *Glugea* infection, which included 299 YOY. In all, the Biological Team examined a total of 531 YOY from the five years preceding the Rainbow Smelt collapse, of which a total of 482, or 91%, were found to contain *Glugea* xenomas.[25] This overall infection rate corresponds to the highest infection rates observed during large Rainbow Smelt die-offs in the published, peer-reviewed literature (discussed above).

To better understand the progressive nature of the infestation within a year class, for two of the years reviewed, *i.e.*, 1991 and 1993, the Biological Team undertook a systematic examination of weekly ichthyoplankton samples. Specifically, the Biological Team retrieved additional archived LRS ichthyoplankton samples containing the full range of life stages from post yolk sac larvae ("PYSL," the first feeding life stage) through older fish, organized the samples by when they were collected during the season (*i.e.*, by weekly "River Run"), and randomly selected a subset of samples within each River Run for the presence of *Glugea*. In 1991 and 1993, 8.6% (231/2,685), and 4.2% (550/13,044), respectively, of the PYSL, YOY, yearling and older fish were randomly selected and examined for the presence of *Glugea*.[26]

In both 1991 and 1993, a clear trend of increasing infestation over time (*i.e.*, over the course of the annual River Runs) and with increasing fish length was demonstrated.[27] As shown in Table 6 and Figure 5 of Appendix 2B, in 1991, fish from River Runs 4 through 8 (May) were predominantly free from infestation until River Run 9 (early June), at which time a transition appears to have taken place, with approximately 60% of fish found to be infested. Subsequently, in River Runs 10 through 19 (from mid-June on), almost all Rainbow Smelt were infested with *Glugea*.[28] The transition in mid-June from absence to presence of *Glugea* occurred within the 26-35 mm length classes[29] which corresponds with the transition from the PYSL life stage to YOY in Hudson River Rainbow Smelt. A similar pattern of infestation was

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[24] As mixed parasitism is common in Rainbow Smelt (*see, e.g.,* Sirois and Dodson (2000)), 12 fish not included among the 256 examined for *Glugea* infestation were examined histopathologically for additional parasites. Of these 12 fish, three were found to be infested with an acanthocephalan (spiny headed worm) parasite (likely *Echinorhynchus salmonis*, *Acanthocephalus dirus*, or one of various *Corynosoma* spp.), one was found to have an ocular trematode (fluke) parasite, and another a cestode (tape worm). These additional parasites are not linked to catastrophic Smelt die-offs, but could have contributed to morbidity and mortality of Rainbow Smelt, *e.g.,* acted synergistically where co-occurring with *Glugea*. *See*, *e.g.,* Buckley and Moran (1989).

[25] *See* Appendix 2B, Table 12.

[26] *See id.* at 11.

[27] *See id.*; *see also* Tables 6 and 7 and Figures 5 and 6 (1991) and Tables 10 and 11 and Figures 8 and 9 (1993).

[28] *See id.*, Table 6 and Figure5.

[29] *See id.*, Table 7 and Figure 6.

seen in 1993, in which a period of low infestation rate (River Runs 6-10) was followed by a transitional period with intermediate levels of infection (River Runs 10-12), after which almost all Rainbow Smelt were found to be infected.[30] As in 1991, the transition from low to high *Glugea* infection levels in mid-to-late-June corresponded with the transition from the PYSL to YOY life stage.[31]

In summary, a review of Rainbow Smelt specimens collected from 1991 through 1995 establishes *Glugea* infestation levels above those that the peer-reviewed, published literature indicates would cause massive die-offs for five consecutive years. Those conditions, consistent with the population projection model, could precipitate collapse of the Hudson River Rainbow Smelt population, as occurred, by 1996. Further, it is clear that infestation rates progressed from typically low infection rates in PYSL to high, nearly universal, infection in YOY, thus compromising each year class and by 1996, the Hudson River Rainbow Smelt population.

B. <u>NRC Staff's Calculation of the Entrainment Mortality Rate for Rainbow Smelt Is Biased Because It Relies on a Single Year of Egg Entrainment Data and Incorrectly Assumes that Egg Entrainment Levels Were the Same Every Year</u>

The SOC calculation presented in the Draft Supplement, and in particular the Entrainment Mortality Rate ("EMR") for Rainbow Smelt used in the SOC calculation, also contains an error that compounds the anomalous "LARGE" finding discussed above. Using the six years of entrainment data gathered in the years 1981 and 1983-1987, the NRC Staff calculated the Indian Point EMR for Rainbow Smelt as the 75th percentile annual number of eggs entrained, divided by the 75th percentile of the sum of annual number of eggs entrained, plus the annual standing crop of eggs, larvae, and juveniles in River Region 4.[32] As we understand the NRC Staff's analysis in Appendix A of the Draft Supplement, in calculating the EMR for Rainbow Smelt, the NRC Staff *assumed* that the number of eggs entrained at Indian Point in Season 1 for 1986 (as documented in entrainment sampling that occurred during January-March of that year) *was the same* as the number of Rainbow Smelt eggs entrained in Season 1 in the years 1981, 1983, 1984, 1985 and 1987 (years in which entrainment sampling did not begin until May, after the period in which eggs would be expected to appear in entrainment samples).[33]

The NRC Staff's reliance on the single year of 1986 entrainment data to represent all six years of Season 1 egg entrainment at Indian Point cannot be reconciled with the well-documented, inter-annual variability in entrainment at Indian Point.[34] In fact, in Appendix A to the Draft Supplement, the NRC Staff acknowledges that the Hudson River datasets for Region 4 show "large variability in the density measure of abundance between years (coefficients of variation (CVs) ranging from 54 to 298 percent)," which correlates with large variability in

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30 *See id.*, Table 9 and Figure 8.

31 *See id.* at 11.

32 *See* Draft Supplement, Appendix A at A-14.

33 *See id.*

34 *See, e.g.*, Draft Supplement, Appendix A at Table A-7 at A-15 (summary of estimated annual number of each species entrained 1981 and 1983-1987).

entrainment.[35] The contrary-to-fact assumption cannot be readily reconciled with the best available evidence. At the very least, it requires confirmation that the selected year is reasonably representative before it reasonably could be replicated across six separate years.

In fact, a review of well-known Rainbow Smelt life history traits demonstrates that 1986 is neither representative nor appropriate to use in the calculation of EMR. The peer-reviewed, published scientific literature, including literature contemporaneous to the Smelt collapse, establishes that coastal populations of Rainbow Smelt are anadromous, with adults migrating upriver beyond estuarine waters to spawn in shallow (less than 1 m deep) riffles typical of freshwater tributaries.[36] As is also clear from the literature, fertilized Rainbow Smelt eggs are demersal and adhesive, such that once they are released, "they sink to the bottom, where they stick in clusters to pebbles, to each other, or to any stick, root, grass, or water weed they chance to touch."[37] Because Rainbow Smelt spawn well upriver of Indian Point in shallow freshwater riffles, and their eggs are demersal and adhesive, those eggs would not be expected to be seen in the pelagic Hudson River in the vicinity of Indian Point in a manner that would make them susceptible to entrainment.[38] This conclusion is reinforced by data collected in the HRBMP. First, as one would expect based on these life history characteristics, LRS sampling has never—not once in 40 years—collected Rainbow Smelt eggs in the vicinity of Indian Point (*i.e.*, Region 4).[39] Second, an extraordinarily high flow event occurred in early-to-mid-March in 1986 (during which flow exceeded 100,000 cubic feet per second ("cfs") on both March 16 and March 20) which would be viewed as an anomalous year not suitable for replication across years, even if Rainbow Smelt eggs were washed out of their spawning beds and were viable.[40] Based on this life history and the HRBMP and 1986 flow information, NRC Staff's use of a single year of data from 1986 does not accurately represent Rainbow Smelt's susceptibility to

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35 Because only organisms in the vicinity of Indian Point are at risk to entrainment, inter-annual variability in the number of organisms found in River Segment 4 provides an indication of the likely magnitude of inter-annual variability in numbers entrained.

36 *See e.g.*, Collette and Klein-MacPhee (2002); Buckley and Moran (1989); Daniels *et al.* (2005); Smith (1985); *see also* Rainbow Smelt entry on NYSDEC website "Common Prey Fish" at http://www.dec.ny.gov/animals/7031.html (hereinafter "NYSDEC Rainbow Smelt Website").

37 *See* Collette and Klein-MacPhee (2002); *see also* Buckley and Moran (1989); Cooper (1978); Able and Fahay (1998); Able and Fahay (2010); NYSDEC Rainbow Smelt Website.

38 *Id.*; *see also* Daniels *et al.* (2005).

39 From 1974-1994, when Rainbow Smelt were present in the Hudson River, Rainbow Smelt eggs have been collected in only 16 LRS samples. All except one of these samples occurred at or north of River Mile 93, or at least 50 miles north of Indian Point (at River Mile 43), and much later in the season (between April 14 and May 13). Further, the overwhelming majority of these samples were taken with an epibenthic sled – from the bottom. In other words, based on this spatial and temporal occurrence, there are very few if any pelagic smelt eggs within the Indian Point Region for Indian Point to entrain.

40 *See* http://help.waterdata.usgs.gov/ for Hudson River daily flow data. In the plot of maximum calendar day flows over the period 1946-2005 in Figure 3 of Appendix 2C, the values for March 15-21 are all from 1986. Historically, the >100,000 cfs values are in the 99th percentile of maximum daily flows for the month of March.

entrainment, and there is no reasonable justification for NRC Staff's use of the anomalous 1986 egg entrainment density as a basis for its calculation of EMR for this species.[41]

Once it is clear that 1986 is not representative, it is necessary to evaluate whether NRC Staff's use of 1986 data alone improperly biased its estimate of EMR. Conceptually, NRC Staff's EMR is the ratio of the sum of the number of eggs, larvae and juveniles entrained to the sum of numbers entrained, plus the standing crop of eggs, larvae and juveniles in Region 4.[42] Therefore, the assumed number of eggs entrained included in the calculation substantially impacts the EMR estimate. As a result, the NRC Staff's use of a single, likely non-representative year of data for its egg entrainment estimates may have introduced significant bias in its EMR estimate of 0.258 for Rainbow Smelt.[43]

To determine whether the NRC Staff's use of only 1986 egg entrainment data biased its estimate of the EMR, the Biological Team conducted an alternative analysis using separate, year-specific estimates of Rainbow Smelt egg entrainment for each of the years 1981, 1983-1985, and 1987.[44] As set forth in Appendix 2D to these comments, this analysis demonstrates that reliance on 1986 data alone creates a material bias.

The annual estimates of minimum River-wide egg abundance, as reflected in Appendix 2D, establish that 1986 was not a representative year. The estimated minimum River-wide egg

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41 We also note that, prior to installation of the Ristroph screens and fish return systems (in 1990), Indian Point periodically impinged gravid Rainbow Smelt as they migrated upriver to spawn. It may be that gravid females released a percentage of those unfertilized, unspawned eggs during those historic impingement events, and that some of these eggs were collected during entrainment sampling in 1986, although there is no clear evidence for that proposition. What is clear is: that, since 1990, Indian Point has maintained state-of-the-art Ristroph screen systems that both rapidly remove impinged fish from the screens and also return them to the water body with minimal damage; that, since 1996, Rainbow Smelt have not been present in the Hudson River; and that using a single year of entrainment data from a period (1986) prior to installation of state-of-the-art impingement-protection systems to predict future entrainment of a locally nonexistent species lacks scientific grounding. Entergy therefore reiterates its position that future Indian Point operations, as properly considered in the Draft Supplement, can have no impact on that species. *See, e.g., Native Ecosystems Council v. Tidwell,* 599 F.3d 926 (2010) (9th Cir. 2014) (agency's use of locally nonexistent species as a Management Indicator Species to assess project's impact did not constitute requisite "hard look" mandated by NEPA).

42 *See* Draft Supplement, Appendix A at A-16 (Table A-8), A-30 (Table A-15).

43 *See* Draft Supplement, Appendix A, Tables A-8, A-15.

44 First, a minimum estimate of annual egg abundance is the maximum number of larvae (*i.e.*, the next life stage) observed in any single week that year. This is based on the simple fact that each larva originated from one egg and thus the minimum number of eggs cannot be less than the maximum number of larvae, assuming equal susceptibility to sampling, as is the case here. Second, annual numbers of Rainbow Smelt larvae and juveniles entrained are accurately predicted by the annual estimates of minimum River-wide egg abundance. Figures 2 and 3 of Appendix 2D demonstrate the high degree of correlation (R^2 value greater than 0.9) between minimum River-wide egg abundance and estimated larval and estimated juvenile entrainment. Thus, one can reasonably estimate the annual egg entrainment at Indian Point in 1981, 1983-1985, and 1987 based on: (a) the annual estimates of minimum River-wide egg abundance in those years; and (b) the ratio of numbers of eggs entrained in 1986 to the estimate of minimum River-wide egg abundance in 1986.

abundance in 1986 was 275 million, whereas the average of estimates over all other years (1981, 1983-1985 and 1987) was only 14 million, with no single year above 37 million.[45] Thus, Rainbow Smelt egg abundance in the one year relied upon by NRC Staff in its EMR calculation is almost twenty times greater than the average of the other five years, and over seven times greater than the highest of those other six years.

Figure 4 of Appendix 2D shows the predicted values of egg entrainment in these years (on a log10 scale) based on application of the ratio of egg entrainment to minimum River-wide egg abundance in 1986 to the estimate of minimum River-wide egg abundance in each year. The estimated total number of eggs, larvae and juveniles entrained is presented numerically beneath each year. In Figure 4, the differences between the 1986 egg entrainment data (solid red bar) used by the NRC Staff and the year-specific predictions of egg entrainment (diagonal red-hashed bars) are readily apparent. These differences confirm that using the 1986 egg entrainment data for all six years is not a valid approach.

The Biological Team recalculated NRC Staff's EMRs, using the year-specific estimates of egg entrainment rather than the single year of 1986 data.[46] Table 1 of Appendix 2D shows the NRC Staff's calculation of the EMR, both based on 1986 egg entrainment data for all years, and as recalculated using the year-specific estimates of entrainment based on demonstrated correlations. The EMR calculated using year-specific estimates of egg entrainment (0.084) is a fraction of that reported in the Draft Supplement (0.258) using the incorrect assumption of constant egg entrainment across years. Thus, analysis of the best available data demonstrates that Rainbow Smelt EMR used in the Draft Supplement's SOC analysis is materially biased and overestimates presumed Indian Point entrainment mortality by a factor of almost three.

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In summary, the best available (scientific) information demonstrates that the Hudson River population of Rainbow Smelt did not "decline," but rather experienced a catastrophic collapse following several years of recruitment failure for reasons wholly unrelated to Indian Point consistent with documented rates of infestation by the parasitic microsporidian, *Glugea*. Moreover, NRC Staff's use of a single, non-representative year of egg entrainment data materially biased its EMR estimate, contributing to an incorrect SOC conclusion for Rainbow Smelt.[47] As a result, the Draft Supplement's intermediate, species-specific finding of "LARGE" impact to the Rainbow Smelt is inconsistent with the best available (scientific) information, which instead clearly supports a finding of "SMALL" impact. Therefore, consistent with NEPA's "best available" information and "hard look" requirements, the Staff should revise Section 4.0 to reflect the data and analyses discussed above, and an intermediate, species-specific finding of "SMALL" impact for Rainbow Smelt.

III. The Best Available Scientific Data Support an Intermediate, Species-Specific Finding of "SMALL" Impact to the Blueback Herring

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[45] *See* Appendix 2D.

[46] Calculated as described in footnote 44 *supra*.

[47] Additional issues with the SOC for Rainbow Smelt are addressed in Section IV of these comments.

Table 4-2 of Draft Supplement also assigns a "LARGE" impact to Blueback Herring, based on the NRC Staff's weight of evidence findings that: (1) the population exhibited a declining trend;[48] and (2) the SOC between Indian Point operations and the declining population is "high."[49] Specifically, the NRC Staff calculated an EMR for Blueback Herring of 0.095, and an impingement mortality rate ("IMR") of 0.004,[50] and used these values in its Monte Carlo analysis to reach a conclusion that the SOC for Blueback Herring was "high."[51]

As detailed below, the 9.5% EMR for Blueback Herring used in the Draft Supplement is so much higher than any previous estimates of entrainment mortality rates for River Herring (Alewife and Blueback Herring) at Indian Point that it cannot be considered reasonable. In the 1999 Draft Environmental Impact Statement ("DEIS") evaluating potential environmental impacts of several Hudson River power plants, for example, annual estimates of River-wide entrainment mortality at Indian Point that are conceptually comparable to NRC Staff's EMR, known as the conditional mortality rate or "CMR,"[52] over the years 1979-1997 ranged from 0.12% (1995) to 5.34% (1984).[53] As shown in Figure 1 of Appendix 2C, the River-wide CMR estimates in the 1999 DEIS are strongly correlated (R^2=0.91) to the fraction of the larval population that occurred within Region 4, where Indian Point is located. Based on the DEIS CMR values, between 1979 and 1997, entrainment mortality was less than 1% in 14 of 19 years, and exceeded 3% in only two years—1983 (3.05%) and 1984 (5.34%).[54] The average CMR value over the 19-year period is 1.11%, or less than 1/8 the 9.5% EMR assumed by the NRC Staff. This evidence suggests that an EMR value of 9.5% overestimates the potential impact of Indian Point operations on Blueback Herring, and at very least should have prompted closer examination of the underlying data.

The Biological Team undertook that examination and determined that NRC Staff's selected EMR value is not representative, and in fact overstates the potential impact of Indian Point entrainment in a manner that is anomalous and inconsistent with NEPA. Specifically, to evaluate whether the 9.5% EMR value is representative of Indian Point entrainment impacts in a typical year, the Biological Team analyzed the patterns of the spatial and temporal distribution of early life stage Blueback Herring collected in the LRS from 1979 through 2005, using the data sets provided to NRC in 2007, and including annual Hudson River flow data and contemporaneous CMR estimates.[55] Figure 9 (top) of Appendix 2C shows the estimate of entrainment CMR for each year from 1974 through 1997 plotted against the maximum daily

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48 Draft Supplement, Appendix A at A-29 (Table A-14).

49 *See id.* at A-32 (Table A-17).

50 Draft Supplement, Appendix A, Table A-15.

51 Draft Supplement, Appendix A, Table A-17.

52 On page A-12 of the Draft Supplement, NRC Staff states "EMR [entrainment mortality rate] and IMR [impingement mortality rate] are conditional mortality rates (CMRs) for entrainment and impingement."

53 *See* Draft Environmental Impact Statement for State Pollutant Discharge Elimination System Permits for Bowline Point, Indian Point 2& 3, and Roseton Steam Electric Generating Stations, prepared by Central Hudson Gas & Electric Corp., Consolidated Edison Company of New York, Inc., New York Power Authority, and Southern Energy New York, December 1999 at Appendix 2D, Table 1.

54 *See* Appendix 2C, Table 1.

55 *See* Appendix 2C.

Hudson River Flow (in cfs) between May 1 and June 15 for the same span of years. As Figure 9 (top) shows, in 15 of the 24 years, the CMR value is below 1%. Indeed, the CMR estimate exceeds 3% in only two out of 24 years (1983 and 1984), and, in a third year (1990), the CMR approaches 3%. In all three of the years, the measured maximum daily flow exceeded 75,000 cfs, which corresponds to the 90th percentile of maximum flow measurements taken during this time period.[56] Thus, although high-flow events did not guarantee a high CMR estimate (as evidenced by the year 1996, in which a maximum flow of almost 90,000 cfs corresponded to a CMR of roughly 0.5%),[57] CMR values of roughly 3% or higher occurred *only* in infrequent years that had an unusually high flow events in the May 1 to June 15 timeframe.

What this means is that the 9.5% EMR value used by the NRC Staff is not reasonably considered representative of Indian Point's potential entrainment mortality, because CMRs at or above 3% are correlated to atypical high-flow events. The non-representative nature of the 9.5% EMR is exacerbated by the fact that it is substantially higher, even, than the previously reported atypical years with major storm events.

The Biological Team's analysis of Blueback Herring spatial and temporal distribution in the Hudson River illustrates clearly the mechanism by which unusually high flow events in the May 1 to June 15 timeframe can result in higher than normal CMR levels. Specifically, Appendix 2C shows that, under typical, moderate-to-low flow regimes in May and June, as seen in the years 1981, 1985 and 1992 , the entrainable life stages of this species are found substantially upstream of Indian Point (*i.e.*, Region 7 and above) and thus are not appreciably vulnerable to entrainment.[58] In contrast, in years in which a high-flow event occurred during the Blueback Herring spawning season, such as 1983, 1984 and 1990, eggs were distributed further downstream than is typical.[59] Thus, in years when high-flow events occur, larvae are transported downstream out of their typical habitat, at which point the larvae may be subject to entrainment at Indian Point, as demonstrated by atypical CMR estimates of 3% to 5%. However, the larval cohorts that are transported downstream and become vulnerable to entrainment at Indian Point have extremely high natural mortality rates, and are highly unlikely to make any contribution to the resulting year class.[60] As a result, the atypical high entrainment mortality rate estimates in high-flow years likely have no actual effect on the Blueback Herring population, and therefore cannot reasonably be considered representative of potential Indian Point impacts.

The loss of early life stages due to extreme weather-related events is well documented in species beyond Blueback Herring and in locations beyond the Hudson River estuary. Generally speaking, early life stages of fishes are susceptible to being moved beyond the environmental conditions (*e.g.*, salinity, substrate, temperature, etc.) in which they can or will thrive, with high rates of mortality attendant to such movements beyond suitable conditions.[61]

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56 *See* Appendix 2C, Figure 9 (bottom).

57 The peak flow event in 1996 occurred just prior to River Herring spawning with the result that the high flow event did not affect that year's entrainment.

58 *See* Appendix 2C, Figures 3, 4, and 5.

59 *See id.*, Figures 6, 7, and 8.

60 *See, e.g.*, Hassler (1970), Lasker (1981), Leggett *et al.* (1984), Govoni (2005).

61 *Id.*

Very similar phenomena were observed in the Hudson for American Shad during the 1984 spawning season. Larvae present at the end of May when the flow event occurred were moved far downstream from their typical locations, and did not contribute to the juveniles observed later in the summer. This variation in within-year survival has also been observed in the Potomac River for Striped Bass, in the Connecticut River for American Shad, and in the Sandusky River for Walleye.[62]

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In summary, a rigorous analysis of the extensive HRBMP data (made available to NRC Staff) indicates that, in most years, entrainable life stages of Blueback Herring (*i.e.,* eggs and larvae) in the Hudson River are found well upstream of Region 4 and are not usually susceptible to entrainment at Indian Point. Only in unusual years with exceptionally high springtime River flow is it possible for entrainable life stages to be present in the Indian Point Region in sufficient numbers to result in a CMR of even 3% to 5%. However, in those atypical years, any larvae transported far enough downstream to be vulnerable to entrainment at Indian Point are highly unlikely to survive due to their large-scale, downstream movement out of preferred habitat and the adverse environmental conditions corresponding to major storm events. As a result, the best available (scientific) information consistent with NEPA indicates that NRC Staff's "LARGE" intermediate finding for Blueback Herring is incorrect, and that the correct intermediate finding for Blueback Herring is a "SMALL" potential impact.

IV. The NRC Staff's SOC Method Results in False-Positive "High" Conclusions for Rainbow Smelt, Blueback Herring, and Hogchoker

In connection with its assessment of NRC Staff's findings with respect to Blueback Herring, the Biological Team also evaluated the simulation used by NRC Staff to establish its SOC. The Biological Team did so, by attempting to replicate NRC Staff's analysis, using the methods described on pages A-11 through A-19 of Appendix A to the Draft Supplement, and particularly using equations (1) and (2) on page A-11.[63]

The first step was to replicate the NRC Staff's SOC conclusions in Table A-16. Using equations (1) and (2) and the input data in Table A-15, the Biological Team initially was not able to approximate the NRC Staff's results in Table A-16. However, since the simulated annual population sizes for many of the cases were negative (which is not possible), the Biological Team set the negative values to zero (0) and re-ran the simulation. By resetting negative population sizes to zero (0), the Biological Team was able to produce results that match Table A-16.[64] Since both the NRC Staff's results and the Biological Team's results are based on a Monte Carlo simulation, the medians, Q1, and Q3 values would not be expected to match exactly, and they do not; however, the SOC conclusions do match exactly, as shown in Table 1 of Appendix 2E.

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62 *See* Polgar *et al.* (1976), Crecco and Savoy (1987), Mion *et al.* (1998).

63 *See* Appendix 2E.

64 *See id.*

The second step was to evaluate the risk of type-1 error (*i.e.*, the probability of finding a "high" SOC when it is in fact "low") in the NRC Staff's SOC methodology. (An appropriate methodology to assess SOC would have low type-1 error rates, *i.e.*, it would have a low probability of reaching a conclusion of "high" SOC when it is actually "low.") To do this, the Biological team repeated the simulation, after setting both the EMR and the impingement mortality rate ("IMR") to zero (0). This analysis, which reflects a theoretical condition of no entrainment or impingement mortality, should result in "low" SOC for all species.

However, as shown in Table 2 of Appendix 2E, three species (Blueback Herring, Rainbow Smelt, and Hogchoker) still were classified as having "high" SOC upon running this simulation with zero assumed entrainment or impingement mortality. This equates to a probability of false positive (*i.e.*, "high") conclusion of 0.231, or almost one-in-four, which is more than four times greater than the widely-used value of 0.05 in statistical analyses. The false positive results for Blueback Herring, Rainbow Smelt, and Hogchoker demonstrate that the methodology is not reliable for these species.

* * *

In summary, NRC Staff's methodology resulted in "high" SOC findings for Blueback Herring, Rainbow Smelt, and Hogchoker, even when impingement and entrainment mortality rates were set to zero. Consequently, the NRC Staff's results for these species are not reliable – yet another reason that these findings should be changed as suggested in these comments.

V. NRC Staff's "Unresolved" Species

NRC Staff categorized the intermediate, species-specific findings for several species, including Atlantic Menhaden and Gizzard Shad, as "Unresolved."[65] NRC Staff assigned this intermediate finding when insufficient data were available for a particular species.[66] Apparent and actual data availability issues for Gizzard Shad and Atlantic Menhaden are summarized below.

For Gizzard Shad, all data, including entrainment density data from the years 1981 and 1983-1987, have been provided to the NRC. However, because the entrainment density files included only non-zero densities, and no Gizzard Shad were collected during entrainment sampling, Gizzard Shad were not listed in the entrainment files.[67] Those data files indicated that no Gizzard Shad were recorded in entrainment sampling (*i.e.*, the estimated number entrained is zero) – this is not surprising as Gizzard Shad spawn in the vicinity of Albany, far upriver from Indian Point.[68] As such, there should be no reason that Gizzard Shad cannot be assigned an

65 *See e.g.*, Draft Supplement, Appendix A at A-33 (Table A-18).

66 *See* Draft Supplement at 36 ("the NRC staff also included a category, 'Unresolved' for those species for which a Population Trend line of evidence (LOE) could not be established and too little data were available to model the SOC.").

67 In the Draft GEIS (December 2008), NRC appeared to recognize that there was no entrainment of gizzard shad when it stated on page 4-13: "The NRC staff found that a total of 66 taxa were identified during entrainment monitoring in data supplied by Entergy (2007b). There were no blue crabs, shortnose or Atlantic sturgeon, or gizzard shad identified in the 1981–1987 entrainment data."

68 *See* Daniels (2005).

impact level. To assist the NRC Staff, the Biological Team has analyzed the data for Gizzard Shad, and determined that the impact is "SMALL." Those analyses are documented in Appendix 2F to these comments.

For Atlantic Menhaden, the NRC's 2007 request for in-river data was for "Year Class Report Table E Series Density Data," which did not include data on this species.[69] Accordingly, in-river density data for Atlantic Menhaden were not provided with the initial response to the NRC's data request and were inadvertently omitted in response to NRC Staff's 2014 data request. Calculation of population trend and SOC LOE values is possible with the addition of the omitted in-river data that is now provided in Appendix 2G to these comments. Again, to assist the NRC Staff, two members of the Biological Team independently have analyzed the data for Atlantic Menhaden, and determined that the impact is "SMALL."[70]

Finally, Entergy submits that it is important to consider the NRC Staff's potential intermediate, species-specific impact determinations, and, indeed, for all the species addressed in the Draft Supplement, from the broader perspective of a complex, managed ecosystem over time, where the interaction of managerial decisions, and the introduction of species, *e.g.*, zebra mussels or Gizzard Shad, have effects on various species that should not be imputed to Indian Point without clear causal evidence.[71] No such evidence exists.

In the final analysis, the manifest health of the Hudson River aquatic community cannot be reconciled with the hypothesis that Indian Point operations have been adversely affecting the Hudson River ecosystem. If this were the case, then a decline in the overall number of organisms (particularly fish) in the River should be apparent after 4 decades of continuous riverwide monitoring. To the contrary, examination of HRBMP LRS data for the period 1974 through 2011 shows that the average annual abundance (expressed as the sum of weekly standing crop[72]) for all taxa identified in the LRS has not declined over time. Specifically, for the first 22 years of Indian Point operations, from 1974-1995, the annual sum of weekly standing crops of larvae collected in the LRS was approximately 20.1 billion fish. During the 17-year period from 1996 through 2011, the sum of weekly standing crops was approximately 22.2 billion fish, an increase of 10% over the earlier period. The absence of a decline (and indeed the increase) in the overall abundance of aquatic organisms in the Hudson River between these two periods suggests that Indian Point operations are not having an adverse impact on the Hudson River's ability to support larval fish (*i.e.*, the life stage most susceptible to potential

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69 *See* December 5, 2007 NRC Request for Additional Information Regarding Environmental Review for Indian Point Nuclear Generating Unit Nos. 2 and 3 License Renewal (TAC NOS. MD5411 AND MD5412), Environmental RAI 2.

70 *See* Appendix 2F. The analysis presented was performed by AKRF. Its results were independently verified by ASA Analysis and Communications.

71 *See, e.g., Dep't of Transportation v. Public Citizen*, 541 U.S. 752, 767 (2004) (noting that "NEPA requires a reasonably close causal relationship between the environmental effect and the alleged cause," and analogizing the determination of whether an environmental effect is caused by an agency action to the doctrine of "proximate cause" in tort law).

72 Sum of weekly standing crops is the abundance metric used in the NRC Staff's SOC methodology. *See* Draft Supplement, Appendix A at A-13 to A-14 (Table A-5).

entrainment at Indian Point). Thus, and consistent with the evidence above, any "LARGE" findings should be considered suspect.

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ATTACHMENT 3 TO NL-16-021

COMMENTS ON SECTIONS 5.1, 5.13, AND 5.14.1 OF THE DRAFT SUPPLEMENT

(AIR QUALITY IMPACTS; GREENHOUSE GAS EMISSIONS AND CLIMATE CHANGE;

CUMULATIVE IMPACTS)

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 & 3
DOCKET NOS. 50-247 AND 50-286

Entergy Comments on Sections 5.1 and 5.13, and 5.14.1 of the Draft Supplement (Air Quality Impacts; Greenhouse Gas Emissions & Climate Change; Cumulative Impacts)

I. Introduction

These comments address the Nuclear Regulatory Commission ("NRC") Staff's consideration of the air-quality and climate-change impacts associated with the proposed action to issue renewed operating licenses to Entergy Nuclear Operations, Inc. ("Entergy") for Indian Point Units 2 and 3 ("IP2" and "IP3"). The relevant NRC Staff discussion of these issues is contained in Sections 5.1. 5.13, and 5.14.1 of the Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 38, Volume 5, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3 ("Draft Supplement"). In the Draft Supplement, the NRC Staff found that the incremental impacts of IP2's and IP3's continued operation on air quality during the proposed 20-year license renewal term (*i.e.*, the period of extended operation), would be "SMALL," and that the cumulative impacts would range from "SMALL to MODERATE," depending on the extent to which future climate change influences other air quality issues that benefit from Indian Point's continued operations.[1] It also found that the incremental impacts of IP2's and IP3's continued operation on climate change during the period of extended operation "would be SMALL," and that the cumulative impacts "would be MODERATE."[2]

The NRC Staff's findings should be viewed in the context of the potential impacts to air quality and climate change should the operating licenses not be renewed. In its December 2010 final supplemental environmental impact statement for IP2 and IP3 license renewal ("FSEIS"), the NRC Staff acknowledged that "[p]lant shutdown will result in a net loss of power generating capacity," which "would likely be replaced by (1) power supplied by other producers (either existing or new units) using generating technologies that may differ from that employed at IP2 and IP3, (2) demand-side management and energy conservation, or (3) some combination of these options."[3] The FSEIS therefore considered potential air-quality impacts from a new gas-fired combined cycle generating facility located either at the Indian Point site or at a different site, perhaps as part of an existing-facility repowering.[4] The NRC Staff found that the air-quality impacts of a new or repowered unit would range from "SMALL to MODERATE," conclusions that Table 9-1 ("Summary of Environmental Significance of License Renewal and Alternatives" Draft Supplement repeats without further comment.[5]

The finding that a new or repowered unit would result in "SMALL to MODERATE" impacts must be reconciled with the portion of Table 9-1 that addresses air-quality impacts of the "no action" alternative—the denial of operating licenses without a new or repowered unit coming online to replace IP2 and IP3's generation.[6]In such a situation, existing electric

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1 Draft Supplement at 46, 97-98.

2 *Id.* at 112.

3 NUREG-1437, Supplement 38, Vols. 1-3, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3, Final Report," at 8-22 (Dec. 2010) ("FSEIS").

4 *See id.* at 8-26 to 8-29, 8-32 to 8-34, 8-59 to 8-60, 8-68.

5 *See id.*; Draft Supplement at 131-32, Table 9-1.

6 *See id.*

generation units—which consist largely of relatively older fossil-fuel units, including some coal units—will necessarily increase their generation to replace IP2 and IP3's lost generation. Yet, in revised Table 9-1 of the Draft Supplement, the NRC Staff repeats its conclusion in the 2010 FSEIS that a decision not to renew the licenses for IP2 and IP3 would have only "SMALL" air-quality impacts—no greater than those expected from the proposed license-renewal action—"because emissions related to plant operation and worker transportation will decrease."[7] No analysis is performed of increased emissions from replacement generation facilities; instead, in footnote (b) to revised Table 9-1, the Draft Supplement merely indicates that the "no action" alternative does not meet the need for increased electric generation that will result if the Indian Point units are retired, and therefore does not analyze the air-quality impacts of such increased generation.[8] It further states that "[n]o action would necessitate other generation or conservation actions which may include—but are not limited to—the alternatives addressed in this table," but Table 9-1 leaves the impression that this would not change the "SMALL" finding.[9]

As detailed below and consistent with the requirements of the National Environmental Policy Act ("NEPA") and 10 C.F.R. Part 51, Entergy respectfully submits that the NRC Staff should include in the Draft Supplement additional substantive discussion of the potential air-quality and climate-change impacts that would result from *not* renewing the IP2 and IP3 operating licenses in the "no action" alternative, and revise the findings of Table 9-1 for that scenario to reflect a "MODERATE" or greater impact.[10] To assist the NRC Staff in that assessment, Entergy summarizes below the substantial evidence concerning the air quality impacts of a "no action" scenario that recently has been developed in the pending adjudicatory proceedings before the New York State Department of Environmental Conservation ("NYSDEC") concerning the CWA water quality certification and state pollution discharge elimination system ("SPDES") permit for IP2 and IP3 That evidence substantiates the expected magnitude of air-pollutant and greenhouse gas emissions that would result if IP2 and IP3 cease generating electricity due to the lack of renewed operating licenses, and their generation is replaced by a mix of resources, including increased generation by fossil-fueled units. As this evidence shows, the potential air quality and climate change impacts of the "no action" alternative properly should be considered MODERATE or greater.

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7 2010 FSEIS at 8-21 (Table 8-2).

8 Draft Supplement at 132, Table 9-1, note (b) ("The no-action alternative does not, on its own, meet the purpose and need of the GEIS.").

9 *Id.*

10 NEPA and 10 C.F.R. Part 51 require the NRC Staff to include a "detailed statement" in the FSEIS concerning the "alternatives to the proposed action." 42 U.S.C. § 4332(C)(iii); *see also* 10 C.F.R. § 51.71(d); 10 C.F. R. Part 51, Appendix A, ¶¶ 4, 5. This requirement "forms 'the heart of the environmental impact statement,'" *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 194 (D.C. Cir. 1991) (quoting 40 C.F.R. § 1502.14)), and gives effect to NEPA's purpose of "insur[ing] a fully informed and well-considered decision." *Vt. Yankee Nuclear Power Corp. v. NRDC*, 435 U.S. 519, 558 (1978); *accord Comm. for Nuclear Responsibility, Inc. v. Seaborg*, 463 F.2d 783, 786-87 (D.C. Cir. 1971). NEPA's directive that the agency consider "alternatives to the proposed action" also "requires a presentation of the environmental risks incident to reasonable alternative courses of action" if those consequences are likely to be significant. *NRDC. v. Morton*, 458 F.2d 827, 834 (D.C. Cir. 1972). Because the universe of "reasonable alternatives" depends on the goals of the agency's action, those goals must themselves be defined in a reasonable manner, so as not to arbitrarily pretermit the consideration of alternatives. *See Theodore Roosevelt Conservation. P'ship v. Salazar*, 661 F.3d 66, 72 (D.C. Cir. 2011).

II. NEPA Requires That the NRC Compare the Environmental Impacts of License Renewal, Including Impacts Related to Air Quality and Climate Change, with Those of the No-Action Alternative

When taking the requisite "hard look" at the environmental consequences of the alternatives to the proposed licensing action required by NEPA, NRC regulations require the FSEIS to discuss the "no action" alternative.The NRC's Generic Environmental Impact Statement ("GEIS") for license renewal defines and explains the "no action" alternative in the context of license renewal as follows:

> The no-action alternative represents a decision by the NRC not to renew the operating license of a nuclear power plant beyond the current operating license term. ... Termination of nuclear power plant operations would result in the total cessation of electrical power production. The no-action alternative, unlike the other alternatives, does not expressly meet the purpose and need of the proposed action, as it does not provide a means of delivering baseload power to meet future electric system needs. No action on its own would likely create a need for replacement power; that need could be met by installation of additional generating capacity, adoption or expansion of energy conservation and energy efficiency programs (including demand-side management), purchased power, or some combination of these options.[11]

In essence, the "no action" alternative is an analysis of what would be reasonably likely to happen were the Commission to deny the requested license renewal.

Pursuant to NEPA, federal agencies "[i]nclude the alternative of no action" in their environmental impact analyses,[12] because the "no action" alternative "serves as a benchmark against which the other alternatives" -including license renewal- "can be evaluated."[13] The NRC is no exception. In fact, NRC guidance instructs the Staff to analyze the potential environmental impacts associated with not renewing the license within the "no action alternative" section of the energy-alternatives chapter in the FSEIS.[14] The need for such plant-specific analyses also is reflected in the GEIS, which states that "[i]n license renewal environmental reviews, the NRC considers the *environmental consequences* of the proposed action, the *no-action alternative* (*i.e.*, not renewing the operating license), and the environmental consequences of various alternatives for replacing the nuclear power plant's generating capacity."[15] The GEIS explains that the "NRC compares the environmental impacts of license renewal with those of the no-action alternative and replacement power alternatives to determine whether the adverse

[11] NUREG-1437, Rev. 1, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants—Final Report," Vol. 1, at 2-17 to 2-18 (June 2013) ("GEIS").

[12] 40 C.F.R. § 1502.14(d); *see also Theodore Roosevelt Conservation P'ship*, 661 F.3d at 72.

[13] *Theodore Roosevelt Conservation P'ship v. Salazar*, 744 F. Supp. 2d 151, 160 (D.D.C. 2010), *aff'd*, 661 F.3d 66 (D.C. Cir. 2011).

[14] *See* NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants, Supplement 1: Operating License Renewal," at 8.1-3 (Oct. 1999).

[15] GEIS at 1-4.

environmental impacts of license renewal are great enough to deny the option of license renewal for energy-planning decision-makers."[16]

Consistent with this obligation, the NRC and other federal agencies routinely give careful consideration to whether the environment—including air quality—would be made worse, not better, if the NEPA lead agency decides not to issue the permit or license under review.[17] This is especially true in situations in which NRC or another federal agency, such as the Federal Energy Regulatory Commission ("FERC"), is considering whether to issue new or renewed operating licenses to sources of electric power—such as nuclear electric generation—that serve as alternatives to fossil-fuel based generation.[18]

In the case of the IP2/IP3 license renewal application, the NRC Staff properly defined the "no action" alternative as deciding not to renew the operating licenses for IP2 and IP3, such that other sources of baseload power generation capability would be needed to meet future electricity generation needs.[19] Some evaluation of the environmental consequences of that alternative should be included in the Draft Supplement, particularly where, as here, reliable, relevant information is readily available to the NRC Staff.[20]

III. Denying Renewal Licenses to IP2 and IP3 Would Result in Large Increases in Emissions of Criteria Air Pollutants and Greenhouse Gas Emissions ("GHGs")

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16 *Id.*

17 *See, e.g., Hillsdale Envtl. Loss Prevention, Inc. v. U.S. Army Corps of Eng'rs*, 702 F.3d 1156, 1163 (10th Cir. 2012) (noting agency's finding that "the no-action alternative would have detrimental impacts on regional traffic and air quality"); *Town of Winthrop v. F.A.A.*, 535 F.3d 1, 5 (1st Cir. 2008) (noting agency's assessment that "[t]he preferred alternative would reduce emissions and improve ambient air quality, as compared to the no action alternative").

18 *See, e.g., Consumers Power Co. (Midland Plant, Units 1 and 2)*, LBP-72-34, 5 AEC 214, 227 (1972) ("Given the already substantial problem of air pollution in the Midland area, we conclude that nuclear power is clearly preferable to available alternatives."); *see also PacifiCorp*, 108 FERC ¶ 61,130, 61,781 (2004) ("If the project is not retired, the power from the project would continue to be useful in meeting a small part of the region's need for power and would continue to avoid the air pollution effects associated with an equivalent amount of fossil-fueled generation."); *James River—N.H. Elec. Inc.*, 59 FERC ¶ 62,138, ¶ 63,419 (1992) ("Taking no action would mean, however, that ... continued use of fossil-fired power plants to supply this incremental amount of energy would result in increased air pollution and other adverse environmental impacts associated with the use of fossil fuels."); *Otter Tail Power Co.*, 57 FERC ¶ 62,186, 63384 (1991) (discussing increased air-pollutant emissions from fossil-fuel based power plants that would result if electric project were not relicensed, and concluding that "no action" is not a reasonable alternative); *Columbus Dev. Corp.*, 35 FERC ¶ 62,242, ¶ 63,403 (1986) (selecting preferred alternative because "[t]he project would also eliminate the extra air pollution and mining impacts that are associated with conventional power production methods").

19 *See* Draft Supplement at 131; FSEIS at xvii

20 *See, e.g., Young v. Gen. Servs. Admin.*, 99 F. Supp. 2d 59, 74 (D.D.C. (2000), *judgment aff'd*, 11 App'x 3 (D.C. Cir. 2000) ("[W]here a choice of 'no action' by the agency would result in predictable actions by others, this consequence of the 'no action' alternative should be included in the analysis) (citation and emphasis omitted); *Ariz. Pub. Serv. Co. v. Fed. Power Comm'n*, 483 F.2d 1275, 1282-83 (D.C. Cir. 1973)

In the ongoing adjudicatory proceedings before NYSDEC, Entergy, the New York Department of Public Service ("NYSDPS"), and New York City developed expert analysis concerning the air quality consequences associated with the cessation of IP2 and IP3 electricity generation. As relevant here, there is broad consensus among these experts as to the following:

- First, if IP2 and IP3 cease operations, then the more than 2,000 MWe of power presently provided by those units will be replaced by generation from other, mostly fossil-fuel burning, electric generation units, as a result of increasing the operation of fossil fueled units.
- Second, and as a consequence, increased power generation by such fossil-fueled units will lead to increased emissions of both criteria air pollutants, such as particulate matter ("PM"), nitrogen oxides ("NO_X") and sulfur dioxide ("SO_2"), as well as GHGs, the estimated scope of which the experts have quantified.[21]

As detailed below, increases in these forms of air pollution will have significant impacts with respect to air quality, human health, and climate change.

A. Increases in Criteria Air Pollutants and the Adverse Environmental and Human-Health Consequences of Such Increases

Fossil-fuel generation units emit regulated or criteria air pollutants, including PM, NO_X and SO_2, which are known to impair respiratory function following even short-term exposure and to contribute to the formation of still other air pollutants, such as ground-level ozone and secondary PM.[22] The emission of such pollutants from nuclear generation units is far lower, on a per MWe basis. A leading published, peer-reviewed study by researchers affiliated with the National Aeronautics and Space Administration ("NASA") and Columbia University found that, on a global basis, nuclear power production is responsible for having prevented "1.84 million human deaths ... from 1971 to 2009 ... with an average of 76,000 prevented deaths/year from 2000 to 2009" that would otherwise have been caused by air pollution from coal- or gas-fired power generation.[23]

In the NYSDEC proceeding described above, NYSDPS Staff witnesses submitted an electric-system modeling analysis that estimated the amount of NO_X and SO_2 that fossil-fired replacement sources likely would emit if IP2 and IP3 were taken offline for a 42-week period in

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21 *See, e.g.*, NYSDEC (2014), at 8738:13-8739:15, 8743:23-8744:3 (testimony of NYSDPS Staff witnesses); NERA (2013), at 29; Russo (2014), at 25:7-17. Full citations to NYSDEC (2014), NERA (2013), and certain other references cited herein are provided in the List of References located at the end of this Attachment.

22 *See, e.g.*, EPA Final Rule, Standards of Performance for Electric Utility Steam Generating Units for Which Construction Is Commenced After September 18, 1978; Standards of Performance for Industrial- Commercial-Institutional Steam Generating Units; and Standards of Performance for Small Industrial- Commercial-Institutional Steam Generating Units, 71 Fed. Reg. 9866 (Feb. 27, 2006) (setting NO_X, SO_2, and PM emissions limits for electric generating units); EPA (2016); NYSDEC (2015), at 148-49, 172-74.

23 Kharecha & Hansen (2013), at 4891.

2022.[24] Based upon their assumptions concerning sources of replacement electric generation, NYSDPS Staff's analysis demonstrated that such an outage would be expected to produce approximately an additional 4,000 tons of NO_X emissions during the 42-week period in a region encompassing New York, Pennsylvania, New Jersey, Maryland, New England and Ontario.[25] With respect to SO_2 emissions, NYSDPS Staff's analysis forecasted almost 6,000 additional tons emitted on a regional basis.[26] Entergy submitted expert analysis showing air-pollutant increases of similar magnitude to those estimated by NYSDPS Staff's analysis: NERA Economic Consulting estimated that a one-year outage at IPEC would increase electric sector NO_X emissions in New York State alone by approximately 17 percent, or approximately 3,100 short tons, on average.[27] Charles River Associates, testifying on behalf of the City of New York, projected (among other things) an increase in electric sector NO_X emissions in New York State of 10-12%.[28]

NYSDPS Staff determined that the impact of these emissions increases would not be evenly distributed across New York State. Roughly two-thirds of the additional NO_X emissions (1,009 out of 1,512 tons) in New York State would occur in densely populated New York City and Long Island, and more than half of the additional SO_2 emissions (910 out of 1,782 tons) in New York State would occur in those locations.[29] The fact that most of the air-emissions impacts would occur in these locales is significant, because portions of these locales, including New York City and its surrounding area, are presently designated a non-attainment area for purposes of EPA's 8-hour national ambient air quality standard ("NAAQS") for ground-level ozone.[30] NO_X "plays a major role in the atmospheric reactions with volatile organic compounds ("VOC") that produce ozone (smog) on hot summer days."[31] Increases in NO_X emissions in New York City threaten to compromise decades of ongoing efforts to achieve compliance with the ozone NAAQS that EPA has determined are necessary for the protection of human health and the environment.[32]

The environmental and human-health implications of these increased air-pollutant emissions are significant. Both NO_X and SO_2 have deleterious consequences for human health, either directly or as a result of their role as precursors for the formation of other pollutants such as ozone and PM. Exposure to atmospheric NO_X for fewer than three hours at elevated levels can result in a number of adverse human health impacts, including increases in respiratory

24 *See* NYSDPS (2014a); NYSDPS (2014b); Gjonaj & Wheat (2014), at 7:6-16:12.

25 NYSDPS (2014b), column R1.

26 *Id.*

27 *See* NERA (2013), at 29, Table 15; Harrison (2014), at 43, Table 2.

28 Russo (2011), at 27 (Table 7).

29 NYSDPS (2014b), column R1.

30 *See* EPA Final Rule, Implementation of the 2008 National Ambient Air Quality Standards for Ozone: State Implementation Plan Requirements, 80 Fed. Reg. 12,264, 12,311 (Mar. 6, 2015).

31 EPA (2016).

32 *Id.*

illnesses in children and impairment of pulmonary function in individuals with pre-existing respiratory illnesses.[33]

Ozone, for which NO_X is a precursor, is likewise toxic, including at low concentrations. One study has shown a 2.3% increase in daily cardiovascular and respiratory deaths for every 10 parts per billion increase in average ozone concentrations over the preceding week.[34] Besides increasing human mortality, ozone also increases human morbidity, potentially resulting in shortness of breath, lung inflammation, decreased lung function, and increased susceptibility to respiratory infection, particularly in persons who are active outdoors or who have preexisting respiratory disorders such as asthma.[35]

SO_2 likewise impairs respiratory function: The human health impacts from even short-term (5-minute to 24-hour) exposure to elevated SO_2 levels include impaired breathing for asthmatic children, the elderly, and adults who are even moderately active outdoors.[36]

In addition to their adverse human-health effects, both NO_X and SO_2 are major contributors to acid rain and to the acidification of soils, lakes, and streams, which adversely affects natural ecosystems.[37]

The human health impacts of shorter outages, *i.e.*, outages lasting 42 or 62 days each summer at both units, were recently quantified and are illustrative of the potential human health consequences of the "no action" alternative. In the pending NYSDEC proceeding, Entergy provided testimony by Dr. Edmund Crouch of Green Toxicology, Inc., who performed an analysis using EPA's widely used, peer-reviewed Co-Benefits Risk Assessment ("COBRA") model to estimate potential adverse human health effects associated with increases in certain criteria air pollutants.[38] Dr. Crouch's analysis found that, over a five-year period, outages at IP2 and IP3 lasting only 62 days each year would lead to between approximately 4 and 51 premature adult deaths and to thousands of additional work days lost due to illness, as well as to increases in respiratory- or cardiovascular-related hospitalizations, asthma-related emergency room visits, and other morbidity events.[39] As Dr. Crouch concluded in his testimony, it is reasonable to assume that the consequences of longer outages (consistent with permanent retirement of IP2 and IP3 over the next 19 years) would be even greater.[40]

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33 *See, e.g.*, EPA Final Rule, Primary National Ambient Air Quality Standards for Nitrogen Dioxide, 75 Fed. Reg. 6474, 6491 (Feb. 9, 2010); *see also* NYSDEC (2015), at 148.

34 *See* NYC Health (2011), at 11.

35 *See* Primary National Ambient Air Quality Standards for Nitrogen Dioxide, 75 Fed. Reg. at 6479-80.

36 *See* EPA Final Rule, Primary National Ambient Air Quality Standard for Sulfur Dioxide, 75 Fed. Reg. 35,520, 35,525 (June 22, 2010); *see also* NYSDEC (2015), at 172.

37 *See* EPA Proposed Rule, Acid Rain Program: Permits, Allowance System, Continuous Emissions Monitoring, and Excess Emissions, 56 Fed. Reg. 63,002, 63,004 (Dec. 3, 1991); *see also* NYSDEC (2015), at 172.

38 *See* Crouch (2015a), at 3:1-16, 4:2-5:18, 8:16-12:3; Crouch (2015b), at 4:8-8:6.

39 Crouch (2015b), at 7.

40 Crouch (2015a), at 15.

For these reasons, Entergy respectfully submits that NRC Staff should more fully consider and evaluate the extent to which air pollutant emissions would increase if the IP2 and IP3 licenses were not renewed in the "no action" alternative, including the implications of those increases for human health and the environment. By including that analysis in its second supplement to the FSEIS, the NRC Staff will better inform the public as to what is at stake as it weighs the Indian Point license renewal issues. Entergy further submits that the recent analyses developed for the NYSDEC proceeding allow the NRC Staff to analyze more fully the extent to which denial of IP2 and IP3 license renewal would increase criteria air pollutant emissions, and thereby result in significant adverse environmental and human-health impacts beyond those above currently set forth in the Draft Supplement.

B. Indian Point Units 2 and 3 Are *De Minimis* Contributors to GHG Emissions and Potentially-Related Climate Change

The Draft Supplement states that "GHG emissions from the continued operation of IP2 and IP3 may contribute to climate change," because "the extent and nature of climate change is not specific to where GHGs are emitted," and "[t]he cumulative impact of a GHG emission source on climate is global."[41] It is important to place these statements in their proper context, however, and recognize that IP2 and IP3 GHG emissions are *de minimis* compared to other sources of GHG emissions.[42] Indeed, as Table 5-4 of the Draft Supplement shows, GHG emissions resulting from operations at IP2 and IP3 during the 2009-2013 timeframe were below the EPA's reporting threshold of 25,000 metric tons ("MT") (27,558 tons) of carbon dioxide equivalent (CO_{2eq}), above which facilities are required to report GHG emissions to EPA annually in accordance with 40 C.F.R. Part 98.[43] Specifically, during the 2009-2013 period, IP2 and IP3 GHG emissions ranged from 4,960 to 10,990 MT of CO_{2eq}.[44] Table 5-6 of the Draft Supplement, reproduced in part below, shows that IP2 and IP3 GHG emissions constitute a very small fraction of Westchester County GHG emissions (approximately 2%), and a minuscule fraction of New York State, U.S. and global GHG emissions (approximately 0.02%, 0.00015%, and 0.00003%, respectively).

Source	CO2eq (Million Metric Tons (MMT)/Year
Global emissions (2013)	35,300
U.S. emissions (2013)	6,673
New York emissions (2013)	42.5

41 Draft Supplement at 111.

42 In discussing direct and indirect sources of GHG emissions from IP2 and IP3, the Draft Supplement states that such sources include refrigerant equipment and delivery vehicles, but that these are not presented in Table 5–4 because data were not readily available to quantify emissions. *See id.* at 85. Entergy notes that it maintains a program to manage stationary refrigeration appliances at IP2 and IP3 to recycle, recapture, and reduce emissions of ozone- depleting substances, and that the site is in compliance with Section 608 of the Clean Air Act.

43 *See id.* at 86.

44 *See id.* at 86 (Table 5-4) & 112.

Westchester County emissions (2013)	0.45
IP2 and IP3 emissions (highest emission from 2009 to 2013)	0.01

Thus, IP2 and IP3, with their minimal GHG emissions, stand in stark contrast to other, non-nuclear facilities in Westchester County and New York State. For example, the Draft Supplement states that in 2013, the EPA's Facility Level Information on GreenHouse Gases Tool ("FLIGHT") identified four facilities in Westchester County that emitted a total of 448,046 MT of CO_{2eq}, and 221 facilities in New York State that emitted a total of 42.5 MMT of CO_{2eq}.

C. <u>Increases in Carbon Dioxide Emissions Likely Resulting From the Cessation of IP2 and IP3 Operations and their Implications for Climate Change</u>

The NRC Staff recognizes, as part of its general policy for evaluating GHG and climate-change impacts in preparing environmental impact statements, that it "should discuss emissions from competitive energy sources that are capable of meeting the purpose and need of the proposed action."[45] According to NRC Staff guidance, "[t]o put emissions into context for decision makers, the EIS should include a comparison of emissions from competitive energy alternatives."[46]

Federal and New York State officials alike have recognized the value of nuclear power plants in reducing air-pollutant and GHG emissions. President Obama recently reaffirmed the value of nuclear power "to combat climate change," noting that the nuclear sector "generated about 60 percent of carbon-free electricity in the United States, [and] continues to play a major role in efforts to reduce carbon emissions from the power sector."[47] New York Governor Cuomo highlighted the importance of "emissions free" nuclear power plants to New York's chances for succeeding in meeting its clean-energy and emission-reduction goals, warning that "elimination of upstate nuclear facilities, operating under valid federal licenses, would eviscerate the emission reductions achieved through the State's renewable energy programs."[48] "The early closure of those plants," Governor Cuomo noted, "would result in increased carbon pollution from fossil fuel generators."[49] In a January 21, 2016 press release, Governor Cuomo noted that the New York State Public Service Commission had approved a public process to adopt a Clean Energy Standard that will also include a "separate support mechanism" for upstate nuclear power plants.[50] The press release explains that "[s]ince nuclear facilities do not produce greenhouse gas emissions, they will help the State transition to a future under the Clean Energy Standard without losing ground on emission reductions statewide."[51]

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45 NRC (2014), at 8.

46 *Id.*

47 White House (2015a).

48 Cuomo (2015b).

49 Cuomo (2015a).

50 Cuomo (2016).

51 *Id.*

The climate-change implications of not issuing renewed licenses for IP2 and IP3 would be significant and merit further consideration. The absence of IP2 and IP3 from the electric system would result in the release of millions of additional tons of GHGs from the fossil-fuel based power sources that inevitably would be called on to replace those units. NYSDPS Staff's modeling analysis indicates that an outage at both IP2 and IP3 of just 42 weeks in 2022 would result in a more than 7.5-million ton increase in CO_2 emissions from the region consisting of New York, Pennsylvania, New Jersey, Maryland, New England, and Ontario.[52] On behalf of Entergy, NERA estimated increases in CO_2 emissions on a regional basis ranging from approximately 6.2 million tons to 7.1 million tons per year for outages occurring during the years 2015-2019, or an annual average increase of about 6.7 million tons.[53] Russo (2011) projected New York State increases in carbon emissions from the electric generation sector of 10-13% each year in the event IP2 and IP3 retire.[54]

To put these figures into perspective, as noted above IP2 and IP3 CO_2 emissions are only about 10,000 tons per year or less. One also can compare the estimated increases in CO_2 emissions if the operating licenses are not renewed to the illustrative GHG emissions-reduction estimates that EPA provided as part of its 2015 Final Clean Power Plan Rule. Specifically, EPA provided a modeling analysis that shows illustrative future CO_2 emissions reductions (calculated using both "rate-based" and "mass-based" approaches) that EPA views as being representative of the future air impacts of the Rule.[55] Under the rate-based model, EPA anticipates that the Clean Power Plan Rule will achieve CO_2 emissions reductions of 69 million tons by the year 2020, while under the mass-based approach, the reduction would be 81 million tons.[56] The 7.5 million ton increase in CO_2 emissions that NYSDPS Staff has estimated as resulting from only a single 42-week outage at IP2 and IP3 represents approximately 10.8 percent of the rate-based reduction and approximately 9.3 percent of the mass-based reduction that EPA predicts—and if the units retire then such increases would be seen every year. Viewed through either lens, a decision not to renew IP2 and IP3's licenses would significantly undercut national efforts to reduce GHG emissions.

As the Draft Supplement presently recognizes, the impact of GHGs, particularly CO_2, on climate change "is long-lasting as a result of their long atmospheric lifetime."[57] Avoiding additional GHG emissions whenever possible is therefore essential to addressing what the President has rightly characterized as "one of the key challenges of our lifetimes and future generations."[58]

For these reasons, Entergy respectfully submits that NRC Staff should more fully consider and evaluate the extent to which GHG emissions will increase each year if IP2 and IP3 are not relicensed—many millions of tons in increased CO_2 emissions, in contrast to about

[52] NYSDPS (2014b), column R1

[53] NERA (2013), at 27, Table 13.

[54] Russo (2011), at 27 (Table 7).

[55] *See* EPA Final Rule, Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, 80 Fed. Reg. 64,662, 64,924 (Oct. 23, 2015).

[56] *Id.*

[57] Draft Supplement at 85.

[58] White House (2015b).

10,000 tons or less if IP2 and IP3 are relicensed—and the implications of those increases for efforts to combat climate change. By including that analysis in the Draft Supplement, the public will be better informed as to what is at stake as NRC weighs the relicensing issue. To assure a fully-informed public and decision-making process, NRC's Draft Supplement should be revised to make clear not only the climate-change implications of IP2's and IP3's continued operation for additional 20-year terms (see Draft Supplement at 112), but also the vastly and unquestionably more significant implications if those units were to cease their operations. Further, Entergy respectfully submits that the recent analyses developed for the NYSDEC proceeding allow NRC to more fully analyze the extent to which denial of license renewal for IP2 and IP3 would increase GHG emissions under the "no action" alternative, and thereby result in significant adverse environmental and human-health impacts, above the conclusions reflected in the FSEIS.

* * *

In conclusion, there is every reason to believe that serious environmental and human-health consequences will result from not renewing the IP2 and IP3 operating licenses, due to increases in both criteria air pollutants and GHGs from fossil-fuel based replacement sources of power. Expert testimony and evidence already submitted in the pending adjudicatory proceedings before NYSDEC demonstrates that to be the case. Accordingly, Entergy requests that the NRC Staff fully consider and evaluate those impacts in the final version of its Draft Supplement to the 2010 FSEIS.

IV. The IP2 and IP3 Generators and Diesel Fire Pumps Are Not Included in the New Combined Air Permit for IP2 and IP3 Issued by the NYSDEC, But Are Subject to the Requirements of the EPA's Reciprocating Internal Combustion Engine Rule

In response to an NRC Staff request for additional information issued Sept 14, 2014, Entergy provided updated information regarding the status of the station air permits and compliance history, and also responded to requests concerning all emission sources relevant to calculations of potential GHG emissions.[59] In two locations in the Draft Supplement (page 43, lines 7-24, and page 45, lines 27-40), there are descriptions of air emission sources regulated under the new combined IP2/IP3 air permit that require clarification.[60] Although the previous individual IP2 and IP3 air permits included generators and diesel fire pumps, the new combined permit regulates emissions from gas turbines and boilers. It does not include the generators and fire pumps, which are exempt from NYSDEC permitting. However, generators and fire pumps are subject to the US EPA's Reciprocating Internal Combustion Engine ("RICE") Rule requirements, as set forth in 40 C.F.R. Part 63, Subpart ZZZZ. Therefore, their run times are tracked and recorded to ensure that they do not exceed the limits set for emergency reciprocating internal combustion engines.

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59 *See* NL-15-028, Letter from F. Dacimo, Entergy, to NRC Document Control Desk, "Reply to Request for Additional Information Regarding the License Renewal Application Environmental Review," Attachment at 4-8 (Mar. 10, 2015) (ADAMS Accession No. ML15089A338).

60 In this regard, Entergy notes that in Section 5.1.1 (page 41, line 10) of the Draft Supplement, the word "permits" should be changed to "permit" because IP2 and IP3 now have a single combined permit.

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ATTACHMENT 4 TO NL-16-021

COMMENTS ON SECTION 5.4 OF THE DRAFT SUPPLEMENT

(RADIONUCLIDES RELEASED TO GROUNDWATER)

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 & 3
DOCKET NOS. 50-247 AND 50-286

Entergy Comments on Section 5.4 of the Draft Supplement (Radionuclides Released to Groundwater)

I. Introduction

As the Nuclear Regulatory Commission ("NRC") Staff notes in NUREG-1437, Supplement 38, Vol. 5, Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3, Draft Report (Dec. 2015) ("Draft Supplement"), the issue of radionuclides released to groundwater is a new Category 2 issue that requires site-specific discussion.[1] Accordingly, Section 5.4 of the Draft Supplement contains a detailed discussion of past releases of radionuclides into the groundwater at the Indian Point site,[2] including an assessment of the negligible potential impact of such releases on human health and to the environment, particularly as such releases may potentially affect groundwater and surface water bodies.[3]

Entergy's comments on Section 5.4 of the Draft Supplement are presented below. In summary, the NRC Staff's conclusion that the current impact of past radionuclide releases on the onsite groundwater quality is "MODERATE"[4] appears to be based largely, if not entirely, on its comparison of radionuclide concentrations in Indian Point site groundwater to standards promulgated under the federal Safe Drinking Water Act ("SDWA") as if such groundwater were being employed for drinking water purposes; *i.e.*, the U.S. Environmental Protection Agency's ("EPA") maximum contaminant levels ("MCLs") for drinking water. As discussed below, this approach is incorrect in at least two major respects.

First, the Draft Supplement fails to identify a correct or reasonable "important attribute" of the onsite groundwater impacted by the radionuclide releases in question, given that such groundwater is not being used for drinking water purposes. Indeed, the Draft Supplement confirms that the groundwater beneath Indian Point is *not* used for potable purposes today and is highly unlikely to ever be used for that purpose. Therefore, applying MCLs issued under the federal SDWA for the purpose of assessing the radiological impacts of radionuclides released to site groundwater under the National Environmental Policy Act ("NEPA") is inappropriate as a legal matter. Furthermore, the groundwater of concern at Indian Point cannot be extracted in sufficient volumes, e.g., without the risk of salt intrusion, to be considered a viable drinking water resource. Finally, the SDWA MCL's are end of the tap values. Therefore, implicitly concluding that "drinkability" is an "important attribute" of the onsite groundwater by applying the SDWA MCLs to

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1 *See* Draft Supplement at 50.

2 Indian Point Units 1, 2, and 3 are referred to herein as IP1, IP2, and IP3, respectively. IP1, which is not the subject of Entergy's pending license renewal application, was shut down in 1974 and is currently in SAFSTOR (a decommissioning strategy that includes maintenance, monitoring, and delayed dismantlement to allow radioactivity to decay prior to decommissioning)

3 *See* Draft Supplement at 50-75.

4 NRC regulations define a "MODERATE" impact as environmental impact that is "sufficient to alter noticeably, but not to destabilize, important attributes of the resource" in question. 10 C.F.R. Part 51, Appendix B, Table B-1.The NRC's environmental impact significance levels are discussed further in Section III below.

groundwater wells representing a fraction of on-site groundwater, as the NRC Staff does in the Draft Supplement, is inconsistent with both the relevant facts and law.

Second, instead of applying SDWA MCLs for drinking water to Indian Point site groundwater, the NRC Staff should adhere to the approach used in the 2010 FSEIS,[5] and evaluate whether previous radionuclide releases and associated doses exceed the permissible levels specified in NRC regulations. The Draft Supplement deviates from this well established practice. NRC regulations explicitly state that "[f]or the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered small," as the term is used in 10 C.F.R. Part 51.[6] Application of the relevant dose limits in 10 C.F.R. Part 50, in lieu of SDWA MCLs for drinking water, to Indian Point site groundwater does not support a finding of "MODERATE" impacts. As discussed further below, it instead supports a finding of "SMALL" impacts with respect to releases of radionuclides from the IP1 and IP2 spent fuel pools to onsite groundwater.

II. The Draft Supplement's "MODERATE" Impact Determination Is Based on the NRC Staff's Comparison of Indian Point Onsite Groundwater Radionuclide Concentrations to EPA's MCLs for Drinking Water

Section 5.4.2.2 ("Extent of Groundwater Contamination") of the Draft Supplement states that to characterize the impacts on groundwater quality (*i.e.*, groundwater as a resource), the NRC Staff compared the concentrations of the radionuclides in the groundwater beneath the Indian Point site to EPA MCLs developed under the SDWA.[7] It further notes that for radionuclides in drinking water, EPA has established a combined MCL of 4 millirem ("mrem") per year for various radionuclides.[8] The MCL represents the sum of all radionuclides (including cesium-137, cobalt-60, nickel-63, strontium-90, and tritium), so that, taken together, the annual dose from all applicable radionuclides will not exceed 4 mrem per year.

Section 5.4.2.2 includes Table 5-2 ("Radionuclide Concentration Levels/Limits"), which lists the cesium-137, cobalt-60, nickel-63, strontium-90, and tritium concentrations, in picocuries per liter ("pCi/L"), that would be required from each individual radionuclide to yield a dose of 4 mrem per year; *i.e.*, without the added contribution of any other radionuclides.[9] Those concentrations are: 200 pCi/L (cesium-137), 100 pCi/L (cobalt-60), 50 pCi/L (nickel-63), 8 pCi/L (strontium-90), and 20,000 pCi/L (tritium).[10]

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5 *See* NUREG-1437, Supp. 38, Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3, Vol. 1 (Dec. 2010) ("2010 FSEIS").

6 10 C.F.R. Part 51, Appendix B, Table B-1. *See also* NUREG-1437, "Final Generic Environmental Impact Statement for License Renewal of Nuclear Plants," Rev. 1, Vol. 1 at 4-136 (June 2013) ("For the purposes of assessing radiological impacts, impacts are considered to be SMALL if releases and doses do not exceed permissible levels in the NRC's regulations. This definition of SMALL applies to occupational doses as well as to doses to individual members of the public.").

7 *See* Draft Supplement at 64.

8 *See id.*

9 *See id.* (Table 5-2).

10 *See id.*

In Sections 5.4.2.2 and 5.4.2.5 ("Corrective Actions"), the NRC Staff compares concentrations listed in Table 5-2 to measured concentrations of the same radionuclides in groundwater at the IPEC site and in the Hudson River. Based on those comparisons, the NRC Staff concludes as follows in Section 5.4.3 ("Environmental Consequences") of the Draft Supplement:

> The NRC staff concludes that groundwater contamination will either remain onsite, or be discharged into the Hudson River. Therefore, off-site groundwater supplies should continue to be unaffected by ongoing operations. At the IP2 and IP3 site, the hydraulic properties of the Inwood Marble will not support large yields of water to wells. *The onsite groundwater quality in the Inwood Marble has been noticeably altered relative to the concentrations in Table 5-2.Therefore, the NRC staff concludes the current impact on the onsite groundwater quality is MODERATE.*[11]

III. The Draft Supplement's Use of EPA MCLs Issued Under the Federal SDWA for the Purpose of Assessing the Radiological Impacts of Radionuclide Releases at Indian Point Under NEPA Lacks Both Factual and Legal Bases

As the foregoing discussion indicates, the NRC Staff's conclusion that current groundwater impacts are MODERATE is based on its comparison of measured radionuclide concentrations in Indian Point site groundwater to EPA MCL-based radionuclide concentrations. For the reasons set forth below, Entergy respectfully disagrees with that method of comparison (and the Staff's associated impact determination) as lacking adequate factual and legal bases, particularly in view of other information presented in the Draft Supplement and previous NRC Staff statements.

A. The Draft Supplement Implicitly, But Unreasonably, Concludes that "Drinkability" Is An Important Attribute of the Groundwater Beneath the Indian Point Site

For purposes of NEPA evaluations performed under 10 C.F.R. Part 51, the NRC defines environmental impact significance levels in terms of the effects of license renewal on "important attributes of the resource" at issue—which in this case NRC concludes is groundwater. 10 C.F.R. Part 51, Subpart A, Appendix B, Table B-1 defines the three significance levels as follows:

> SMALL – For the issue, environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. *For the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed* ***permissible levels in the Commission's regulations*** *are considered small as the term is used in this table.*
>
> MODERATE – For the issue, environmental effects are sufficient to alter noticeably, but not to destabilize, ***important attributes of the resource***.
>
> LARGE – For the issue, environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.[12]

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[11] *Id.* at 75 (emphasis added).

[12] 10 C.F.R. Part 51, Appendix B, Table B-1 (emphasis added).

In other words and as detailed in Sections IV and V below, for NEPA purposes, environmental impacts through 2014 (and to date) are properly designated SMALL if the levels do not exceed "permissible levels in the Commission's regulations." The "Commission's regulations" for radiological releases, including the releases in question through 2014 (and to date), are those found at 10 C.F.R. Parts 20 and 50, which do not incorporate SDWA MCL's. Viewed in light of the *applicable* Commission regulations, therefore, potential impacts through 2014 (and to date) should be defined as SMALL pursuant to 10 C.F.R. Part 51 definitions. To the extent that the Draft Supplement also elects to compare measured radionuclide concentrations to the MCLs promulgated by the EPA under the SDWA, there is no basis in NRC's NEPA regulations for altering the appropriate SMALL finding.[13]

Nonetheless, these comments also address the NRC Staff's comparison of radiological releases to SDWA MCL's to underscore flaws in that comparison and in the MODERATE finding. First, to reach a MODERATE finding, the Draft Supplement must conclude, and in fact implicitly concludes, that "drinkability" is an "important attribute" of Indian Point's onsite groundwater, *i.e.*, because it compares sampled radionuclides concentrations to drinking water standards applicable to those radionuclides.[14] This analytical approach is inappropriate for at least two reasons.

First, the SDWA does not apply to the groundwater beneath Indian Point. The primary and secondary drinking water regulations developed pursuant to the SDWA apply to "public water systems," defined by statute to be "a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals."[15] The groundwater beneath Indian Point is not collected for drinking. Moreover, the groundwater at Indian Point does not communicate with any other groundwater-based drinking water source. Section 5.4.1.3 ("Water Resources") of the Draft Supplement confirms these facts, insofar as it states:

- Potable water is supplied to the Indian Point site by the Village of Buchanan, New York, Public Water Supply system. Thus, the site does not use groundwater either for plant operations or for potable water.[16]

- Potable water sources near the Indian Point site are not presently derived from groundwater sources or the Hudson River.[17]

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[13] *See* Draft Supplement at 64 ("To better characterize the impacts on groundwater quality (i.e., the groundwater as a resource), it is helpful to compare the concentrations of the radionuclides in the groundwater to EPA maximum contaminant levels (MCL).").

[14] The SDWA authorizes the EPA to set national standards, including MCLs, for *drinking water* to protect against health effects from exposure to naturally-occurring and man-made contaminants, including radionuclides, that may be found in drinking water. *See* 42 U.S.C. § 300g-1; *see also* 40 C.F.R. § 141.2 (defining "maximum contaminant level" as "the maximum permissible level of a contaminant in water which is delivered to any user of a public water system"); *id.* § 141.66 (establishing MCLs for radionuclides and indicating that the concentration limit represents the dose that would result if one were to drink two liters of water with that radionuclide concentration every day for a year).

[15] 42 U.S.C. §§ 300f(1)-(4), 300g.

[16] *See* Draft Supplement at 56.

[17] *See id.*

- There are no residential or municipal groundwater-based drinking water wells near IP2 and IP3. Further, because municipal water is readily available in the area, it is unlikely that groundwater-based drinking water wells will be installed in a location that would be reasonably expected to communicate with on-site groundwater in the reasonably foreseeable future.[18]

- Drinking water in the area (Village of Buchanan and City of Peekskill) is obtained from surface water reservoirs located in Westchester County and the Catskills region of New York. The closest reservoir (Camp Field) is located 3.3 mi (5.3 km) north and upstream of the site. The other local public drinking water supply is the New Croton Reservoir, which is 6.3 mi (10.1 km) east of the site. Both of these public drinking water supplies are at much higher elevations, and therefore not reasonably considered in communication with Indian Point groundwater, even ignoring distance. Surface water samples collected from the drinking water reservoirs do not exhibit radiological impacts from IP2 and IP3 operation.[19]

In view of these undisputed facts, SDWA standards clearly are not appropriate tools for evaluating the impact of inadvertent releases of radionuclides to groundwater at Indian Point, because no one drinks the groundwater underlying the site, and that groundwater does not contribute to other sources that are consumed.[20]

Additionally, the term "maximum contaminant level" is defined by statute to be "the maximum permissible level of a contaminant in water *which is delivered to* any user of a public water system."[21] In other words, the SDWA sets MCLs for water "at the tap," rather than at the source. Accordingly, even if the water beneath Indian Point were (incorrectly) considered a source of drinking water, the MCLs for any contaminant would not apply to the concentration of that contaminant within groundwater as measured in groundwater wells, but to the delivered resource. The Draft Supplement contains no analysis converting concentrations at Indian Point to concentrations for a hypothetical consumer at the tap. Even if such a hypothetical analysis had

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18 *See id.*

19 *See id.*

20 Notably, the Commission concluded as much as in its 1997 rulemaking amending its regulations setting forth specific radiological criteria for the decommissioning of lands and structures and license termination. It stated:

> [I]t is the Commission's position that protection of public health and safety is fully afforded by limiting exposure to persons from all potential sources of radioactive material by means of a TEDE at a decommissioned facility. ***There is, therefore, no compelling reason to impose a separate limit on dose from the drinking water pathway, and the rule has been modified to delete a separate groundwater standard.*** To make clear NRC's concern over the importance of protecting this resource as a source of potential public exposure, the rule has also been modified to include a direct reference to the groundwater pathway in the all-pathways unrestricted use dose criterion in [10 C.F.R.] § 20.1402.

Final Rule, Radiological Criteria for License Termination, 62 Fed. Reg. 39,058, 39,075 (July 21, 1997) (emphasis added). *See also id.* at 39,081 ("[T]he Commission believes that the overall approach to license termination in this final rule ... protects public health and safety, and that the approach to drinking water protection in the final rule provides an appropriate and more consistent level of protection of public health and safety than use of MCLs.").

21 42 U.S.C. §300f(3) (emphasis added).

been conducted, assumptions about delivered concentrations, which depend on a variety of considerations including source water, dilution and treatment, would be speculative, and therefore are inconsistent with NEPA's requirement that only reasonably foreseeable impacts be considered.[22]

In this same vein, the Draft Supplement recounts the many facts that support the conclusion that the groundwater beneath Indian Point cannot be extracted in volumes sufficient to constitute a meaningful drinking water resource for a public water system. For example, it notes that "[t]he rock matrix of the Inwood Marble has very low porosity, and groundwater does not easily flow through it," and "although the fracture network forms the groundwater pathways through the rock, it does not hold a large volume of water."[23] Further, "[o]nsite, the hydraulic properties of the Inwood Marble will not support large yields of water to wells. Although wells drilled with conventional techniques might be able to produce enough water to supply an individual household, the low hydraulic conductivities and porosities of the fractures are insufficient to supply a public water system."[24] Finally, the Draft Supplement acknowledges that "[b]ecause municipal water is readily available in the area, it is unlikely that potable or irrigation wells will be installed near the site in the reasonably foreseeable future."[25] Therefore, there is no reasonable basis to conclude that "drinkability" is now, or ever will be, an "important attribute" of the groundwater "resource" beneath Indian Point.

B. The Draft Supplement Also Takes An Inappropriately Narrow View of the Groundwater Resource at Indian Point

In a related vein, 10 C.F.R. § 51.53(c)(2) states that the Draft Supplement "must contain a description of the proposed action [and] ... must describe in detail the affected environment ***around the plant***, the modifications directly affecting the environment or any plant effluents, and any planned refurbishment activities."[26] In June 2013, the NRC adopted a final rule that, among other things, added a new Category 2 issue for site-specific analysis as follows:

> An applicant shall assess the impact of any documented inadvertent releases of radionuclides into groundwater. The applicant shall include in its assessment a description of any groundwater protection program used for the surveillance of piping and components containing radioactive liquids for which a pathway to groundwater may exist. The assessment must also include a description of any past inadvertent releases ***and the projected impact to the environment (e.g., aquifers, rivers, lakes, ponds, ocean) during the license renewal term.***[27]

The clear directive is to evaluate impacts of inadvertent releases "to the environment." Nothing in this regulation suggests a narrow view of the groundwater resource within the

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22 *See, e.g., N. Plains Res. Council, Inc. v. Surface Transp. Bd.*, 668 F.3d 1067, 1079 (9th Cir. 2011) (internal quotation marks and citation omitted) (NEPA requires agency to engage in *reasonable* forecasting of impacts).

23 Draft Supplement at 54.

24 *Id.* at 56.

25 *Id.*

26 10 C.F.R. § 51.53(c)(2) (emphasis added).

27 10 C.F.R. 51.53(c)(3)(ii)(P) (emphasis added).

environment. Presumably, if the rule had been intended to focus exclusively on onsite groundwater, then it would have said so explicitly. Moreover, NEPA requires that agencies take a "hard look" at *relevant data* and explain the rational connection between the facts and the impact finding, while not ignoring pertinent information.[28] Clearly, the data indicating the complete absence of impacts to off-site groundwater resources is relevant to the findings in the Draft Supplement, and such information should not be ignored in the overall evaluation of impacts.

This direction on the appropriate context for the NRC Staff's groundwater inquiry, in fact, is reflected in the Draft Supplement in the evaluation of impacts to surface water. In that context, among the many facts informing the NRC Staff's "SMALL" impact finding with respect to surface water were relevant data (1) providing results from surface water samples collected "from several watersheds away" demonstrating the absence of impacts to drinking water reservoirs located 3.3 and 6.3 miles away from the Indian Point site, and (2) supporting the conclusion that the formerly-proposed Haverstraw Water Supply Project—located approximately four miles from Indian Point—would not be impacted by Indian Point operations.[29] A similarly expansive view of the groundwater resource is required, and the absence of offsite groundwater impacts should be given substantial weight in the overall groundwater impacts analysis.

Further to this point, there is no evidence of *any* off-site groundwater impacts associated with the inadvertent release of radionuclides at Indian Point. The Draft Supplement properly notes that groundwater beneath Indian Point does not communicate with any other groundwater in the vicinity of the plant or across the Hudson River: "The direction of groundwater flow in the water table prevents contaminated groundwater from migrating off the site property to the north, east or south."[30] Therefore, groundwater in areas immediately adjacent to the plant has not been impacted by inadvertent releases of radionuclides into groundwater. Moreover, "[t]he size and depth of the Hudson River and the direction of groundwater flow under and on each side of the river mean that it is extremely unlikely that onsite groundwater in the Inwood Marble could flow under the Hudson River to the other side."[31] Consequently, there is no pathway by which onsite groundwater contamination can spread to *any* groundwater elsewhere. As a result, there are no impacts—not even "SMALL" impacts—to offsite groundwater. This conclusion should be given substantial weight in any analysis of groundwater impacts in "the environment."

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28 *See, e.g., New Mexico ex rel. Richardson v. Bureau of Land Management,* 565 F.3d 683, 713 (10th Cir. 2009) (NEPA's "hard look" requirement necessitates examination of the relevant data and articulation of a rational connection between the facts found and the decision made); *Sierra Club v. U.S. Army Corps of Eng'rs,* 701 F.2d 1011, 1029 (2d Cir. 1983) (agency cannot ignore pertinent information in NEPA analysis).

29 *See* Draft Supplement at 56, 106-107.

30 *Id.* at 60.

31 *Id.* at 55. Relatedly, on page 56 of the Draft Supplement, the NRC Staff states: "Entergy has used an analytical equivalent porous media groundwater flow model based on a precipitation mass balance analysis to estimate groundwater flux beneath the site and into the discharge canal and the Hudson River." As a point of clarification, Entergy notes that the precipitation mass balance model is not "equivalent" to the porous media groundwater flow model, which is based on Darcy's Law. The two models use different sets of input parameters that are not dependent upon, or related to, each other. Nevertheless, Entergy notes that the precipitation mass balance model currently used to estimate flow agreed with, and was further calibrated by, the porous media model. The relationship between the two models is discussed in greater detail in the January 7, 2008 Hydrogeologic Site Investigation Report prepared by GZA GeoEnvironmental, Inc. and in Entergy's Quarterly Long-Term Groundwater Monitoring Reports.

IV. Consistent With the Approach Used in the 2010 FSEIS, the NRC Staff Should Base Its Impact Assessment of Radionuclides in Groundwater at Indian Point on a Comparison to NRC Dose Limits, Not to EPA's MCL-Derived Concentration Limits

As noted above, NRC regulations explicitly state that "[f]or the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered small" as the term is used in 10 C.F.R. Part 51.[32] By way of background, the NRC requires its reactor licensees to quantify all significant effluent discharges (including discharges to groundwater) and, based on site-specific characteristics, to determine the impact to public health and safety and to assure compliance with NRC dose limits. In addition to the radiation dose limits in 10 C.F.R. Part 20, specific requirements governing the release of radioactive liquid effluents are provided in 10 C.F.R. § 50.36a, and are detailed in Appendix I of 10 C.F.R. Part 50 ("Appendix I"). These requirements are structured to maintain the dose to members of the public from all radioactive effluent releases to levels that are as low as reasonably achievable ("ALARA").

The NRC regulates radioactive effluents from nuclear power plants based on the calculated doses resulting to members of the public from the effluents, rather than by setting a limit on the total volume or type of radioactive material discharged. Thus, licensees are required to establish radiological effluent release technical specifications ("RETS") that contain the ALARA dose criteria from Appendix I, which control the dose to members of the public.[33] As set forth in Appendix I, Section II, licensees must provide reasonable assurance that the following ALARA design objective will be met, for liquid effluents: The calculated annual quantity of all radioactive material above background to be released from each reactor to unrestricted areas will not result in an estimated annual dose or dose commitment from liquid effluents for any individual in an unrestricted area (*i.e.*, the hypothetical maximally exposed member of the public) in excess of (a) 3 mrem to the total body per year, or (b) 10 mrem to any organ per year.[34]

The NRC further requires nuclear power plant licensees to conduct an operational radiological environmental monitoring program ("REMP"), which directs the number and distribution of environmental sampling locations, the types of samples for collection, and the types of analyses to be performed for measurement of radioactivity.[35]The requirements of the REMP are specified in

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32 10 C.F.R. Part 51, Appendix B, Table B-1. *See also* NUREG-1437, "Final Generic Environmental Impact Statement for License Renewal of Nuclear Plants," Rev. 1, Vol. 1 at 4-136 (June 2013) ("For the purposes of assessing radiological impacts, impacts are considered to be SMALL if releases and doses do not exceed permissible levels in the NRC's regulations. This definition of SMALL applies to occupational doses as well as to doses to individual members of the public.").

33 The numerical design objectives of Appendix I to Part 50 are a fraction of the Part 20 limits. Thus, in practice, because the Part 50, Appendix I design objectives are far more restrictive than Part 20 allowable dose limits or effluent concentration levels, the Part 50, Appendix I ALARA objectives are controlling for power reactor licensees.

34 Appendix I also establishes requirements for demonstrating compliance with the design objectives, actions to be taken if the effluent releases in any calendar quarter exceed one-half of any of the annual design objectives and requirements to conduct surveillance and monitoring programs to demonstrate compliance.

35 The REMP is designed to: (1) enable the identification and quantification of changes in the radioactivity of the area, and (2) measure radionuclide concentrations in the environment attributable to plant operations regardless of the sources. The REMP supplements the radioactive effluent release program by verifying that any measurable concentrations of radioactive materials and levels of radiation in the environment are not higher than those calculated using the radioactive effluent release measurements

the licensee's RETS or Offsite Dose Calculation Manual ("ODCM"). At Indian Point, the ODCM specifies the radiological environmental monitoring activities that Entergy must perform as part of its REMP. To identify changes in activity, analyses are conducted for specific environmental media (*e.g.*, water, soil) on a regular basis. The radioactivity profile of the environment is established and monitored through routine evaluation of the results obtained.

Radiological releases, doses to members of the public, and the associated environmental impacts are summarized annually in two reports for IP2 and IP3: (1) the Annual Radioactive Effluent Release Report ("ARERR") and (2) the Annual Radiological Environmental Operating Report ("AREOR").[36] The ARERR describes the quantities of liquid and gaseous radioactive materials released to the environment during the calendar year, and must be consistent with the objectives outlined in Appendix I, Section IV.B.1. It also assesses the dose impact of radiological effluent releases into the environment, as calculated using radiation monitoring data and NRC-approved methods. The AREOR provides the means to verify the radiological concentrations in the environment resulting from plant operations, consistent with projections based on plant effluent releases, and essentially describes the results of the REMP for the previous year. It also serves to verify the calculated dose impacts from plant effluent releases.

In Entergy's view, the impact of radionuclide releases to groundwater at the Indian Point site should be evaluated within the context of the above-described regulatory framework. NRC regulations do not preclude releases to site groundwater, but instead require that licensees account for such releases, evaluate them relative to NRC regulatory requirements, and report the quantity of radioactivity released and the dose to the hypothetical maximally exposed member of the public. Thus, the NRC Staff's impact assessment in the Draft Supplement should focus on whether radionuclide releases to groundwater and associated doses exceed the permissible levels in NRC regulations.

Significantly, the NRC Staff used this approach in its 2010 FSEIS, wherein it concluded that the radiological impacts to human health resulting from radioactive effluent releases (including releases to groundwater) at Indian Point are "SMALL." In brief, in evaluating the radiological impacts of effluent releases to groundwater, the NRC Staff considered the results of Entergy's groundwater investigations and groundwater monitoring program as well as data from the REMP and Annual Radioactive Effluent Release Reports.[37] The Staff noted that "calculated doses to maximally exposed individuals in the vicinity of IP2 and IP3 were a small fraction of the limits specified in the IP2 and IP3 ODCM to meet the dose design objectives in Appendix I to 10 CFR Part 50, as well as the dose limits in 10 CFR Part 20 and EPA's 40 CFR Part 190."[38] Consistent

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and transport models. In this way, the REMP confirms whether or not plants are operating in accordance with applicable NRC requirements.

36 For Indian Point, these reports are available at http://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-specific-reports/ip2-3.html.

37 *See generally* 2010 FSEIS, § 2.2.7 ("Radiological Impacts"), at 2-104 to 2-114.

38 The Staff also discussed the NRC Region I inspection team's findings, documented in a final report dated May 13, 2008, concerning the radiological impacts of the spent fuel pool leaks. *See* 2010 FSEIS at 2-111. Among other things, the team found that there is no drinking water exposure pathway to humans that is affected by the contaminated groundwater conditions at Indian Point Energy Center, and that the annual calculated exposure to the maximum exposed hypothetical individual is expected to remain less than 0.1 % of the NRC's ALARA guidelines in Appendix I of Part 50 (3 mrem/year total body and 10 mrem/year maximum organ), which is considered to be negligible with respect to impacts on public health and safety and the environment. *See id.*

with the evaluation in FSEIS Section 2.2.7, the NRC Staff concluded that impacts to human health resulting from radionuclide releases to groundwater during the license renewal term are "SMALL."[39] That same conclusion—"SMALL"—should be reiterated in the Draft Supplement because the subsequent releases do not exceed NRC's permissible dose limits, as explained below.

V. The Radiological Impacts of Past Radionuclide Releases to Groundwater at Indian Point are Properly Categorized as "SMALL" Because the Resulting Doses Do Not Exceed the NRC's Permissible Dose Limits

By comparing measured radionuclide concentrations in site groundwater to EPA MCL-derived concentration limits, the NRC Staff incorrectly concluded in Section 5.4.3 of the Draft Supplement that the current impact on the onsite groundwater quality is "MODERATE." As explained above, the NRC Staff should compare the radionuclide concentrations and associated doses to the permissible levels specified in NRC regulations. Based on this appropriate comparison, it is clear that Indian Point is in compliance with the federal radiation protection standards set forth in Appendix I to 10 C.F.R. Part 50 and 10 C.F.R. Part 20.

In fact, Entergy continues to meet all NRC 10 C.F.R. Part 20 and Part 50, Appendix I requirements at Indian Point by a very wide margin.[40] This is evidenced, in part, by calculated doses reported in Indian Point's Annual Radioactive Effluent Release Reports for the years 2005 to 2014,[41] which include the April 2014 release near IP2 that is discussed in the Draft Supplement.[42] The combined groundwater and storm water dose remains less than 0.1 percent of the ALARA guidelines in Appendix I of 10 C.F.R. Part 50.[43] In this regard, the dose from groundwater and storm water is so small as to be inconsequential to human health or the environment. The Draft Supplement essentially acknowledges this fact, stating that "[m]easurements of the media

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[39] 2010 FSEIS at 2-112.

[40] As noted above, the 10 C.F.R. Part 50, Appendix I design objectives are 3 mrem to the total body and 10 mrem to any organ.

[41] The 2005 to 2010 and 2012 to 2014 reports are available at http://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-specific-reports/ip2-3.html. The 2011 report is available at http://pbadupws.nrc.gov/docs/ML1213/ML12132A122.pdf.).

[42] As discussed on page 57 of the Draft Supplement, in April 2014, elevated tritium was detected in three monitoring wells located near the building containing the IP2 spent fuel pool. The elevated levels of tritium are believed to have been caused by a floor drain that backed up during refueling activities in 2014. The backed-up water then came into contact with floor/wall joints that provided a pathway for the water to reach the groundwater. As the Draft Supplement further notes, groundwater monitoring program quickly detected the April 2014 leaks of tritium into the groundwater. Draft Supplement at 75.

[43] On pages 72 and 75 of the Draft Supplement, the NRC Staff states that "[s]hould onsite groundwater contamination remain after the period of license renewal, Entergy would be required to address any residual contamination during decommissioning of the facility, as necessary." Entergy concurs with this point. As discussed above, estimated doses due to the groundwater contamination at Indian Point are well below NRC dose limits, and are expected to remain so given the natural attenuation of radionuclide concentrations discussed above. In any case, at the end of licensed activities and facility decommissioning, the site will be required to meet the NRC's criterion for unrestricted use of the property. That dose limit includes the dose from drinking groundwater. The Indian Point licensee will be required to show that the site can meet this criterion before the license will be terminated for unrestricted use. In addition, it will need to show that the amounts of residual radioactivity have been reduced to ALARA levels. *See* 10 C.F.R. § § 20.1402; Final Rule, Radiological Criteria for License Termination, 62 Fed. Reg. 39,058, 39,081 (July 21, 1997).

comprising the waterborne pathway have indicated that there is *no radiological impact to the surrounding environment from the IP2 and IP3 site.*"[44]

With respect to the waterborne pathway, every agency that has investigated the potential impacts to human health of inadvertent releases of radionuclides to Indian Point groundwater has concluded that the only avenue for human exposure to such releases is the consumption of fish.[45] All investigations of radionuclides in fish found only background levels, with no identified contribution from Indian Point.[46] And, as documented in the Draft Supplement, every agency involved in the investigation of groundwater contamination at Indian Point has reached the same conclusion: there have been no impacts to public health from the inadvertent releases of radionuclides from the spent fuel pools to groundwater.[47] The complete absence of an actual threat to public health associated with those historic releases of radionuclides to groundwater should be given substantial weight in the impacts analysis.

The recent detection of elevated tritium levels in groundwater monitoring wells at IP2 does not alter the foregoing conclusions. Specifically, during preparations for the spring 2016 refueling outage at Unit 2, elevated levels of tritium were identified in certain wells near the Unit 2 Fuel Storage Building by Entergy's ongoing groundwater monitoring activities. Entergy promptly notified the NRC and Stakeholders and entered the event into the Indian Point corrective action program.[48] Entergy is conducting a root cause investigation of potential causes of the elevated tritium levels. While that investigation is ongoing, preliminary evidence indicates that the elevated tritium levels were associated with use of a temporary reverse osmosis skid used to filter water from the Unit 2 Refueling Water Storage Tank in preparation for the upcoming outage. Namely, effluent discharges from that evolution may have backed up near a floor drain and from there released to site groundwater. That evolution has concluded and, therefore, Entergy believes the release has been terminated. Entergy's bounding dose assessment for the 2016 release, based on information obtained to date, demonstrates that the combined groundwater and storm water dose at Indian Point remains less than 0.1 percent of the 3 mrem annual dose limit in Appendix I of 10 C.F.R. Part 50.

The NRC is inspecting Entergy's response through the resident inspectors and a specialist health physics inspector from the NRC's Region I office. Notably, on February 16, 2016, the Branch Chief for the NRC's Region I Division of Reactor Projects stated as follows in response to an inquiry from a member of the public regarding the 2016 leak:

> The NRC has determined that the current leak does not present a health and safety issue. The onsite groundwater flows west to the Hudson River. There are no public drinking water sources downstream of Indian Point as the

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44 Draft Supplement at 66 (emphasis added).

45 *See id.* at 66 (NRC Staff finding); *id.* at 67 (NYSDEC finding).

46 *See id.* at 68. Even early in the investigation, when concentrations of radionuclides were at their highest, Entergy's dose calculations were extremely small: the 2007 calculated doses to the public through fish consumption, confirmed by the New York State Department of Health, were less than one percent (1%) of the NRC dose limits that are protective of human health and the environment. *See id.*

47 *See id.* at 66.

48 *See* Event Notification Report, Event Number 51274, "Offsite Notification Via New Release Concerning Tritium Levels in Groundwater Monitoring Wells" (Feb. 10, 2016), *available at* http://www.nrc.gov/reading-rm/doc-collections/event-status/event/2016/20160211en.html#en51724.

Hudson River is brackish. Plant workers are also not impacted since local city water supply is used for potable water at the site. In addition, any tritium migrating to the Hudson River would be a small fraction of NRC liquid effluent release requirements. Unanticipated releases within NRC limits are permitted and these limits are in place to ensure that the health and safety of the public is maintained.[49]

In conclusion, the Commission has concluded that impacts are of small significance if doses and releases do not exceed permissible levels in NRC regulations. Therefore, in accordance with the preceding discussion, the NRC Staff should revise Section 5.4.3 of the Draft Supplement to incorporate (1) the appropriate comparisons of calculated doses to NRC dose limits, and (2) the consequent conclusion that the current impact of past radionuclide releases on groundwater quality is "SMALL."

VI. The NRC Staff Should Revise the Draft Supplement to Indicate That the Haverstraw Water Supply Project Has Been Abandoned at the Direction of the State of New York Public Service Commission

In Section 5.4.1.3 of the Draft Supplement, the Staff states that United Water has proposed to construct and operate a desalination facility in the town of Haverstraw, approximately 4 miles south-southwest and downstream of the Indian Point site.[50] This facility, referred to as the Haverstraw Water Supply Project, would provide desalinated (fresh) water from the Hudson River as a source of drinking water for Rockland County. In Section 5.14.4, the Staff concludes that it is unlikely that the proposed Haverstraw Water Supply Project would be adversely affected by groundwater discharging to the Hudson River at the Indian Point site, due to "the extremely low levels of contamination in the Hudson River that might result from the flow of groundwater into the river."[51] It further states that should the facility be built, United Water will be required to meet NYSDEC's permit requirements and EPA's drinking water standards, thus assuring public safety.[52]

Entergy agrees with the conclusions reached by the NRC Staff regarding the impact of Indian Point operation on the proposed Haverstraw Water Supply Project. However, Entergy notes that SUEZ Water New York Inc. (formerly United Water) has abandoned the project at the direction of the State of New York Public Service Commission ("NYPSC"), as there is no longer an immediate need for a new water supply source. This fact is documented in a December 18, 2015 NYPSC Order, and a December 21, 2015 letter from SUEZ Water New York Inc. to the NYPSC responding to the Order and stating that the company "hereby confirms abandonment of the plan to construct the desalination plant in the Town of Haverstraw."[53]

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[49] E-mail from Glenn Dentel, Branch Chief, Division of Reactor Projects, NRC Region I, to Paul Blanch, "Subject: RE: Tritium leak at Indian Point" (Feb. 16, 2016) (ADAMS Accession No. ML16050A318).

[50] *See* Draft Supplement at 56.

[51] *Id.* at 105-06.

[52] *Id.* at 106.

[53] *See* State of New York Public Service Commission, Case 13-W-0303 – Proceeding on Motion of the Commission to Examine United Water New York, Inc.'s Development of a New Long-Term Water Supply Source, "Order Adopting Alternative Demand/Supply Strategies and Abandoning Haverstraw Project (Issued and Effective December 18, 2015)"; Letter from Christopher J. Graziano, General Manager, SUEZ Water New York Inc., to the Honorable Kathleen Burgess, Secretary, New York State Public

In view of the aforementioned development, Entergy recommends that the discussion related to the Haverstraw Water Supply Project be removed throughout the Draft Supplement. Affected portions of the Draft Supplement include the following:

Section	**Page**	**Line(s)**
5.4.1.3	56	32 - 37
5.4.3	75	32
Table 5-5	96	NA
5.14.1.1	97	42 – 47
	98	1 - 3
5.14.3	102	41
5.14.4	105	45- 46
	106	1 - 4
5.14.6	107	9 - 19
9.0	144	7 - 10
		26 - 29

Service Commission, "RE: Case 13-W-0303 - Proceeding on Motion of the Commission to Examine United Water New York, Inc.'s Development of a New Long-Term Water Supply Source" (Dec. 21, 2015). The Order and letter are available at http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=13-w-0303.

ATTACHMENT 5 TO NL-16-021

COMMENTS RELEVANT TO NRC STAFF DISCUSSION OF

CERTAIN FEDERALLY-LISTED ENDANGERED AND THREATENED SPECIES

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 & 3
DOCKET NOS. 50-247 AND 50-286

Entergy Comments Concerning the NRC Staff's Evaluation and Characterization of Environmental Impacts to Certain Federally-Listed Terrestrial and Aquatic Species

I. Introduction

In its December 2010 Final Supplemental Environmental Impact Statement ("FSEIS") for the Indian Point Units 2 and 3 ("IP2" and "IP3") license renewal application, the Nuclear Regulatory Commission ("NRC") Staff concluded that the closed-cycle cooling alternative would have "SMALL" impacts on federally-listed endangered and threatened species, including the endangered Indiana bat (*myotis sodalis*), because "of the lack of evidence of [endangered or threatened] species existing at the facility."[1] Likewise, it concluded that the New York State-listed threatened bald eagle (*Haliaeetus leucocephalus*) was not present on the Indian Point site.[2] However, Algonquin Gas Transmission, LLC ("Algonquin") recently commissioned surveys in connection with its Algonquin Incremental Market Project ("AIM Project"), parts of which are located on the Indian Point site.[3] Those surveys establish that the Indiana bat and the recently listed threatened Northern Long-eared bat (*myotis septentrionalis*) are potentially present on the Indian Point site, and that the bald eagle is present on the site. Therefore, Entergy requests that in revising its December 2015 Draft Supplement (Volume 5) to the FSEIS in response to public comments,[4] the NRC Staff consider this information, and include an evaluation of the impacts of alternative actions (*e.g.*, the closed-cycle cooling alternative) on these federally-listed terrestrial species.

Additionally, in its first supplement to the FSEIS, the NRC Staff concluded that renewal of Indian Point's NRC operating license would have a "SMALL" impact on both the shortnose and Atlantic sturgeon. However, in the Draft Supplement, "the NRC now expresses results for ESA-listed species not as Small, Moderate, or Large, but in language prescribed by the [Endangered Species Act ("ESA")].[5] Specifically, the NRC Staff's impact findings for shortnose and Atlantic sturgeon are now characterized as "likely to adversely affect, but not jeopardize the continued existence" of both species.[6] For reasons explained further below, Entergy requests that the NRC Staff provide further explanation of this new characterization and, more importantly, clarify that given the demonstrated lack of entrainment and limited impingement impacts to these species, continued operation of IP2 and IP3 would not change the status or trend of the Hudson River population of either species, the population of the shortnose sturgeon as a whole, or the New York State Distinct Population Segment of Atlantic sturgeon.

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1 NUREG-1437, Supplement 38, Vol. 1, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3, Final Report," at 8-10 (Dec. 2010) ("FSEIS").

2 *See id.* at 2-89 to 2-90.

3 As discussed in the FSEIS, Algonquin owns and operates a natural gas pipeline that traverses a portion of the Indian Point site. *See* FSEIS at 8-7, 8-30, 8-61. Section 5.14 of the Draft Supplement discusses Algonquin's Aim Project, which involves construction and operation of a new 37.4-mile natural gas pipeline and associated equipment, in the context of cumulative impacts. *See* Draft Supplement at 95, 97-99, 106-111.

4 Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Supplement 38, Volume 5, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3 ("Draft Supplement").

5 *Id.* at 37.

6 *See, e.g., id.* at 37-38.

II. Comments Regarding Impacts to Federally-Listed Terrestrial Species

A. The Indiana Bat and Northern Long-eared Bat

In 2014, Algonquin commissioned a U.S. Fish and Wildlife Service ("FWS")-approved acoustic survey for the Indian bat and Northern Long-eared bat in connection with its AIM Project, parts of which are located on the Indian Point site.[7] As stated by the New York State Department of Environmental Conservation ("NYSDEC"), the Algonquin bat survey establishes that "both Indiana bats and the Northern Long-Eared [b]at may utilize the IPEC site as part of its summer habitat."[8]

The closed-cycle cooling alternative action reviewed in the FSEIS involves activities that are known to adversely affect both the Indiana bat and Northern Long-eared bat.[9] Specifically, construction of closed-cycle cooling at Indian Point is estimated to involve the elimination of 16 acres of forested land, blasting for 3 to 4 years and overall construction of six (6) years in duration within the forested area of the Indian Point site. In addition, the operation of closed-cycle cooling will increase noise levels within the remaining forested area on the site by at least 16 decibels (dBA).[10]

The FWS previously considered construction, tree clearing and noise activities in its consultation on the renewal of Indian Point's NRC operating license,[11] which underscores the potential for these activities to adversely affect both the Indiana bat and Northern Long-eared bat. Likewise, FERC's FEIS for the AIM Project stated that should bats be present in suitable summer habitat, tree clearing could potentially kill, injure, or disturb breeding or roosting bats and that bats could also be impacted by the loss of tree habitat or changes to vegetation if significant amounts of clearing were done.[12] These statements were made with respect to the AIM Project but they apply

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7 Barton & Loguidice, "Phase 2 Acoustic Survey for Indian Bats and Northern Long-Eared Bats. AIM Incremental Market (AIM) Project – New York, Connecticut, Rhode Island and Massachusetts" (Aug. 2014).

8 Rebuttal Testimony of Christopher M. Hogan: Permanent Mandatory Summertime Outages, *In the Matter of Entergy Nuclear Indian Point 2, LLC, and Entergy Nuclear Indian Point 3, LLC*, DEC Nos. 3-5522-00011/00004, 3-5522-00011/00030, & 3-5522-00105/00031 (Aug. 10, 2015) ("Hogan Rebuttal Testimony on Behalf of NYSDEC").

9 *See* FSEIS at 8-9 (internal citations omitted) ("Construction of the closed-cycle cooling alternative would entail clear cutting of onsite trees and excavation of areas for the two cooling towers as described in the Land Use section. These activities would destroy fragments of onsite eastern hardwood forest habitat. Effects of removing these habitats could include localized reductions in productivity or relocations of some species."); *see also id.* at 8-10 ("Entergy noted in its comments (included in Appendix A of this [F]SEIS) that constructing cooling towers may have an effect on the Indiana Bat or its habitat.").

10 *See* New York State Environmental Quality Review Act Entergy Response Document to the Tetra Tech Report and the Powers Engineering Report In Support of the Draft SEIS for a State Pollutant Discharge Elimination System (SPDES) Permit (No. NY-0004472) (Dec. 13, 2013); New York State Environmental Quality Review Act August Update Entergy Supplemental Environmental Report Permanent Mandatory Summertime Outages In Support of the Draft SEIS for a State Pollutant Discharge Elimination System (SPDES) Permit (No. NY-0004472) (Aug. 10, 2015) ("Entergy August 10 Response Document").

11 FWS Correspondence to David J. Wrona, NRC (July 14, 2015).

12 Federal Energy Regulatory Commission, "Algonquin Incremental Market Project Final Environmental Impact Statement (FEIS)," Volume 1 (2014).

as well to the construction and operation of closed-cycle cooling at Indian Point.[13] Finally, the FWS previously has agreed that "'noise may impact bats by interfering with echolocation, causing arousal during roosting or hibernation, inducing stress, causing avoidance of preferred habitats, or causing hearing loss.'"[14] For these reasons, sustained construction activities, including blasting, and the 16 dBA operational noise increases associated with the closed-cycle cooling alternative may adversely affect both the Indiana and Northern Long-eared bats.

Accordingly, Entergy respectfully requests that NRC revise and update the Draft Supplement to discuss the potential impacts of the closed-cycle cooling alternative action on both the Indiana and Northern Long-eared bat.

B. The Bald Eagle

In connection with the AIM Project, Algonquin also commissioned a survey of bald eagles.[15] Conducted in March and April 2014, the survey identifies a bald eagle wintertime roost on the southern edge of the Indian Point site and northern edge of Lent's Cove Park (near the forested block of the Indian Point site). NYSDEC has confirmed these findings.[16]

As with the Indiana and Northern Long-eared bats, the closed-cycle cooling alternative action reviewed in the 2010 FSEIS involves activities that are known to adversely affect the bald eagle. Specifically, the NYSDEC Draft Conservation Plan for Bald Eagles recognizes that new construction and blasting in the vicinity of bald eagle habitat, as required for the closed-cycle cooling alternative action, have the potential to adversely affect the bald eagle.[17]

Therefore, Entergy respectfully requests that NRC revise and update the Draft Supplement to discuss the potential impacts of the closed-cycle cooling alternative action on the bald eagle.

C. Conclusions Regarding Impacts of Closed-Cycle Cooling Alternative Action on the Indiana Bat, Northern Long-eared Bat, and Bald Eagle

Entergy is not aware of any reasonable mitigation for the impacts on the Indiana bat, Northern Long-eared bat and bald eagle of the protracted, continuous blasting that is necessary to install the closed-cycle cooling alternative. Entergy therefore respectfully requests that NRC revise Table 8-1 ("Summary of Environmental Impacts of a Closed-Cycle Cooling Alternative at IP2 and IP3") of the 2010 FSEIS (FSEIS Volume 1) to account for the unmitigated impacts that the closed-cycle cooling alternative action would have on the endangered and threatened species present at the Indian Point site, as presented above.

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[13] Entergy August 10 Response Document.

[14] FWS Correspondence to Peter Rowland, US Army (Feb. 14, 2012).

[15] Spectra Energy Partners, "Bald Eagle Survey Report for the Algonquin Incremental Market Project" (May 5, 2014).

[16] *See* Hogan Rebuttal Testimony on Behalf of NYSDEC.

[17] *See* NYSDEC, "Draft Conservation Plan for Bald Eagles" (Feb. 23, 2015).

III. Comments Regarding Draft Supplement Characterization of Impacts to the Federally-Listed Shortnose and Atlantic Sturgeon

In Supplement 1 (Volume 4) to the FSEIS, issued in June 2013, the NRC Staff concluded that renewal of Indian Point's NRC operating license would have a "SMALL" impact on both the shortnose and Atlantic sturgeon.[18] The NRC Staff's finding was based on National Marine Fisheries Service's ("NMFS") 2013 Biological Opinion,[19] which found that renewal of Indian Point's NRC operating license would not change the status or trend of the Hudson River population of either species, the population of the shortnose sturgeon as a whole, or the population of the New York State Distinct Population Segment of Atlantic sturgeon.[20] Consistent with the 2013 Biological Opinion, Entergy developed and submitted a draft monitoring plan for sturgeon and is currently waiting for NMFS' review and approval of that plan.

The Draft Supplement presents "no information ...that would further resolve the impact levels" to sturgeon.[21] However, based on guidance provided in the NRC's 2013 revised Generic Environmental Impact Statement ("GEIS") for license renewal,[22] the NRC Staff recharacterizes the impact to match the federal ESA finding.[23] The NRC Staff's impact findings for shortnose and Atlantic sturgeon are now characterized as "likely to adversely affect, but not jeopardize the continued existence" of both species.[24] NRC also states that it directly incorporated the conclusions of the 2013 Biological Opinion into the Draft Supplement.[25] Entergy recommends that, in revising the Draft Supplement in response to public comments, the NRC Staff provide additional explanatory information on this issue.

Specifically, to provide greater clarity, Entergy requests that the NRC Staff briefly explain the extremely limited extent to which sturgeon interact with the Indian Point cooling water intake structure. It is important to underscore that, as NMFS found, Indian Point has never entrained shortnose or Atlantic sturgeon eggs or larvae.[26] The eggs of both species typically are not present in the Indian Point vicinity and are demersal—sinking and adhering to the bottom of the river. The

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[18] NUREG-1437, Vol. 4, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants Supplement 38 Regarding Indian Point Nuclear Generating Units Nos. 2 and 3. Final Report – Supplemental Report and Comment Responses, at 8-9, 24, 29-30 (June 2013) ("FSEIS Supplement 1").

[19] NMFS, Biological Opinion for Continued Operations of Indian Point Nuclear Generating Unit Nos. 2 and 3. (Jan. 30, 2013) ("NMFS 2013 Biological Opinion").

[20] *See* FSEIS Supplement 1 at 24, 29.

[21] Draft Supplement at 37.

[22] NUREG-1437, Rev. 1, Vol. 1, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants—Final Report," at 2-18 (June 2013) ("GEIS").

[23] *See id.* ("Based on the guidance contained in the GEIS update, the NRC now expresses results for ESA-listed species not as Small, Moderate, or Large, but in language prescribed by the ESA. To be consistent with the NRC's updated practice, the NRC staff's new analysis incorporates the conclusions of NMFS's biological opinion concerning the effects of IP2 and IP3 cooling water system operation on the endangered Atlantic and Shortnose sturgeon.").

[24] *Id.* at 37-38 & Appendix A at A-32 to A-33, A-41 to A-42.

[25] *See id.* at 37.

[26] *See* NMFS 2013 Biological Opinion.

larvae of shortnose and Atlantic sturgeon reside in the deep channels of the Hudson River, where they are not susceptible to entrainment.

Healthy juvenile and adult sturgeon are strong swimmers that NMFS concluded are able to readily avoid Indian Point's intake structure.[27] For this reason, the NMFS 2013 Biological Opinion concluded that only the smallest juveniles would be susceptible to passing through the Indian Point trash racks, and they then would be picked up by the IP2 and IP3 specially design Ristroph screens, at which point they would be returned to the River through Indian Point's state of the art fish return system.[28] The Environmental Protection Agency ("EPA") has determined that Indian Point's Ristroph screens constitute the Best Technology Available for addressing impingement mortality, particularly of armored species such as sturgeon.[29] In EPA's own words, Indian Point's modified Ristroph screens "feature capture and release modifications"—they are "fitted with troughs ... containing water that catch the organisms" and "a low-pressure spray" is used to "remove impinged fish gently from the collection buckets" and return them to the source waterbody.[30]

The NMFS 2013 Biological Opinion also recognized that only dead or moribund shortnose and Atlantic sturgeon are impinged on the IP2 or IP3 trash racks, because such fish, if healthy, have the swimming capability to avoid impingement.[31] This conclusion has been demonstrated since issuance of the NMFS 2013 Biological Opinion: On February 25, 2015, divers removing debris in the River in front of the Indian Point Unit 2 trash rack found one dead adult Atlantic Sturgeon in a state of moderate decomposition.[32]

Based on the lack of entrainment and limited impingement impacts, NMFS determined that Indian Point's current operations would not change the status or trend of the Hudson River population of either species, the population of the shortnose sturgeon as a whole, or the New York State Distinct Population Segment of Atlantic sturgeon.[33] As NMFS recently noted "[t]he Hudson River shortnose sturgeon population is currently considered to be the largest extant population," with estimates ranging from 52,898-72,191 adults.[34] NMFS's recent statement underscores what the peer-reviewed and published studies have consistently concluded—the Hudson River population of shortnose sturgeon has recovered. For example, such studies have concluded as follows:

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[27] *See id.*

[28] *See id.*

[29] *See* EPA Final Rule, National Pollutant Discharge Elimination System—Final Regulations To Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities, 79 Fed. Reg. 48,300 (Aug. 14, 2014).

[30] *Id.*

[31] *See* NMFS 2013 Biological Opinion.

[32] Correspondence from Mark Mattson to Peter Kelliher, NOAA (Mar. 2, 2015).

[33] *See* NMFS 2013 Biological Opinion.

[34] NMFS, Endangered and Threatened Wildlife; 12-Month Finding on a Petition To Identify and Delist a Saint John River Distinct Population Segment of Shortnose Sturgeon Under the Endangered Species Act, 80 Fed. Reg. 65,183 (Oct. 26, 2015).

- "Our results suggest that shortnose sturgeon of the Hudson River have experienced several strong year-classes concomitant with the observed population recovery during the 1980s and 1990s."[35]

- "Our [Hudson River shortnose sturgeon] population estimates exceed the government and scientific population recovery criteria by more than 500%."[36]

- "As the demographic parameters have been exceeded and the spawning and overwintering habitats appear stable, some biologists have recommended that the Hudson River population be designated as a distinct population segment and removed from the endangered species list as recovered species."[37]

35 Woodland and Secor, "Year-Class Strength and Recovery of Endangered Shortnose Sturgeon in the Hudson River," New York, Transactions of the American Fisheries Society, 136:72-81 (2007).

36 Bain et al, "Recovery of a US Endangered Fish", PLoS ONE 2(1): e168 (2007).

37 Center for Biological Diversity, "Endangered Species Act Work."http://www.biologicaldiversity.org /campaigns/esa_works/profile_pages/ShortnoseSturgeon.html. (Last visited Jan. 29, 2015).

ATTACHMENT 6 TO NL-16-021

MISCELLANEOUS COMMENTS ON

OTHER SECTIONS OF THE DRAFT SUPPLEMENT

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 & 3
DOCKET NOS. 50-247 AND 50-286

Entergy's Miscellaneous Comments On Other Sections of the Draft Supplement

- In Section 5.5, page 76, lines 17-18, the Draft Supplement states: "Entergy further monitors areas with the potential for spills of oil or other regulated substances under a Spill Prevention, Control, and Countermeasure Plan [SPCC] ...." Since IP2 and IP3 each have a SPCC, Entergy suggests that the NRC Staff revise this statement as follows: "Entergy further monitors areas at **IP2 and IP3** with the potential for spills of oil or other regulated substances under ~~**a**~~ **each unit's** Spill Prevention, Control, and Countermeasure Plan ...."

- In Section 5.5, page 76, lines 20-22, the Draft Supplement states: "Collectively, these measures ensure that the effects to terrestrial resources from pollutants carried by stormwater would be minimized during the proposed license renewal term." Since no impacts to terrestrial resources were identified, Entergy suggests that the NRC Staff revise this statement as follows: "Collectively, these measures ensure that ~~**the effects to terrestrial resources from**~~ pollutants carried by stormwater ~~**would be minimized**~~ **are unlikely to have any adverse effects on terrestrial resources** during the proposed license renewal term."

- In Section 5.11, page 82, lines 37-39, the Draft Supplement states: "Wastewater discharges from IP2 and IP3, including wastewater that may contain minimal amounts of chemicals or metals, are controlled in accordance with a water discharge permit issued by the State of New York." Given that Entergy Indian Point has multiple SPDES permits, Entergy suggests that the NRC Staff revise this statement to read: "Wastewater discharges from IP2 and IP3, including wastewater that may contain minimal amounts of chemicals or metals, are controlled in accordance with **a** water discharge permit**s** issued by the State of New York."

- In Section 5.14.3, page 104, lines 16-27, Entergy suggests that the NRC Staff consider noting (as it did in the context of discussing seismic hazards) that flooding hazards are evaluated under an ongoing NRC oversight program, and flooding hazard evaluation is not within the scope of license renewal.

- In connection with Section 5.14.5, page 106, lines 10-21, Entergy suggests that the NRC Staff distinguish between current impacts on terrestrial resources resulting from IP2 and IP3 operation, and *cumulative* impacts on terrestrial resources from past, present and foreseeably projects, by including a statement similar to the following: "**As previously discussed in Section 5.5, the NRC Staff concluded that the incremental impacts to terrestrial resources from the proposed license renewal of IP2 and IP3 would be SMALL.**"

- In Section 6.1.2, page 122, line 16, the citation to "10 CFR 51.**2353**(c)(3)(iii) and (iv)" is incorrect and should be changed to "**10 CFR 51.53(c)(3)(i) and (iv)**."

Appendix 2A:

Hudson River Rainbow Smelt Population Projection Model for Examining Conditions that Could Have Led to Catastrophic Decline

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March 2016

Table of Contents

I. Introduction

As noted in Daniels et.al. (2005), rainbow smelt larvae and juveniles that once were abundant in the Hudson River, all but disappeared from samples collected by the Hudson River Biological Monitoring Program beginning in 1996.

This report describes the development and use of a population projection model to formulate a hypothesis regarding the possible cause of that catastrophic decline. The model was intended to ascertain whether one or a series of unusual events affecting specific year classes of rainbow smelt could have led to the catastrophic loss of rainbow smelt from the Hudson River.

II. Historical Patterns of Abundance

Annual riverwide abundance of rainbow smelt larvae and juveniles in the Hudson River was estimated for the years 1974-2011, based on data from the Longitudinal River Survey ("LRS") of the Hudson River Biological Monitoring Program ("HRBMP"). The LRS used a stratified random sampling design to sample three habitat strata (bottom, channel and shoal) in 12 geographic regions (in all years of the program) that compose the Hudson River from the Federal Dam at Troy, New York to the George Washington Bridge. The LRS used ichthyoplankton nets with 1.0 square meter mouth openings and 505 micron mesh for sampling. Weeks of sampling by the LRS varied among years, with weeks 17 (end of April) through 27 (end of July) sampled in all years.

The average riverwide abundance from weeks 17 through 27 was computed as the measure of annual abundance ($\overline{A}_y$):

$$\overline{A}_y = \sum_{w=17}^{27} \hat{A}_{y,w} \tag{1}$$

Week-specific estimates of riverwide abundance ($\hat{A}_{y,w}$) were computed as the sum of region- and strata-specific abundance estimates ($\hat{A}_{y,w,r,s}$):

$$\hat{A}_{y,w} = \sum_{r=1}^{12}\sum_{s=1}^{3} \hat{A}_{y,w,r,s} = \sum\sum \overline{D}_{y,w,r,s} \times V_{r,s} \tag{2}$$

where the region- and strata-specific abundance estimates were calculated as the product of the mean density, $\overline{D}_{y,w,r,s}$ (number per m^3 sampled) and the river volume, $V_{r,s}$, (m^3) within the corresponding region and strata (from ASAAC 2016).

From 1974 through 1995, the abundance of rainbow smelt larvae and juveniles in the Hudson River exhibited considerable inter-annual variability (Figures 1 and 2), but no statistically significant trend. The estimated slope, based on ordinary least-squares

regression with larval annual abundance as the response variable and year as the predictor variable, was positive but not significant with linear or log-transformed response variables.

In 1996, the Hudson River population of rainbow smelt exhibited a catastrophic decline in abundance, from a high during the HRBMP-monitored years of almost 100 million larvae (an 11 week average) in 1994 to fewer than one thousand per year on average from 1996 through 2011. Among all fish species collected by the LRS, this pattern of catastrophic decline was unique to rainbow smelt.

Statistical tests were conducted to determine whether the catastrophic decline of smelt was unique among species in the Hudson River. Specifically, parametric (ANOVA with F-statistic) and non-parametric (Wilcoxon rank-sum test with Z-statistic (Conover 1971)) tests for differences in average larval abundance, 1974-1995 (Period 1) versus 1996-2011 (Period 2), were conducted for 33 common taxa reported by the LRS. Very infrequently caught taxa were not included in the analysis because the results for those taxa could have been determined by the collection of just a few individual larvae. Common taxa were defined as having a catch frequency of least 1 larva collected per 100 samples in either Period 1 or Period 2. Eighteen of the 33 common taxa had statistically significant (0.05 probability level based on either the parametric or non-parametric test) changes in average abundance between the two periods of years (Table 2). Of the 18 taxa with statistically significant changes in average larval abundance, 12 exhibited increases and 6 exhibited decreases. No taxa other than rainbow smelt exhibited a catastrophic decline (near extirpation) in larval abundance between the two periods of years.

These historical patterns of abundance for rainbow smelt, as compared to other fish species inhabiting the Hudson River, strongly support the conclusion that a severe species-specific event, or series of events, caused the sudden catastrophic decline in rainbow smelt abundance. What caused the near extirpation of rainbow smelt from the Hudson River was sudden and did not affect the other species.

III. Population Projection Model

The population projection model used for this assessment was a deterministic, age-structured, Leslie Matrix model with six age classes. The model projected expected age-specific abundances in year, $t+1$, based on the age-specific abundances in year, t, and age-specific estimates of fecundity and survival:

$$\begin{pmatrix} F_0 & F_1 & F_2 & F_3 & F_4 & F_5 \\ P_0 & 0 & 0 & 0 & 0 & 0 \\ 0 & P_1 & 0 & 0 & 0 & 0 \\ 0 & 0 & P_2 & 0 & 0 & 0 \\ 0 & 0 & 0 & P_3 & 0 & 0 \\ 0 & 0 & 0 & 0 & P_4 & 0 \end{pmatrix} \times \begin{pmatrix} N_0 \\ N_1 \\ N_2 \\ N_3 \\ N_4 \\ N_5 \end{pmatrix}(t) = \begin{pmatrix} N_0 \\ N_1 \\ N_2 \\ N_3 \\ N_4 \\ N_5 \end{pmatrix}(t+1) \qquad (3)$$

where,

N_i = number of fish entering age class, i,
N_0 = number of eggs spawned,
F_i = annual number of eggs spawned by one age-i fish
P_i = proportion of age-i fish that survive to age, $i+1$.

This population projection model is non-negative, irreducible and primitive[1] and therefore has a dominant eigenvalue (Caswell 2001). The characteristic equation of this population projection model (Caswell 2001) is:

$$1 = F_0\lambda^{-1} + \sum_{i=1}^{5}\left[\left(\prod_{j=0}^{i-1} P_j\right) F_i \lambda^{-(i+1)}\right] \quad (4)$$

where,

λ = dominant eigenvalue of the projection matrix,
$\lambda = e^r$, and
r = intrinsic rate of population increase, and

for a stationary population, $r = 0$ and $\lambda = 1$. Because the rainbow smelt population exhibited no statistically significant trend in abundance prior to the collapse in 1996, the intrinsic rate of increase was assumed to be zero. In this case, and with all age-0 fish being immature, (i.e., $F_0 = 0$), equation (4) can be rewritten as:

$$\frac{1}{P_0} = \sum_{i=1}^{5}\left[\left(\prod_{j=1}^{i-1} P_j\right) F_i\right] \quad (5)$$

The right-hand side of equation (5) is the expected number of eggs per age-1 recruit (males and females), and the left-hand side of equation (5) is the inverse of the age-0 survival fraction (from eggs to age-1).

This relationship between eggs per recruits and age-0 survival is well recognized as a basis for estimating age-0 survival in stationary fish populations. For example, Boreman (1997) described the following approach for estimating the age-0 survival fraction as a function of the number of eggs per female recruit:

> "To maintain stationary population abundance, i.e., population abundance that is neither increasing nor declining over generations, the survival rate of a female egg to age 1 (S_0) must be equal to two times the reciprocal of the *EPR*-value (assuming the sex ratio of deposited eggs is 50:50), so that: *EPR* x $S_0 = 2$." (Boreman, 1997)

[1] The word "primitive" in this context is a technical term for the property of a matrix to become positive when raised to a sufficiently high power (Caswell 2001).

Note that with at 50:50 sex ratio, the number of eggs per recruit (including males and females) is half the number of eggs per female recruit. Eggs per female recruit (EPFR) can be calculated (Boreman, 1997) as:

$$EPFR = \sum_{i=1} \rho_i \varphi_i \prod_{j=1}^{i-1} e^{-(z_j)} \left(\frac{1}{\gamma} \right) \tag{6}$$

where,

ρ_i = proportion of females mature at age, *i*,

φ_i = average fecundity (number of eggs) of a mature age-*i* female,

Z_j = instantaneous mortality rate for age, *j*.

γ = interval (years) between successive spawnings per female

The terms in equation (6) are related to the terms in equation (5) as follows:

$$F_i = \frac{\rho_i \varphi_i}{\gamma}, \tag{7}$$

$$P_j = e^{-(z_j)} \quad j=1 \text{ to } 5, \text{ and} \tag{8}$$

$$P_0 = S_0 \tag{9}$$

where P_0 is the product of the hatching success rate (H) and the survival fractions for eggs (S_{eggs}), larvae (S_{larv}) and juveniles (S_{juv}):

$$P_0 = H \times S_{egg} \times S_{larv} \times S_{juv} \tag{10}$$

IV. Input Parameter Estimates

A. Inputs to Eggs per Recruit Estimates

Fecundity at age (φ_i) estimates (eggs per mature female per year) were computed using the relationship from Dunstall (1980), as reported in Lantry and Stewart (1993):

$$\log_{10}(\varphi_i) = 2.97 \log_{10}(L_i) - 2.43 \tag{11}$$

Mean length at age (L_i) was taken from Murawski (1976), as reported in Buckley (1989) for rainbow smelt (sexes combined) from the Parker River, Massachusetts.

Age-specific survival fractions (P_j) for ages 1-5 were estimated as the average of five lake-specific estimates of age-specific survival fractions from Lantry and Stewart (1993). All surviving age-2 and older rainbow smelt were assumed to be sexually mature, i.e., $\rho_i = 1$ for $i = 2 - 5$, and to spawn every year, i.e., $\gamma = 1$ (Lantry and Stewart 1993). The assumed percentage of mature age-1 rainbow smelt was set to 17% so that 26% of spawners each year

were age-1 (Murawski (1976), as reported in Buckley (1989) for the Parker River, Massachusetts).

B. Inputs to Stage-Specific Age-0 Survival Estimates

An estimate of the egg hatching success rate of 3.6% was taken from McKenzie (1964), as reported in Buckley (1989) for the Miramichi River, Maine. The survival fraction from hatching to the beginning of the larval stage (S_{egg}) was assumed to be 1% (Rupp 1965 as reported in Lantry and Stewart 1993). Estimates of the survival fraction from the beginning of the larval life stage to the beginning of the juvenile life stage (S_{larv} = 0.32), and from the beginning of the juvenile stage to age-1 (S_{juv} = 0.34) were computed as the average of five lake-specific estimates of stage-specific survival fractions reported in Lantry and Stewart (1993).

C. Intermediate Calculations and Calibration

The expected number of eggs per recruit was calculated using equation (5) to be 8,572, which corresponds to a stationary population age-0 survival fraction of P_0 = 0.00011666. The age-0 survival fraction for the model was calibrated to equal the inverse of the calculated eggs per recruit by adjusting the survival fraction from hatching to the beginning of the larval stage from the literature value of 1% to 3.01%. The calibrated age-0 survival fraction expressed as an instantaneous mortality rate is Z_0 = 9.06.

Because the population projection model was non-negative, irreducible and primitive, the projections were ergodic (Caswell 2001), i.e., the asymptotic behavior of the model projections did not depend on the initial age distribution, and the projections converged to a stable age distribution. Although the projections converged to the same stable age distribution (proportion in each age class) regardless of the initial age distribution, the stable age distribution was scaled based on the scale of the initial distribution. For this assessment, the initial age distribution was scaled so that the asymptotic average larval abundance was equal to the historical average larval abundance for Period 1 (i.e., 21,272,714). The projected average larval abundance in each year was calculated (Ricker 1978) as:

$$\overline{N}_{larv} = \left(N_0 \times H \times S_{egg}\right)\frac{\left(1-e^{-Z_{larv}}\right)}{Z_{larv}} \qquad (12)$$

where $Z_{larv} = -\ln\left(S_{larv}\right)$.

The initial age distribution was set to 1960 so that the stable age distribution had been attained by 1974 (the first year of historical data).

V. Population Projections

The population projection model was run with four scenarios. Each scenario was defined in terms of the reproductive failure of one or more year classes of rainbow smelt. The complete loss of a year class due to high mortality prior to age-1 (the first reproductive age) would result in reproductive failure of that year class. However, even if a year class survived, but was unable to produce any viable eggs, it would exhibit reproductive failure as well. Reproductive failure of a year class was modeled by setting the eggs produced by that particular year class to zero in all years.

The first scenario was that only one year class, the 1995 year class, suffered reproductive failure. The projection for that scenario is depicted in Figure 3. The results indicate that if only the 1995 year class suffered reproductive failure, then the projected larval abundance starting in 1996 would have declined and stabilized to a level of about 12 million (down from 21 million on average prior to 1996).

The second scenario was that four year classes, the 1992 through 1995 year classes, suffered reproductive failure. The projection for that scenario is depicted in Figure 4. The results indicate that if the 1992 through 1995 year classes all suffered reproductive failure, then the projected larval abundance starting in 1996 would have declined drastically and stabilized to a level of about 70 thousand.

The third scenario was that five year classes, the 1991 through 1995 year classes, suffered reproductive failure. The projection for that scenario is depicted in Figure 5. The results indicate that if the 1991 through 1995 year classes all suffered reproductive failure, then the projected larval abundance would have dropped to zero starting in 1996.

The third scenario was that six year classes, the 1990 through 1995 year classes, suffered reproductive failure. The projection for that scenario is depicted in Figure 6. The results indicate that if the 1990 through 1995 year classes all suffered reproductive failure, then the projected larval abundance would have dropped to zero starting in 1995.

VI. Discussion

The population projection model runs indicate that the reproductive failure of five consecutive year classes leading up to 1996 could have caused the catastrophic near-extirpation of the Hudson River rainbow smelt stock. The results also indicate that the reproductive failure of fewer than five consecutive year classes could have caused drastic declines in larval abundance. However, with fewer than five consecutive years of reproductive failure, the population model predicted that after the years of reproductive failure, the population would have persisted albeit at a lower level of abundance. The results from the model runs for those scenarios are not consistent with the historical larval abundance estimates of zero in most years beginning in 1996. Results from the model run with six consecutive years of reproductive failure beginning in 1990 are not consistent with

the historical pattern of abundance estimates either. For that scenario the model projected zero larvae in 1995, whereas the historical larval abundance estimate for 1995 was over 5 million, not becoming zero until 1996.

The population projection model did not distinguish between, and did not need to distinguish between, reproductive failure due to: 1) complete mortality of a year class prior to age 1, and 2) survival past age 1 with the inability to produce viable eggs. However, data from the Fall Shoals Survey ("FSS") of the HRBMP indicate that few rainbow smelt survived past age 1 in the late-1990's. The FSS used a sampling design similar to the LRS, but sampled weeks later in the year with sampling gear designed to collect juvenile and older fish. The estimated average riverwide abundance of yearling and older rainbow smelt collected by the FSS during consistent weeks of sampling was approximately 140,000 for the period 1974-1995. However, none were collected from 1996 through 2011. If the 1991-1995 year classes suffered reproductive failure, but survived nonetheless, some members of those year classes should have been present as yearling and older fish from 1996 through 2000.

The population projection model used for this assessment was fairly simple, with stationary survival and fecundity rates and no terms for density dependent mortality, stochastic inter-annual variability, or re-colonization of the river by other rainbow smelt stocks. Accordingly, it was not intended to reflect all of the dynamics of the Hudson River rainbow smelt population. Rather, it was intended to provide insight into the pattern of reproductive failures that could have caused a catastrophic decline like the one suffered by the Hudson River rainbow smelt stock.

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VIII. Tables

Table 1. Taxa of Hudson River larvae with statistically significant (0.05 probability level based on either parametric or non-parametric test) changes in average riverwide abundance between two periods of years: 1974-1995 and 1996-2011. Results of statistical tests are listed for all taxa reported by the LRS that had at catch frequency of least 1 larva collected per 100 samples in either Period 1 or Period 2.

Taxon	Average Riverwide Abundance (number of larvae) Weeks 17 through 27		Abundance Ratio (Period 2 divided by Period 1)	Parametric ANOVA Test for Different Period Means		Non-Parametric Wilcoxon Rank-Sum Test for Different Period Means		Catch Frequency (ave. number collected per 100 samples)	
	Period 1 (1974-1995)	Period 2 (1996-2011)		Test Statistic (F)	Probability Level	Test Statistic (Z)	Probability Level	Period 1	Period 2
River Herring	768,509,633	329,964,252	0.4294	20.807	<.0001	-4.095	<.0001	20,954.35	11,081.37
White Perch	389,179,995	288,063,829	0.7402	3.947	0.0546	-2.439	0.0147	12,811.09	9,308.52
Striped Bass	330,979,974	1,124,808,755	3.3984	18.810	0.0001	3.858	0.0001	9,778.27	37,947.25
American Shad	34,122,826	5,381,977	0.1577	25.659	<.0001	-4.716	<.0001	920.85	170.35
Morone Unidentified	21,536,633	73,843,325	3.4287	12.509	0.0011	3.592	0.0003	663.52	2,442.65
Rainbow Smelt	21,272,714	982	<.0001	8.591	0.0058	-5.272	<.0001	709.20	0.04
Atlantic Tomcod	12,949,692	3,516,161	0.2715	8.546	0.0060	-2.380	0.0173	462.92	168.32
Gobiidae Gobies	4,774,041	13,596,664	2.8480	2.640	0.1129	3.438	0.0006	118.00	457.89
Winter Flounder	720,374	955,673	1.3266	0.605	0.4419	2.114	0.0345	13.38	35.51
Weakfish	646,226	3,805,047	5.8881	9.587	0.0038	3.624	0.0003	19.39	149.72
Carp	376,502	1,420,773	3.7736	12.420	0.0012	3.787	0.0002	7.68	36.07
Atlantic Menhaden	204,926	2,991,270	14.597	4.622	0.0384	3.744	0.0002	7.98	98.30
Gizzard Shad	201,732	2,151,333	10.664	3.523	0.0686	4.281	<.0001	6.37	82.84
Windowpane	120,945	235,701	1.9488	2.066	0.1593	2.796	0.0052	2.75	6.90
Conger Eel	49,634	34,398	0.6930	0.327	0.5709	2.182	0.0291	1.28	1.11
Walleye	7,957	91,948	11.556	3.593	0.0661	3.274	0.0011	0.25	3.13
Tautog	6,253	100,776	16.115	9.203	0.0045	3.787	0.0002	0.18	3.00
Freshwater Drum	293	496,655	1,696.7	12.850	0.0010	5.150	<.0001	0.03	17.03

Table 2. Average (over 5 lakes) annual mortality fractions for age 1-5 rainbow smelt (from Lantry and Stewart, 1993), and mean total lengths (mm), sexes combined from the Parker River in Massachusetts (from Murawski (1976) as reported in Buckley (1989)). .

Age Class	Mortality Fraction	Mean Total Length (mm)
1	0.5474	141
2	0.6942	192
3	0.8192	213
4	0.8876	240
5	0.8893	245

IX. Figures

Figure 1. Historical pattern of larval rainbow smelt abundance in Hudson River (blue bars), with ordinary least-squares regression trend line (red line). Orange dashed vertical line indicates timing of catastrophic decline.

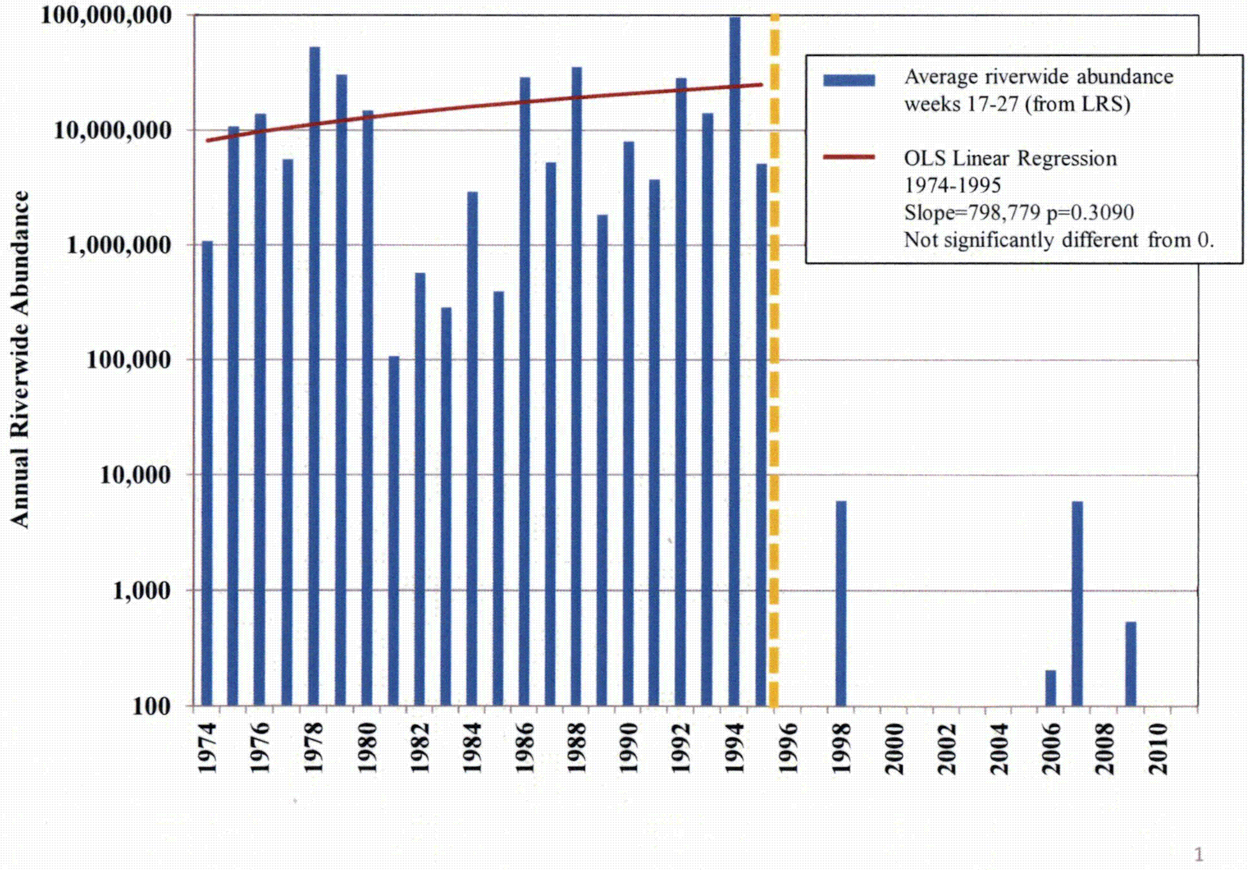

Figure 2. Historical pattern of larval rainbow smelt abundance in Hudson River (blue bars), with ordinary least-squares regression trend line based on log_{10}-transformed abundance estimates (red line). Orange dashed vertical line indicates timing of catastrophic decline.

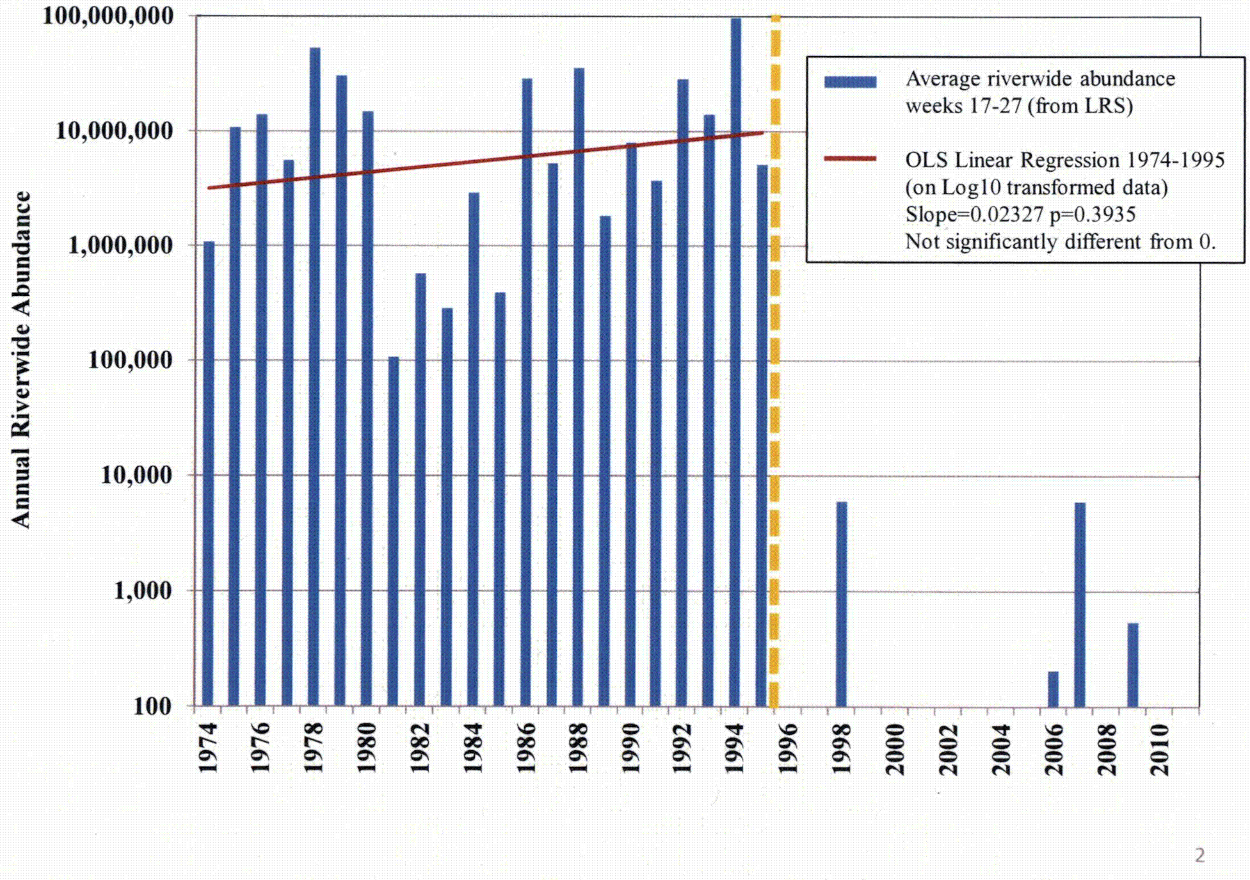

Figure 3. Projected rainbow smelt larval abundance (blue bars) assuming reproductive failure of the 1995 year class. Orange dashed vertical line indicates historical timing of catastrophic decline.

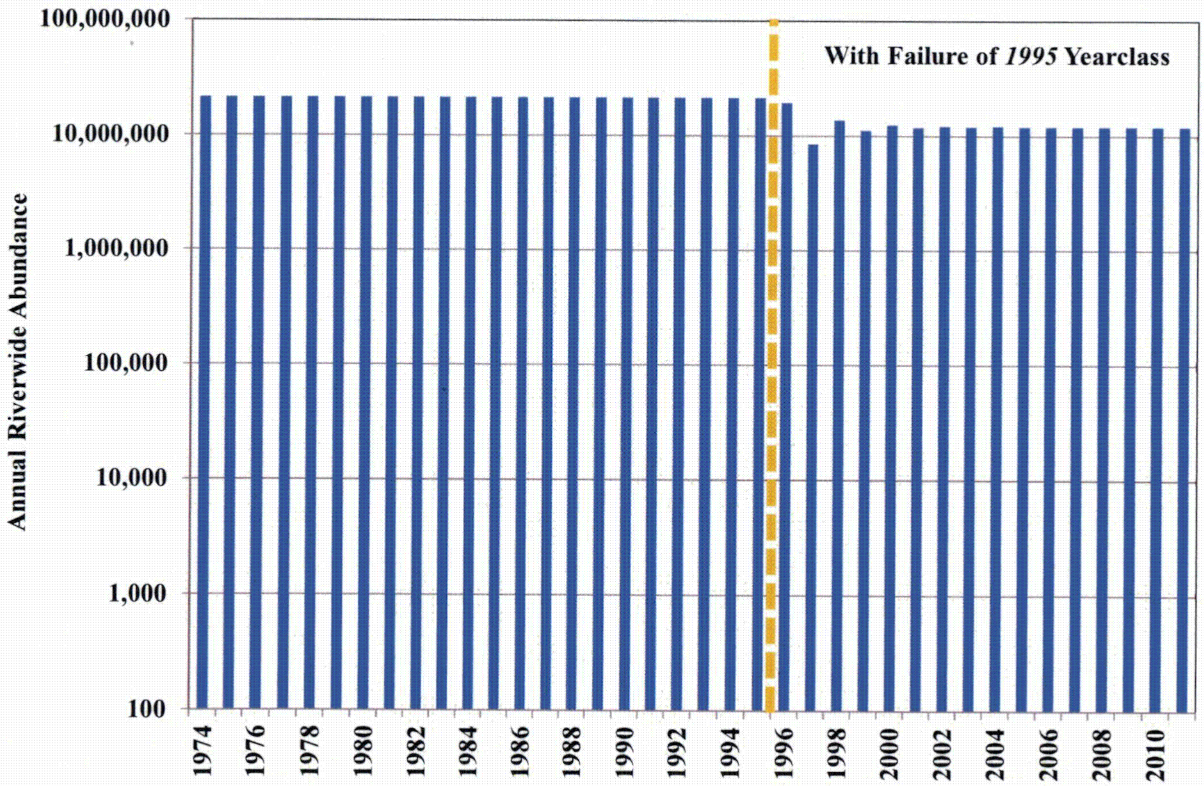

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Figure 4. Projected rainbow smelt larval abundance (blue bars) assuming reproductive failure of the 1992 through 1995 year classes. Orange dashed vertical line indicates historical timing of catastrophic decline.

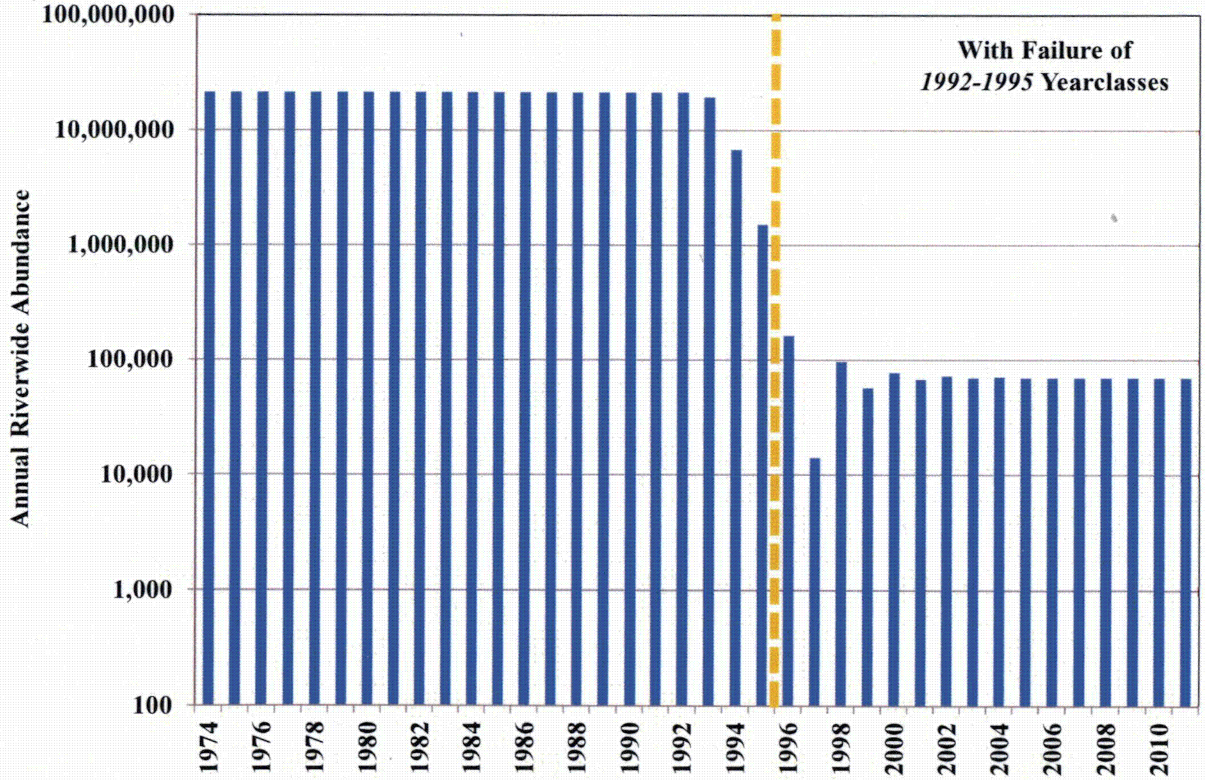

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Figure 5. Projected rainbow smelt larval abundance (blue bars) assuming reproductive failure of the 1991 through 1995 year classes. Orange dashed vertical line indicates historical timing of catastrophic decline.

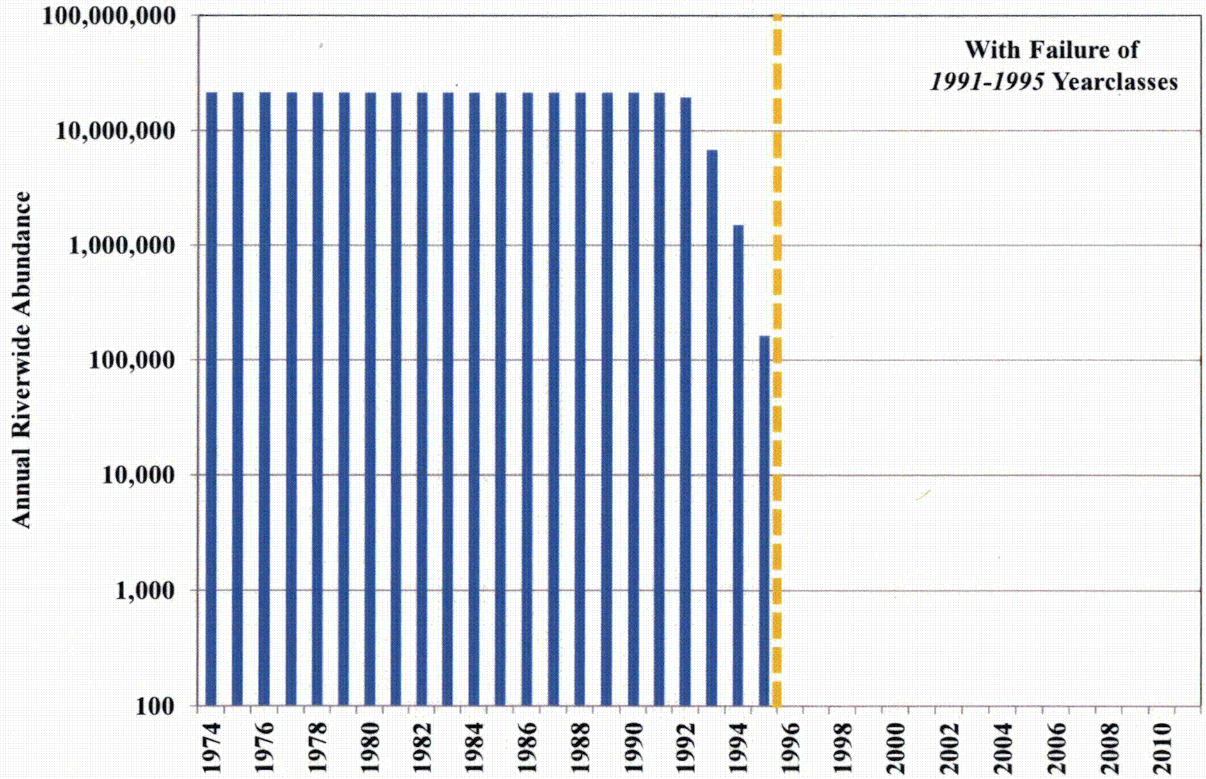

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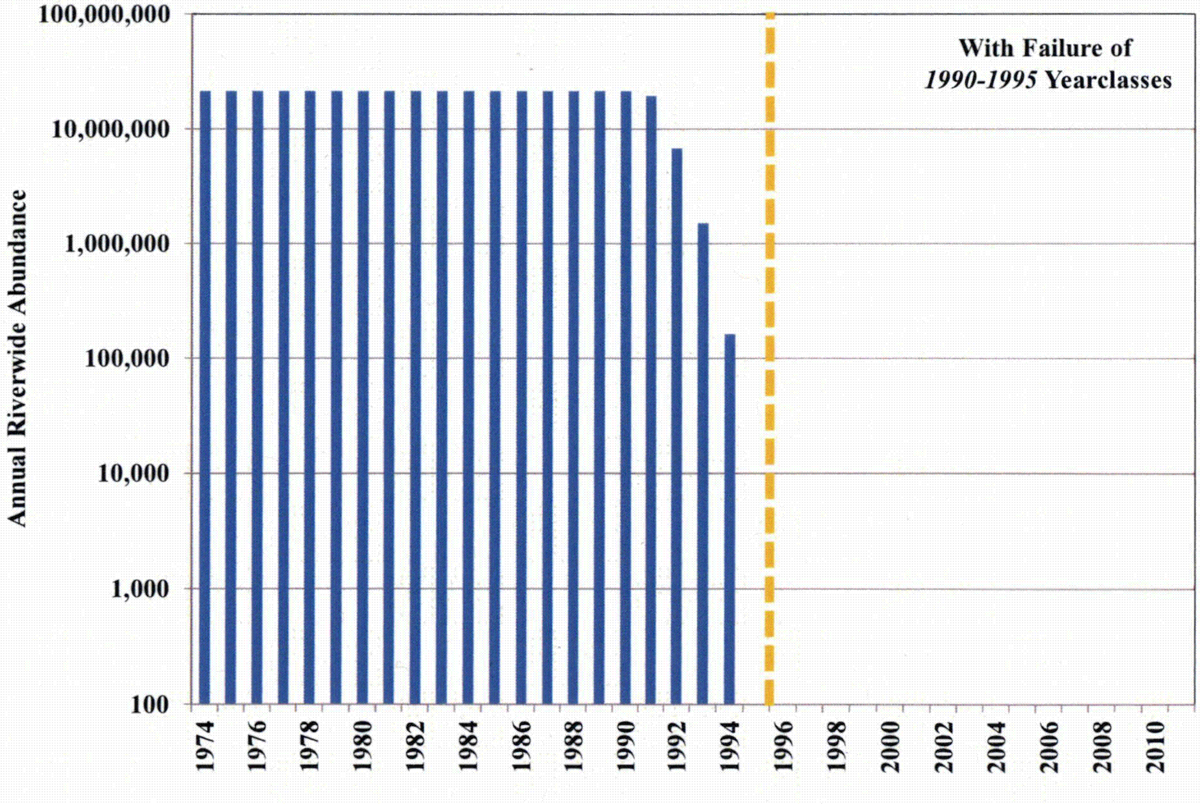
Figure 6. Projected rainbow smelt larval abundance (blue bars) assuming reproductive failure of the 1990 through 1995 year classes. Orange dashed vertical line indicates historical timing of catastrophic decline.



6

NORMANDEAU ASSOCIATES
Environmental Consultants

Appendix 2B
Hudson River Rainbow Smelt infestation by the Microsporidian Parasite *Glugea hertwigi*

Presented To:
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Submitted On:
3 March 2016

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1.0 Introduction

Rainbow Smelt (*Osmerus mordax*) are anadromous, typically spawning in shallow freshwater riffles, and maturing in coastal marine waters. Adults spawn in fresh water above the head of the tide in the Hudson River when winter water temperatures rise to about 9°C (Smith 1985), and then return to sea (Buckley 1989). The eggs are demersal and adhesive, and are typically retained near the spawning site until hatching (Able and Fahay 1998; 2010). Egg development times vary inversely with water temperature, from about 29 days at 6°C to 7°C to 8-10 days at 20°C (Collette and Mc-Phee 2002). Newly hatched yolk sac larvae (YSL) are 5 mm to 6 mm total length (TL), absorb the yolk sac at 7 mm TL, and develop from post yolk sac larvae (PYSL) into young of the year (YOY) by about 35 mm TL (Collette and Mc-Phee 2002; Normandeau lab observations of Hudson River fish). After hatching, Rainbow Smelt larvae develop as they are carried downstream to the estuarine portion of the Hudson River below West Point. YOY Rainbow Smelt develop and grow during July through October, and then congregate downstream with adults and migrate to sea during their first year (Collette and Mc-Phee 2002). The growth rate of Rainbow Smelt is fastest during the first year and for fish from the southern regions of their distribution, including the Hudson River (Buckley 1989). The majority of Rainbow Smelt are sexually mature by Age 2 and range in length from 127 to 203 mm TL, but a portion of the fish in the southern extent of their range (e.g., Hudson River) may mature at Age 1 (Collette and Mc-Phee 2002). Since the Hudson River is at the warmer southern extent of their range, development and growth rates would likely have been more rapid than in the north.

Microsporidia are now considered to be fungal parasites in the Division Microsporidia, class Microsporidia that cause serious disease of marine fishes (Noga 2010). All microsporidial infections are intracellular in fish, and proliferate by dividing into a large number cells called meronts, that in turn cause hypertrophy of these host fish cells and form grossly visible cysts (called xenomas) up to 5 mm in size (Noga 2010; Sinderman 1970). Crippling or disfiguring diseases are caused by microsporidian infestations in fish, seriously affecting the muscles, skin, digestive tract and nerves. The microsporidian genera *Glugea*, *Plistophora*, and *Nosema* all contain severe pathogenic species of marine fishes (Sindeman 1970). The microsporidians are widely distributed in marine and estuarine fishes, and their effects on the host are among the most severe of any parasitic group (Sinderman 1970). Because the microsporidian *Glugea hertwigi* is known to infest Rainbow Smelt and some infestation levels may be lethal (e.g., Sinderman 1970; Haley 1954; Legault and Delisle 1967; Nepzy and Dechtiar 1972; 1978; Scarborough and Weidner 1979), and because the Rainbow Smelt population experienced a catastrophic decline in the Hudson River estuary in 1996, Normandeau was asked to retrieve archived Hudson River ichthyoplankton samples from the five years immediately preceding this 1996 decline and examine a selection of the Rainbow Smelt in those samples to determine if *Glugea hertwigi* infestations were present.

2.0 Methods

The examination of Hudson River Rainbow Smelt from previously collected and processed ichthyoplankton samples proceeded in two phases. In the first phase (Phase 1), formalin-preserved Hudson River ichthyoplankton samples from 1992, 1994, and 1995 that were previously sorted and processed to enumerate all fish species by taxon and life stage (and therefore known by examination of the database to contain Rainbow Smelt young of the year (YOY)) were retrieved from long-term storage, with a portion of these fish examined for the presence of *Glugea hertwigi* xenomas (cysts). The second phase (Phase 2) of laboratory analysis was to systematically examine the ontogeny of *G. hertwigi* xenomas in Hudson River Rainbow Smelt from the two remaining unanalyzed years, 1991 and 1993, among the five years prior to the catastrophic decline of Rainbow Smelt in the Hudson River, to determine if the percentage of fish with cysts increased within each year from early to late weeks (River Runs) or from smaller to larger post yolk sac larvae (PYSL) and YOY individuals that were sampled.

Hudson River ichthyoplankton samples previously processed were retained in long-term heated storage at a facility located in north central Massachusetts, about 1.5 hours from Normandeau's Bedford (NH) Biological Laboratory. Previously processed Hudson River ichthyoplankton samples were available from 1991 through present. A "previously processed sample" is one that was examined in the laboratory to separate the fish from the debris and other organisms (i.e., sorted), labeled with a unique sample number, and placed in vials or small jars of preservative (10% buffered formalin) after the contents were identified by taxon and life stage and enumerated. The debris, preservative, and other organisms in these previously processed samples were discarded, retaining only the fish in long-term storage. If a sample was originally split into equal fractions for processing (i.e., ½, ¼, 1/8, etc.), only the split fraction analyzed was retained for long-term storage. Each previously processed sample was a collection of jars and vials, e.g., one vial for eggs, one vial for "larvae", one for "*Morone* sp." and finally one jar for larger fish that were removed from the original field catch before sorting.

To recover the Rainbow Smelt from a given sample or year, each box of previously processed ichthyoplankton samples was retrieved from the storage facility and thoroughly examined; after 20+ years of storage, some samples had deteriorated, lost preservative (i.e., desiccated), or had missing identification labels, in which case they were not analyzed. As such, once located, each sample that should contain Rainbow Smelt was examined first for quality of preservative (i.e., well preserved, dried sample, or disintegrated contents), and then to confirm that indeed the target species was present. Each sample to be analyzed for Rainbow Smelt was set aside for wash-down to remove the formalin, and then the Rainbow Smelt were removed, identified and processed for the presence or absence of *G. hertwigi*. Therefore, splitting at the time of first processing, preservation state, and label integrity identifying unique samples were three factors that for some previously processed samples either reduced the number of Rainbow Smelt recovered, or disassociated the connection between Rainbow Smelt selected for parasite examination from the database and the actual recovery of those samples.

2.1 Phase 1 Methods

In the first phase of analysis, a subset of previously processed samples containing Rainbow Smelt in good condition (i.e., the unique sample number label was intact, the container(s) retained formalin preserved Rainbow Smelt, and the fish were not desiccated) from 1992, 1994, and 1995 were selected for gross parasitological examination analysis of individual fish according to the standard methods of Noga (2010). A target number of approximately 85 YOY Rainbow Smelt per year (1992, n = 85; 1994, n = 87; 1995, n = 84) were removed from each selected sample and examined both externally and internally under dissecting microscope magnification of 40X to determine the presence or absence of microsporidium cysts attributed to *Glugea hertwigi*. In 1994 and 1995, after initially examining 87 and 85 YOY Rainbow Smelt respectively, an additional 13 and 141 Rainbow Smelt, including both YOY and post yolk sac larvae (PYSL), were selected to provide additional observations of the *G. hertwigi* infestation rates in the earliest feeding life stage (i.e., PYSL).

Each Rainbow Smelt examined was first measured for total length (nearest mm), and then visually inspected for any external parasites. Each Rainbow Smelt was then examined internally for the presence of *G. hertwigi* cysts by slitting open the abdominal cavity and inspecting the outer surface of the organs for cysts (xenomas). Since *G. hertwigi* is an obligate parasitic microsporidian that selectively targets the Rainbow Smelt digestive tract and mesenteries, the gross parasitological examination at 40X would reveal the presence (or absence) of large (1 mm to 5 mm) xenomas in Rainbow Smelt, considered to be a diagnostic characteristic of *G. hertwigi* infestation (Noga 2010, Weiss and Becnel 2014).

The presence of absence of *G. hertwigi* xenomas was observed to vary in number of cysts as illustrated in Figure 1, however our examination did not enumerate the number of cysts per fish. Instead we noted the number of cysts per fish on a relative scale from no cysts observed (Level = 0; absent) to present in increasing relative numbers from 1 (Level 1) to 5 (Level 5), as illustrated in Figure 1 below. Note that the red color of the Rainbow Smelt tissue in the images shown in Figure 1 is due to the presence of Rose Bengal vital stain added to each sample at the time of first preservation, to facilitate sorting of fish and debris during sample processing.

Also in Phase 1, 12 whole YOY Rainbow Smelt were selected from each year (1992 n=8 and 1994 n=4) and delivered to the New Hampshire Veterinary Diagnostic Laboratory (NHVDL) at the University of New Hampshire in Durham, NH for whole body sectioning, staining and high resolution microscopy to determine if other parasites were present within the tissues and organs of these specimens. Given the destructive nature of the NHVDL analysis, Rainbow Smelt were not afterward available to process by Normandeau's Bedford Biological Laboratory for the presence of *G. hertwigi* by gross parasitological examination methods.

2.2 Phase 2 Methods

The second phase of laboratory analysis was to systematically examine the ontogeny of *Glugea hertwigi* xenomas in Hudson River Rainbow Smelt from the two remaining unanalyzed years, 1991 and 1993, to determine if the percentage of fish with cysts increased progressively within each year from early to late weeks (River Runs) that were sampled. In each year 1991 and 1993, samples in good condition containing post yolk sac larvae (PYSL, the first feeding life stage) or YOY Rainbow Smelt were identified by examining the data base and condition of the sample containers as described above in Phase 1, organized by River Run (week), and then a random subset of these PYSL + YOY were selected in each River Run (week) for extraction of Rainbow

Smelt for gross parasitological examination using the same methods (Noga 2010) as in Phase 1. As in Phase 1, some samples initially selected for analysis contained either a portion of the total catch (i.e., were split) or desiccated Rainbow Smelt and were not examined. A total of 231 PYSL and YOY Rainbow Smelt were examined from 1991, and a total of 550 PYSL and YOY Rainbow Smelt were examined from 1993 in Phase 2.

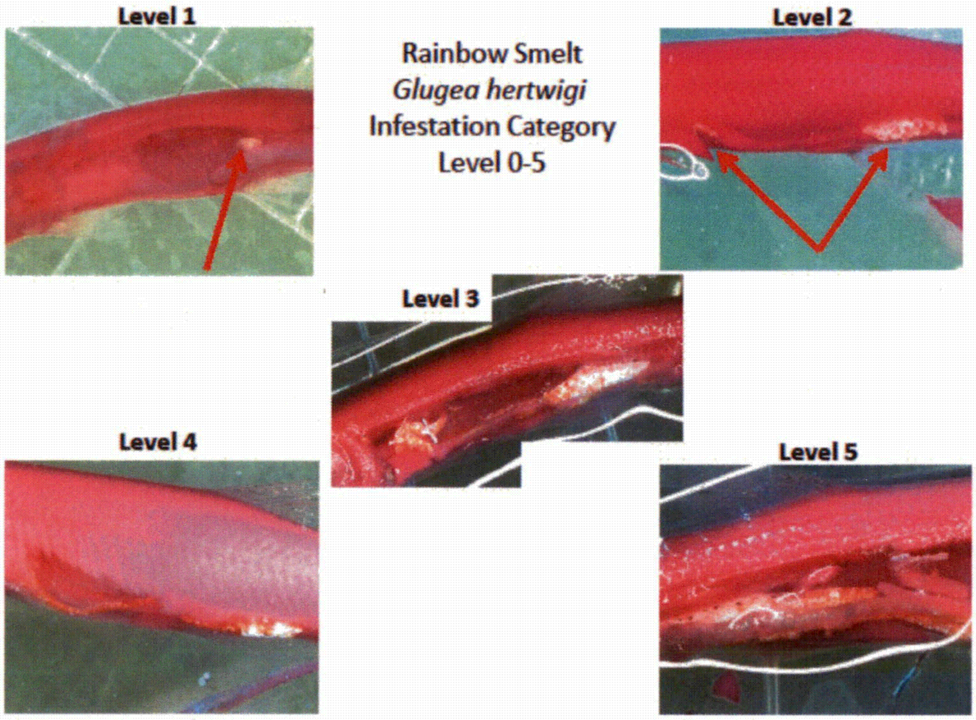

Figure 1. Examples of five levels of increasing *Glugea hertwigi* infestation observed in Hudson River Young of the Year Rainbow Smelt (*Osmerus mordax*) from 1992 and 1995.

<u>Fish Information for Figure 1:</u>

Level 0: not shown, no infection observed
Level 1: 1992, River Run 20, 13 October 1992, Sample No. 9971, TL 49mm
Level 2: 1995, River Run 17, 21 July 1995, Sample No. 3091, TL 45mm
Level 3: 1992, River Run 19, 30 September 1992, Sample No. 9875, TL 54mm
Level 4: 1995, River Run 17, 21 July1995, Sample No. 3091, TL 45mm
Level 5: 1992, River Run 19, 30 September 1992, Sample No. 9875, TL 60mm

3.0 Results

3.1 Results Phase 1

In Phase 1, we examined 3% of the total Rainbow Smelt catch from 1992 (85/2,666 total catch), 2% from 1994 (100/6,415 total catch) and 25% from 1995 (225/910 total catch; Table 1). *Glugeia hertwigi* infestations were present in each of the three years (Table 1, Figure 1). Among the 410 Rainbow Smelt examined in Phase 1, no external infestation, but substantial internal infestation, of *G. hertwigi* cysts was observed among the Rainbow Smelt examined. Appendix 1 provides a listing of each of these 410 fish examined from 1992, 1994, and 1995, sorted by year and week (River Run), the total length in mm, and the level of infestation observed by gross parasitological examination methods.

No post yolk sac larvae (PYSL) and only young of the year (YOY) Rainbow Smelt were examined from 1992, while 30% of the fish examined from 1994 (30/100) were PYSL and 66% (148/225) of the Rainbow Smelt examined from 1995 were PYSL (Table 2). Consistently higher infestation rates were observed in years when proportionally more older YOY Rainbow Smelt were examined, as occurred in 1992 (Tables 1 and 2). In 1994 and 1995, a greater percentage of the younger PYSL Rainbow Smelt were examined among the annual totals (Table 2), giving the impression of lower overall infestation rates in those years (Table 1).

The ontogeny of infestation is more clearly illustrated by examining *G. hertwigi* infestation percentages in relation to length classes of Rainbow Smelt among these three Phase 1 years (1992, 1994, 1995), particularly for 1995 (Table 3, Figure 3). The total lengths of all the Rainbow Smelt analyzed in Phase 1 ranged from 11 mm to 60 mm (Table 3, Figure 3). Fish analyzed from 1992 had a mean total length of 49mm, minimum total length of 40 mm, and maximum total length of 60 mm (Table 3, Figure 3). Fish analyzed for 1994 had a mean total length of 36 mm, minimum total length of 27 mm and maximum total length of 44 mm (Table 3, Figure 3). The mean total length of the fish examined for 1995 was 41 mm with a minimum total length of 15 mm and maximum total length of 49 mm (Table 3, Figure 3).

G. hertwigi infestation was typically most prevalent in the largest length classes of the Rainbow Smelt examined among the three years (Table 3, Figure 3). This increased prevalence of the *G. hertwigi* infestation was best observed in 1995, when the greatest range of Rainbow Smelt sizes were examined, including both PYSL and YOY life stages. In 1995, the *G. hertwigi* infestation rate was 0% for fish less than 26 mm total length, 65% for the 26-30 mm total length class, 92% for the 31-35 mm total length class, 95% for the 36-40 mm total length class, and 100% for Rainbow Smelt larger than 40 mm total length (Table 3, Figure 2). Among all three years of Rainbow Smelt examined in Phase 1, the observed level of *G. hertwigi* infestation intensity increased with increasing length (Figure 4).

As noted above, a sample of 12 YOY Rainbow Smelt were selected from two years (1992 n=8 and 1994 n=4) and delivered to the NHVDL at the University of New Hampshire in Durham, NH for whole body sectioning, staining and high resolution microscopy to determine if other parasites were present within the tissues and organs of these specimens. The NHVDL found five of the eight fish from 1992 to have acanthocephalan parasites with moderate, chronic peritonitis and no infestations in the four fish from 1994 (individual Rainbow Smelt identified as gray-shaded records in Appendix 1; full NHVDL report in Appendix 2). None of the

parasites found by the NHVDL examination have been associated with massive Rainbow Smelt die-offs in the published literature.

Table 1. Number (and percent) of Hudson River Rainbow Smelt (*Osmerus mordax*) examined for *Glugea hertwigi* infestation from 1992, 1994, and 1995.

Year	Date	River Run	*G. hertwigi* Present	Total Analyzed	Total Catch*	% Analyzed
1992	7/6/1992	13	100%	22	1,319	2%
	8/4/1992	15	100%	22	621	4%
	9/1/1992	17	100%	10	295	3%
	9/28/1992	19	100%	5	158	3%
	10/12/1992	20	92%	26	273	10%
All 1992 (RR 13-20)			**98%**	**85**	**2,666**	**3%**
1994	6/20/1994	11	44%	18	2,533	1%
	6/27/1994	12	67%	12	1,238	1%
	7/5/1994	13	62%	13	678	2%
	7/12/1994	14	58%	26	1,474	2%
	7/26/1994	15	50%	10	446	2%
	8/8/1994	16	33%	12	34	35%
	8/22/1994	17	50%	2	2	100%
	9/6/1994	18	25%	4	6	67%
All 1994 (RR 11-18)			**50%**	**100**	**6,415**	**2%**
1995	5/30/1995	11	0%	120	408	29%
	6/12/1995	13	67%	30	243	12%
	6/26/1995	15	94%	32	190	17%
	7/19/1995	17	100%	43	69	62%
All 1995 (RR 11-14)			**41%**	**225**	**910**	**25%**

*Total catch represents numbers from any split samples expanded up to the total number using the split fraction.

Table 2. Number of Hudson River Rainbow Smelt (*Osmerus mordax*) examined for *Glugea hertwigi* infestation by life stage and River Run (week) from 1992, 1994, and 1995.

Year	Date	River Run	PYSL	YOY	All
1992	7/6/1992	**13**	0	22	22
	8/4/1992	**15**	0	22	22
	9/1/1992	**17**	0	10	10
	9/28/1992	**19**	0	5	5
	10/12/1992	**20**	0	26	26
Total 1992			**0**	**85**	**85**
1994	6/20/1994	**11**	11	7	18
	6/27/1994	**12**	2	10	12
	7/5/1994	**13**	1	12	13
	7/12/1994	**14**	9	17	26
	7/26/1994	**15**	1	9	10
	8/8/1994	**16**	6	6	12
	8/22/1994	**17**	0	2	2
	9/6/1994	**18**	0	4	4
	10/3/1994	**20**	0	3	3
Total 1994			**30**	**70**	**100**
1995	5/30/1995	**11**	120	0	120
	6/12/1995	**13**	28	2	30
	6/26/1995	**15**	0	32	32
	7/19/1995	**17**	0	43	43
Total 1995			**148**	**77**	**225**

Table 3. Number of Hudson River Rainbow Smelt (*Osmerus mordax*) observed with *Glugea hertwigi* infestation present by length class (mm total length) during 1992, 1994, and 1995.

River Run	Date	6-10 mm	11-15 mm	16-20 mm	21-25 mm	26-30 mm	31-35 mm	36-40 mm	41-45 mm	46-50 mm	51-55 mm	56-60 mm	Total Examined
13	7/6/1992							3	13	6			22
15	8/4/1992									10	12		22
17	9/1/1992								1	4	5		10
19	9/28/1992									1	3	1	5
20	10/12/1992									7	11	6	26
1992 Total Infested								**3**	**14**	**28**	**31**	**7**	**83**
1992 No. Examined								**3**	**14**	**30**	**31**	**7**	**85**
1992 % Infested								**100%**	**100%**	**93%**	**100%**	**100%**	**98%**
11	6/20/1994						6	2					18
12	6/27/1994						2	5	1				12
13	7/5/1994							7	1				13
14	7/12/1994						9	5	1				26
15	7/26/1994						2	1	2				10
16	8/8/1994							2	2				12
17	8/22/1994								1				2
18	9/6/1994								1				4
20	10/3/1994												3
1994 Total Infested						**0**	**19**	**22**	**9**				**50**
1994 No. Examined						**8**	**43**	**36**	**13**				**100**
1994 % Infested						**0%**	**44%**	**61%**	**69%**				**50%**
11	5/30/1995												120
13	6/12/1995					13	7						30
15	6/26/1995						4	18	8				32
17	7/19/1995							3	26	14			43
1995 Total Infested						**13**	**11**	**21**	**34**	**14**			**93**
1995 No. Examined			**2**	**71**	**50**	**20**	**12**	**22**	**34**	**14**			**225**
1995 % Infested			**0%**	**0%**	**0%**	**65%**	**92%**	**95%**	**100%**	**100%**			**41%**

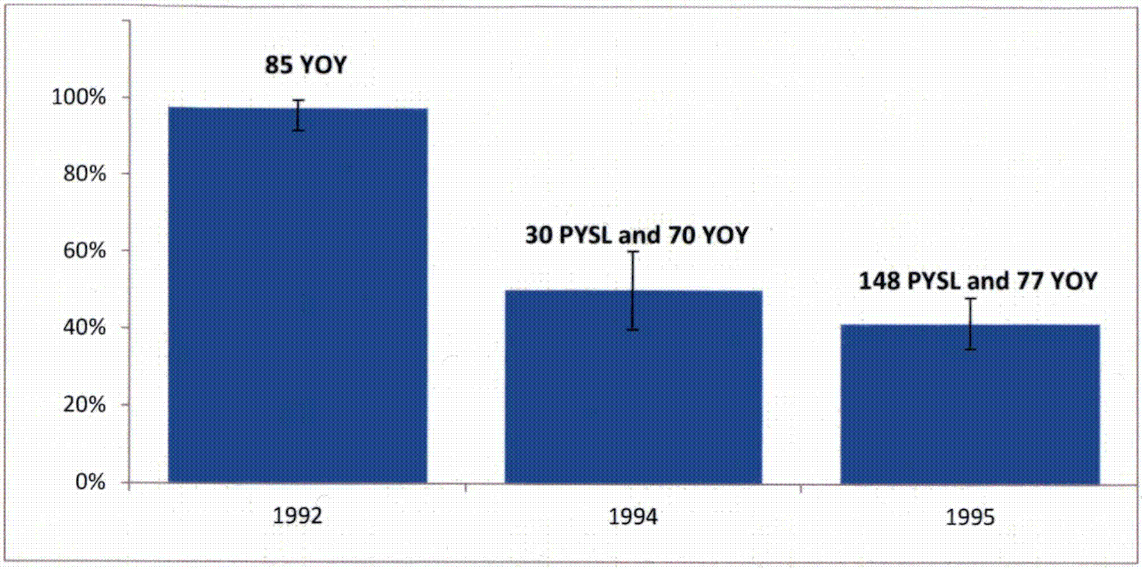

Figure 2. **Overall percent of Hudson River Rainbow Smelt (*Osmerus mordax*) observed with *Glugea hertwigi* infestation present for 1992 (n=85 YOY), 1994 (n=30 PYSL and 70 YOY), and 1995 (n=148 PYSL and 77 YOY)*.**

* 95% binomial confidence intervals shown as black lines and number of individuals examined by life stage is shown at the top of each bar.

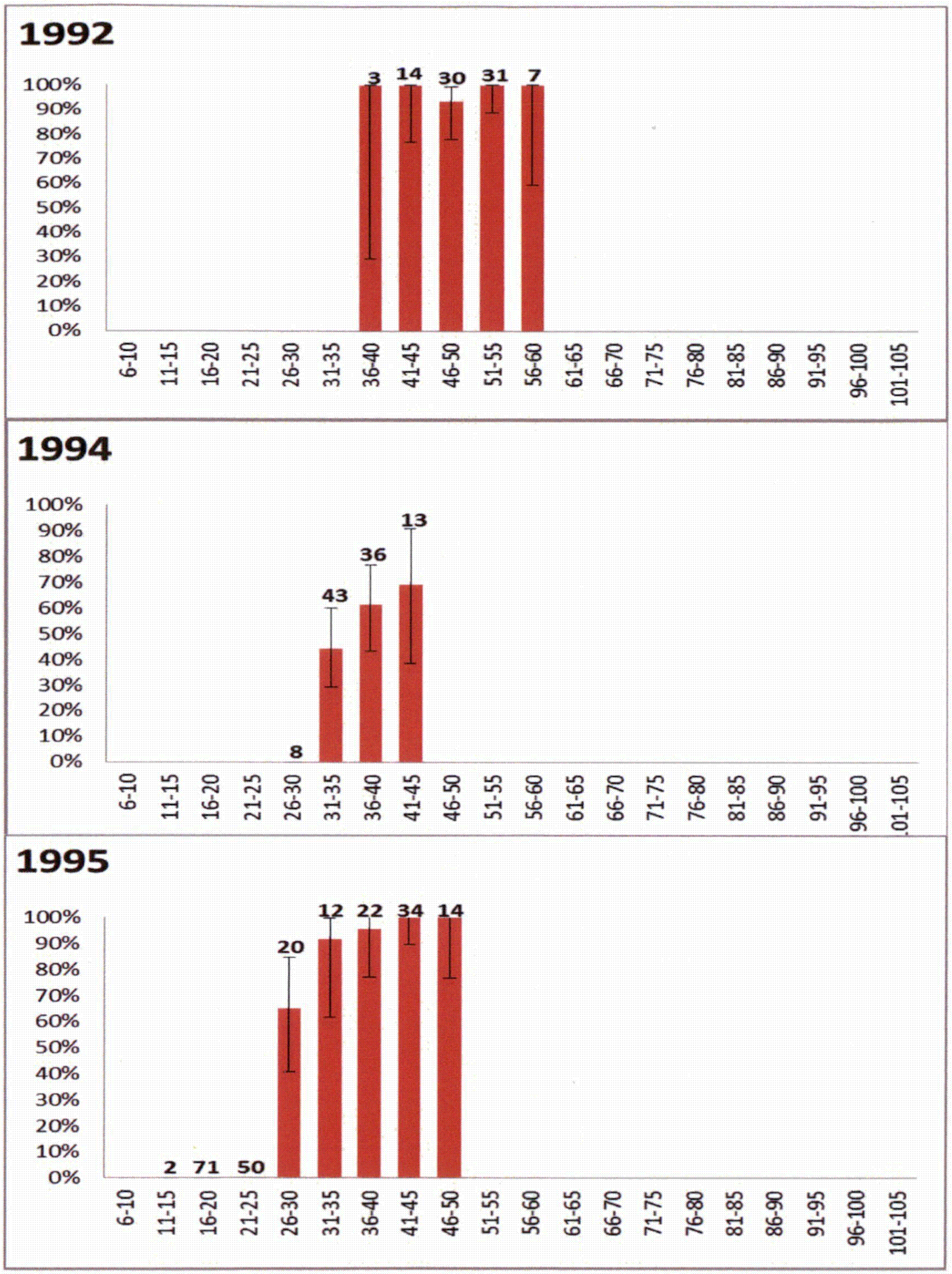

Figure 3. Number and percent of Hudson River Rainbow Smelt (*Osmerus mordax*) observed with *Glugea hertwigi* infestation present by length class (mm total length) during 1992, 1994, and 1995*

* 95% binomial confidence intervals shown as black lines and number of individuals examined is shown at the top of each bar, zeros omitted.

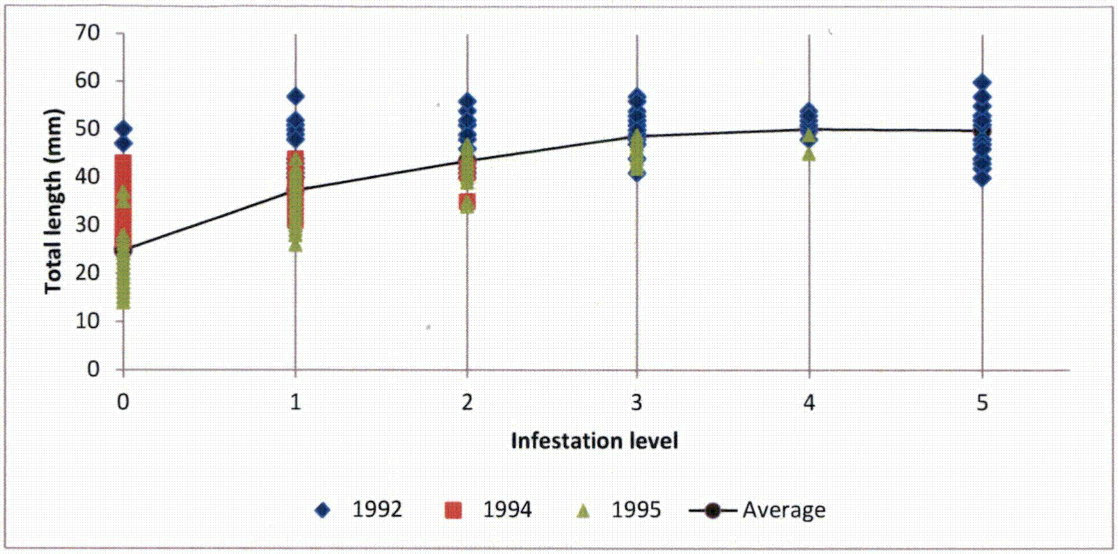

Figure 4. Total Length (mm) of Hudson River Rainbow Smelt (Osmerus mordax) categorized by level of Glugea hertwigi infestation for 1992, 1994, and 1995 (Level 0=absent, Levels 1 - 5 show increasing numbers of cysts).

3.2 Results Phase 2

Rainbow Smelt were randomly selected in Phase 2 from each River Run (week) of 1991 and 1993 with predominantly PYSL and YOY life stages present and subjected to gross parasitological examination for the presence of *Glugea hertwigi*. More River Runs (weeks) and sizes of Rainbow Smelt were examine in these two years than in Phase 1. Therefore, Phase 2 supplemented the *G. hertwigi* infestation information obtained in Phase 1 (1992, 1994, and 1995).

In 1991, about 10% (231/2,237) of the total catch of Rainbow Smelt PYSL and YOY (combined) was randomly selected and examined for the presence of *G. hertwigi* (Tables 4 and 5; Appendix 1). A clear trend of increasing infestation with increasing River Run (week, Table 6 and Figure 5) and fish length class (Table 7 and Figure 6) was observed. Rainbow Smelt examined from River Runs 4 through 7 of 1991 (May) were free from infestation, and then a transition occurred during June 1991 (River Runs 8 through 11) when the percentage of *G. hertwigi* infestation increased from 0% to 100%, and remained 100% through the end of the 1991 survey (Table 6 and Figure 5). The transition from absence to presence of *G. hertwigi* was observed for Rainbow Smelt within total length classes 26-30 mm, 31-35 mm, and 36-40 mm (Table 7 and Figure 6), which also represents the transition from life stage PYSL to YOY in Rainbow Smelt while present in the Hudson River estuary. Among all Hudson River Rainbow Smelt examined from 1991 in Phase 2, the observed level of *G. hertwigi* infestation intensity increased with increasing length (Figure 7).

In 1993, about 6% (550/9,398) of the total catch of Rainbow Smelt PYSL and YOY (combined) was randomly selected and examined for the presence of *G. hertwigi* (Tables 8 and 9; Appendix 1). As observed in 1991, there was also a clear trend of increasing infestation with increasing River Run (week, Table 10 and Figure 8) and fish length class (Table 11 and Figure 9) for the Hudson River Rainbow Smelt examined from 1993 (excluding three adults examined from

River Runs 4, 5, and 6). The smaller (<26 mm total length) PYSL life stage of Hudson River Rainbow Smelt was nearly free from infestation during 1993 (Table 11 and Figure 9), and the onset of *G. hertwigi* infestation was observed within total length classes 26-30 mm, 31-35 mm and 36-40 mm, which is during the transition from PYSL to YOY. A similar relationship as described for 1991 was also observed for the Hudson River Rainbow Smelt examined from 1993 with respect to the level of *G. hertwigi* infestation intensity and fish length; the highest infestation level 5 was prevalent among the largest fish (Figure 9).

The YOY and PYSL life stages of Hudson River Rainbow Smelt were selected for characterization of the inter-annual variation of the infection rates among all five years (cohorts) to standardize the comparison within life stage due to the observed confounding effects of increasing *G. hertwigi* infestation percent with increasing size and developmental age. The overall percent of Hudson River YOY Rainbow Smelt with *G. hertwigi* infestation present as observed by gross parasitological examination among the 531 YOY examined from 1991 through 1995 was 91% (Table 12). *G. hertwigi* infestation levels of YOY Rainbow Smelt were 92% or higher in four out of the five years examined that preceded the 1996 population crash; the lowest percent infection was 63% of the YOY in 1994 (Table 12). In contrast, the overall percent of Hudson River PYSL Rainbow Smelt with *G. hertwigi* infestation present among the 298 PYSL examined from 1991 through 1995 was 33% (Table 13). The highest *G. hertwigi* infestation level of PYSL Rainbow Smelt was 67% in 1995, the year that preceded the 1996 population crash (Table 13).

Table 4. Total number* of Hudson River Rainbow Smelt (*Osmerus mordax*) collected by life stage and River Run (week) during 1991.

Year	River Run	Date	Eggs	YSL	PYSL	YOY	Yearling	Older	Total Collected
1991	1	4/15/1991					47	1	48
	2	4/22/1991		2	8		23		33
	3	4/29/1991		2	41		17		60
	4	5/6/1991		10	97		45		152
	5	5/13/1991			186		42		228
	6	5/20/1991			188		28	1	217
	7	5/27/1991			660		21		681
	8	6/3/1991			399	38		23	460
	9	6/10/1991			157	5		33	195
	10	6/17/1991			52	21		24	97
	11	6/24/1991			2	112		61	175
	12	6/30/1991			1	159		4	164
	13	7/8/1991			8	62		30	100
	14	7/22/1991			2	15		11	28
	15	8/6/1991				23		4	27
	16	8/20/1991				1		14	15
	17	9/3/1991						11	11
	18	9/16/1991						1	1
	19	10/1/1991						3	3
	20	10/15/1991						4	4
All				**14**	**1,801**	**436**	**223**	**225**	**2,699**

*total number represents numbers from any split samples expanded up to the total number using the split fraction.

Table 5. Number of Hudson River Rainbow Smelt (*Osmerus mordax*) examined for *Glugea hertwigi* infestation by life stage and River Run for 1991.

Year	River Run	Date	PYSL	YOY	YRLNG	All
1991	4	5/6/1991	1			**1**
	6	5/20/1991	22			**22**
	7	5/27/1991	14			**14**
	8	6/3/1991	94	7		**101**
	9	6/10/1991	4	6		**10**
	10	6/17/1991		14		**14**
	11	6/24/1991		16		**16**
	12	6/30/1991		26		**26**
	13	7/8/1991		13		**13**
	14	7/22/1991		1		**1**
	15	8/6/1991		9		**9**
	17	9/3/1991		3		**3**
	19	10/1/1991			1	**1**
All			**135**	**95**	**1**	**231**

Table 6. Number (and percent) of Hudson River Rainbow Smelt (*Osmerus mordax*) observed with *Glugea hertwigi* infestation present by River Run (week) for 1991.

River Run Date	River Run	Percent *Glugea hertwigi* Present	Total Analyzed	Total Catch*	% Analyzed
5/6/1991	4	0%	1	97	1%
5/20/1991	6	0%	22	188	10%
5/27/1991	7	0%	14	660	2%
6/3/1991	8	27%	101	437	22%
6/10/1991	9	40%	10	162	5%
6/17/1991	10	93%	14	73	14%
6/24/1991	11	100%	16	114	9%
7/1/1991	12	100%	26	160	16%
7/8/1991	13	100%	13	70	13%
7/22/1991	14	100%	1	17	4%
8/6/1991	15	100%	9	27	33%
9/3/1991	17	100%	3	11	27%
10/1/1991	19	100%	1	3	33%

*total catch represents numbers from any split samples expanded up to the total number using the split fraction.

Table 7. Number of Hudson River Rainbow Smelt (*Osmerus mordax*) observed with *Glugea hertwigi* infestation present by 5 mm total length classes for each River Run (week) during 1991.

River Run	Date	11-25 mm	26-30 mm	31-35 mm	36-40 mm	41-45 mm	46-50 mm	101-105 mm	Total Examined
4	5/6/1991								1
6	5/20/1991								22
7	5/27/1991								14
8	6/3/1991		2	23	2				101
9	6/10/1991			2	2				10
10	6/17/1991			3	8	2			14
11	6/24/1991				6	10			16
12	6/30/1991				6	19	1		26
13	7/8/1991				2	6	5		13
14	7/22/1991						1		1
15	8/6/1991					4	5		9
17	9/3/1991				2	1			3
19	10/1/1991							1	1
1991 Total Infested		**0**	**2**	**28**	**28**	**42**	**12**	**1**	**113**
1991 No. Examined		**45**	**52**	**50**	**29**	**42**	**12**	**1**	**231**
1991 % Infested		**0%**	**4%**	**56%**	**97%**	**100%**	**100%**	**100%**	**49%**

Table 8. Total number* of Hudson River Rainbow Smelt (*Osmerus mordax*) collected by life stage and River Run (week) during 1993.

Year	River Run	Date	Eggs	YSL	PYSL	YOY	Yearling	Older	Total Collected
1993	1	4/12/1993					2		2
	2	4/19/1993		1		1	80		82
	3	4/26/1993	1	41	3		13		58
	4	5/3/1993		589	29		66		684
	5	5/10/1993		353	1,296		89		1,738
	6	5/17/1993			1,548		185	1	1,734
	7	5/24/1993	1	9	1,234		233	1	1,478
	8	5/31/1993			1,176			207	1,383
	9	6/7/1993			1,075			423	1,498
	10	6/14/1993			609	49		147	805
	11	6/21/1993			607	67		352	1,026
	12	6/28/1993			246	299		186	731
	13	7/6/1993			70	99		213	382
	14	7/12/1993			43	149		98	290
	15	7/26/1993			46	505		164	715
	16	8/10/1993			21	137		71	229
	17	8/23/1993			3	41		66	110
	18	9/7/1993			7	16		31	54
	19	9/20/1993			4	18		13	35
	20	10/4/1993						9	9
All			**2**	**993**	**8,017**	**1,381**	**668**	**1,982**	**13,044**

*total number represents numbers from any split samples expanded up to the total number using the split fraction.

Table 9. Number of Hudson River Rainbow Smelt (*Osmerus mordax*) examined for *Glugea hertwigi* infestation by life stage and River Run (week) for 1993.

Year	River Run	Date	PYSL	YOY	All
1993	4	5/3/1993		1	**1**
	5	5/10/1993		1	**1**
	6	5/17/1993	158	1	**159**
	8	5/31/1993	10		**10**
	9	6/7/1993	34		**34**
	10	6/14/1993	118	15	**133**
	11	6/21/1993	13	8	**21**
	12	6/28/1993	10	14	**24**
	13	7/6/1993	1	10	**11**
	14	7/12/1993	2	31	**33**
	15	7/26/1993		39	**39**
	16	8/10/1993		29	**29**
	17	8/23/1993		35	**35**
	18	9/7/1993		19	**19**
	20	10/4/1993		1	**1**
All			**346**	**204**	**550**

Table 10. Number (and percent) of Hudson River Rainbow Smelt (*Osmerus mordax*) observed with *Glugea hertwigi* infestation present by River Run (week) for 1993.

River Run Date	River Run	Percent *Glugea hertwigi* Present	Total Analyzed	Total Catch*	% Analyzed
5/3/1993	4	100%	1	66	2%
5/10/1993	5	100%	1	1385	0%
5/17/1993	6	1%	159	1734	9%
5/31/1993	8	0%	10	1383	1%
6/7/1993	9	6%	34	1498	2%
6/14/1993	10	45%	133	805	17%
6/21/1993	11	62%	21	1026	2%
6/28/1993	12	50%	24	731	3%
7/6/1993	13	73%	11	382	3%
7/12/1993	14	88%	33	290	11%
7/26/1993	15	92%	39	715	5%
8/10/1993	16	93%	29	229	13%
8/23/1993	17	94%	35	110	32%
9/7/1993	18	95%	19	54	35%
10/4/1993	20	100%	1	9	11%

*total catch represents numbers from any split samples expanded up to the total number using the split fraction.

Table 11. Number of Hudson River Rainbow Smelt (*Osmerus mordax*) observed with *Glugea hertwigi* infestation present by 5 mm total length classes for each River Run (week) during 1993.

River Run	Date	6-20 mm	21-25 mm	26-30 mm	31-35 mm	36-40 mm	41-45 mm	46-50 mm	71-75 mm	76-80 mm	81-85 mm	86-90 mm	91-95 mm	96-100 mm	Total
4	5/3/1993									1					1
5	5/10/1993								1						1
6	5/17/1993										1				159
8	5/31/1993														10
9	6/7/1993				2										34
10	6/14/1993		1	26	26	6					1				133
11	6/21/1993			1	10	2									21
12	6/28/1993				6	6									24
13	7/6/1993					5	3								11
14	7/12/1993				1	13	11	4							33
15	7/26/1993					11	22	3							39
16	8/10/1993					9	17	1							29
17	8/23/1993					5	21	7							35
18	9/7/1993						1	3			1	4	6	3	19
20	10/4/1993												1		1
1993 Total Infest		**0**	**1**	**27**	**45**	**57**	**75**	**18**	**1**	**1**	**3**	**4**	**7**	**3**	**242**
1993 No. Exam		**169**	**60**	**79**	**66**	**62**	**77**	**18**	**1**	**1**	**3**	**4**	**7**	**3**	**550**
1993 % Infest		**0%**	**2%**	**34%**	**68%**	**92%**	**97%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**44%**

Table 12. Number of Hudson River Rainbow Smelt (*Osmerus mordax*) Young of the Year (YOY) examined for presence and absence of *Glugea hertwigi* from 1991 through 1995 and the percent infected.

Year	Infection Absent	Infection Present	Total YOY Inspected	% Infected
1991	3	92	95	97%
1992	2	83	85	98%
1993	16	188	204	92%
1994	26	44	70	63%
1995	2	75	77	97%
Grand Total	**49**	**482**	**531**	**91%**

Table 13. Number of Hudson River Rainbow Smelt (*Osmerus mordax*) Post Yolk-Sac Larvae (PYSL) examined for presence and absence of *Glugea hertwigi* from 1991 through 1995 and the percent infected.

Year	Infection Absent	Infection Present	Total Inspected	% Infected
1991	83	20	103	19%
1993	84	54	138	39%
1994	24	6	30	20%
1995	9	18	27	67%
Grand Total	**200**	**98**	**298**	**33%**

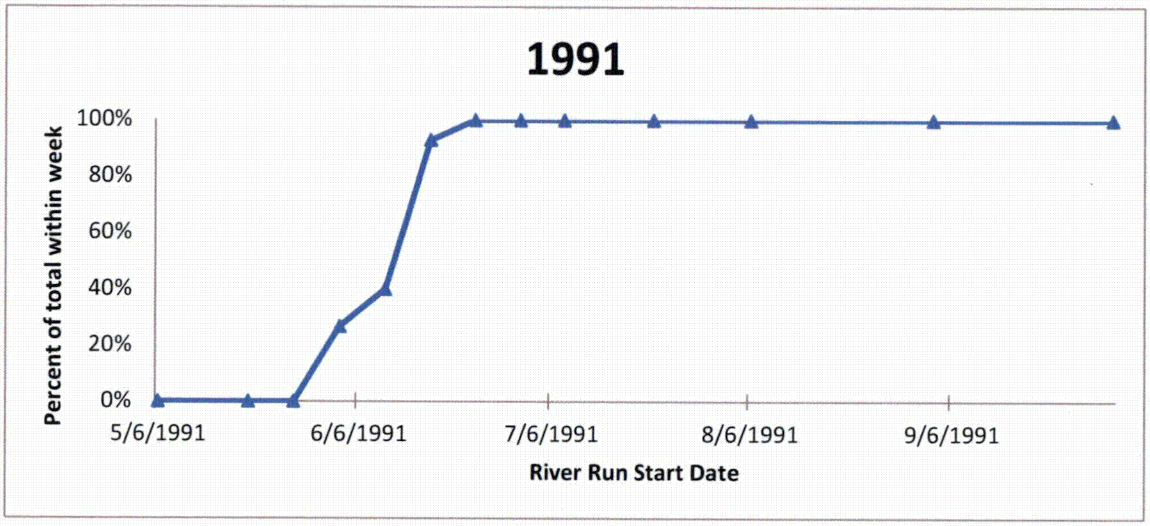

Figure 5. Percent of Hudson River Rainbow Smelt (*Osmerus mordax*) observed with *Glugea hertwigi* infestation present by River Run (week) during 1991.

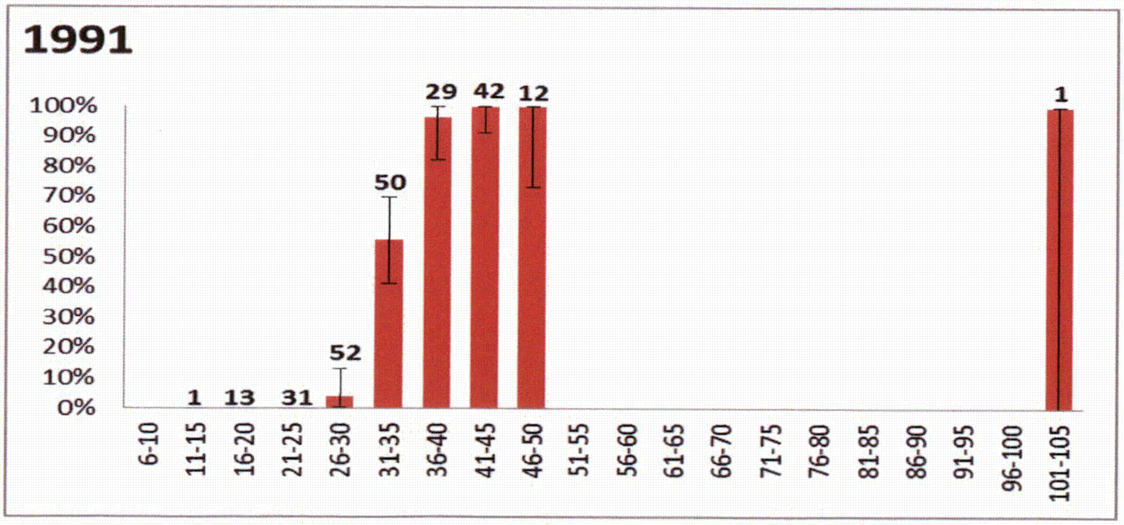

Figure 6. Hudson River Rainbow Smelt (*Osmerus mordax)* observed with *Glugea hertwigi* infestation present by length class (mm total length) during 1991*.

* 95% binomial confidence intervals shown as black lines and number of individuals examined is shown at the top of each bar, zeros omitted.

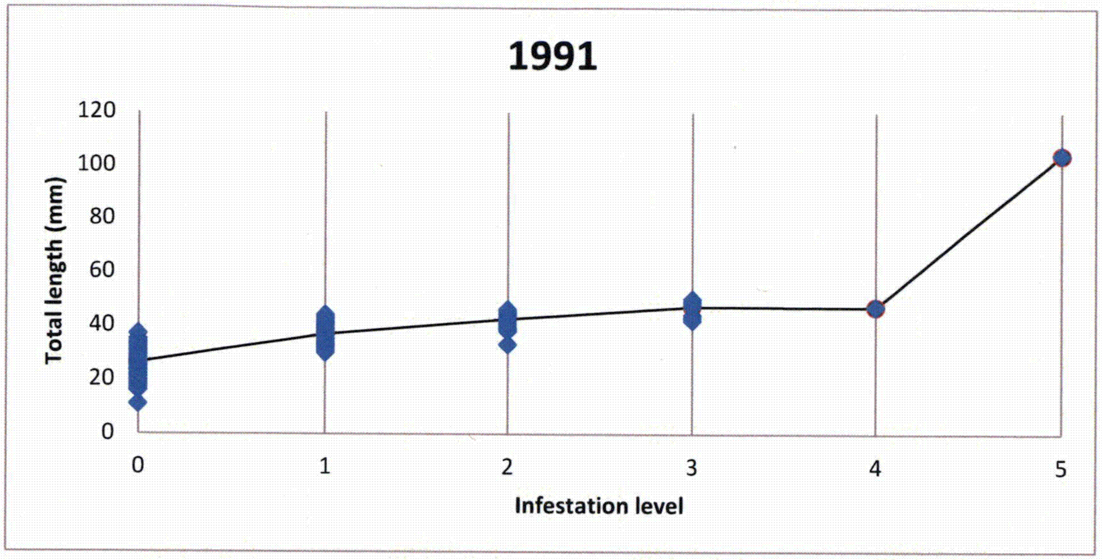

Figure 7. Hudson River Rainbow Smelt (*Osmerus mordax*) categorized by level of *Glugea hertwigi* infestation by total length (mm) for 1991 (Level 0=absent, Levels 1 - 5 show increasing numbers of cysts). Line indicates mean total length for each infestation level.

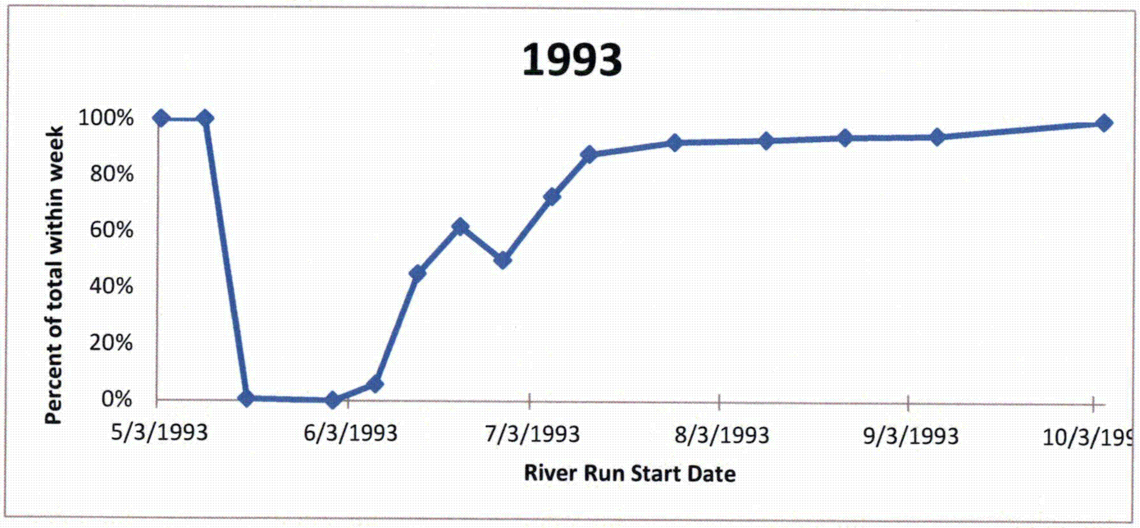

Figure 8. Percent of Hudson River Rainbow Smelt (*Osmerus mordax*) observed with *Glugea hertwigi* infestation present by River Run (week) during 1993.

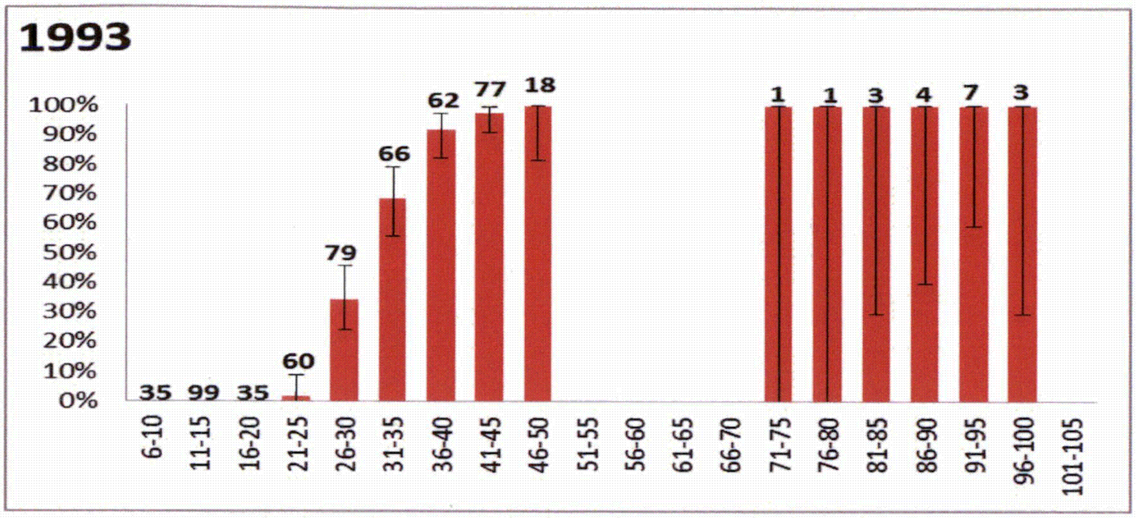

Figure 9. **Hudson River Rainbow Smelt, *Osmerus mordax*, observed with *Glugea hertwigi* infestation present by length class (mm total length) during 1993*.**

* 95% binomial confidence intervals shown as black lines and number of individuals examined is shown at the top of each bar, zeros omitted.

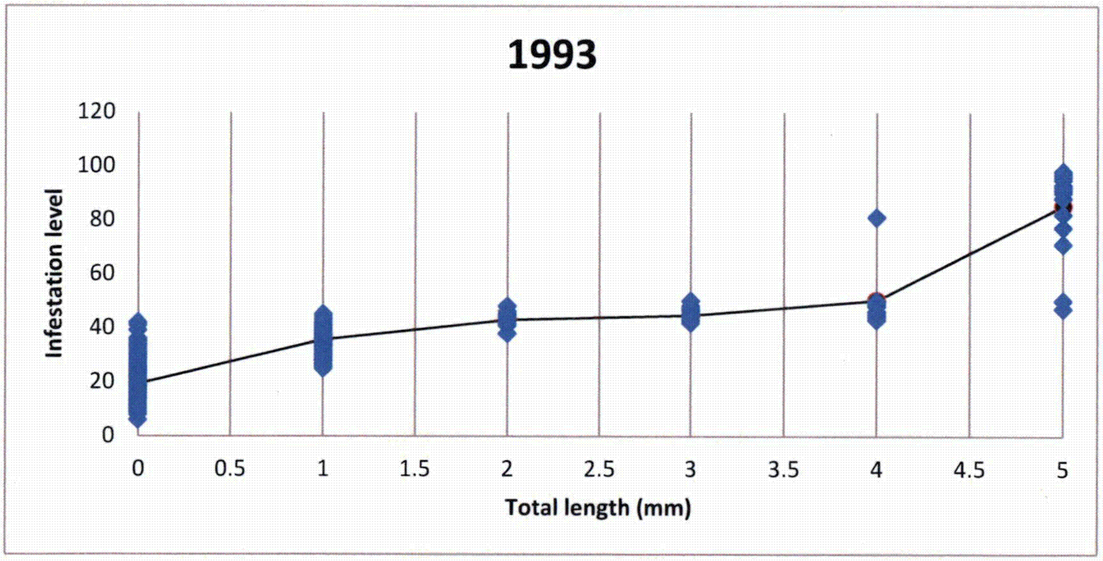

Figure 10. **Hudson River Rainbow Smelt (*Osmerus mordax*) categorized by level of *Glugea hertwigi* infestation by total length (mm) for 1993 (Level 0=absent, Levels 1 - 5 show increasing numbers of cysts). Line indicates mean total length for each infestation level.**

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Appendix 1

Collection and Processing Data for Individual Hudson River Rainbow Smelt Examined for the Presence of the Microsporidian Parasite *Glugea hertwigi* from 1991, 1992, 1993, 1994 and 1995 Ichthyoplankton Samples.

Appendix Table 1. Collection and Processing Data for Individual Hudson River Rainbow Smelt Examined for the Presence of the Microsporidian Parasite *Glugea hertwigi* from 1991, 1992, 1993, 1994 and 1995 Ichthyoplankton Samples.

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
4	23	1991	5/6/1991	3560	11	0	0	Random	
6	32	1991	5/21/1991	3990	16	0	0	Random	
6	32	1991	5/21/1991	3990	17	0	0	Random	
6	32	1991	5/21/1991	3990	18	0	0	Random	
6	32	1991	5/21/1991	3990	18	0	0	Random	
6	32	1991	5/21/1991	3990	18	0	0	Random	
6	32	1991	5/21/1991	3990	19	0	0	Random	
6	32	1991	5/21/1991	3990	20	0	0	Random	
6	32	1991	5/21/1991	3990	20	0	0	Random	
6	32	1991	5/21/1991	3990	20	0	0	Random	
6	32	1991	5/21/1991	3990	20	0	0	Random	
6	32	1991	5/21/1991	3990	20	0	0	Random	
6	32	1991	5/21/1991	3990	21	0	0	Random	
6	32	1991	5/21/1991	3990	21	0	0	Random	
6	32	1991	5/21/1991	3990	21	0	0	Random	
6	32	1991	5/21/1991	3990	21	0	0	Random	
6	32	1991	5/21/1991	3990	21	0	0	Random	
6	32	1991	5/21/1991	3990	21	0	0	Random	
6	32	1991	5/21/1991	3990	22	0	0	Random	
6	59	1991	5/24/1991	4157	19	0	0	Random	
6	59	1991	5/24/1991	4157	21	0	0	Random	
6	59	1991	5/24/1991	4157	21	0	0	Random	
6	59	1991	5/24/1991	4157	27	0	0	Random	
7	39	1991	5/28/1991	4206	23	0	0	Random	
7	39	1991	5/28/1991	4206	23	0	0	Random	
7	39	1991	5/28/1991	4206	25	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
7	39	1991	5/28/1991	4206	25	0	0	Random	
7	39	1991	5/28/1991	4206	25	0	0	Random	
7	39	1991	5/28/1991	4206	25	0	0	Random	
7	39	1991	5/28/1991	4206	25	0	0	Random	
7	39	1991	5/28/1991	4206	25	0	0	Random	
7	39	1991	5/28/1991	4206	25	0	0	Random	
7	39	1991	5/28/1991	4206	26	0	0	Random	
7	39	1991	5/28/1991	4206	26	0	0	Random	
7	39	1991	5/28/1991	4206	27	0	0	Random	
7	39	1991	5/28/1991	4206	27	0	0	Random	
7	39	1991	5/28/1991	4206	30	0	0	Random	
8	25	1991	6/6/1991	4520	27	0	0	Random	
8	25	1991	6/6/1991	4520	29	0	0	Random	
8	25	1991	6/6/1991	4520	29	0	0	Random	
8	25	1991	6/6/1991	4520	31	0	0	Random	
8	57	1991	6/6/1991	4502	21	0	0	Random	
8	57	1991	6/6/1991	4502	22	0	0	Random	
8	57	1991	6/6/1991	4502	23	0	0	Random	
8	57	1991	6/6/1991	4502	24	0	0	Random	
8	57	1991	6/6/1991	4502	25	0	0	Random	
8	57	1991	6/6/1991	4502	25	0	0	Random	
8	57	1991	6/6/1991	4502	25	0	0	Random	
8	57	1991	6/6/1991	4502	25	0	0	Random	
8	57	1991	6/6/1991	4502	26	0	0	Random	
8	57	1991	6/6/1991	4502	26	0	0	Random	
8	57	1991	6/6/1991	4502	27	0	0	Random	
8	57	1991	6/6/1991	4502	27	0	0	Random	
8	57	1991	6/6/1991	4502	28	0	0	Random	
8	57	1991	6/6/1991	4502	28	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
8	57	1991	6/6/1991	4502	29	0	0	Random	
8	57	1991	6/6/1991	4502	29	0	0	Random	
8	57	1991	6/6/1991	4502	32	0	0	Random	
8	53	1991	6/7/1991	4613	20	0	0	Random	
8	53	1991	6/7/1991	4613	27	0	0	Random	
8	53	1991	6/7/1991	4613	28	0	0	Random	
8	53	1991	6/7/1991	4613	28	0	0	Random	
8	53	1991	6/7/1991	4613	29	0	0	Random	
8	53	1991	6/7/1991	4613	29	0	0	Random	
8	53	1991	6/7/1991	4613	30	0	0	Random	
8	53	1991	6/7/1991	4613	30	0	0	Random	
8	53	1991	6/7/1991	4613	30	0	0	Random	
8	53	1991	6/7/1991	4613	30	0	0	Random	
8	53	1991	6/7/1991	4613	30	0	0	Random	
8	53	1991	6/7/1991	4613	30	0	0	Random	
8	53	1991	6/7/1991	4613	30	0	0	Random	
8	53	1991	6/7/1991	4613	31	0	0	Random	
8	53	1991	6/7/1991	4613	31	0	1	Random	
8	53	1991	6/7/1991	4613	31	0	1	Random	
8	53	1991	6/7/1991	4613	32	0	1	Random	
8	53	1991	6/7/1991	4613	32	0	1	Random	
8	53	1991	6/7/1991	4613	32	0	0	Random	
8	53	1991	6/7/1991	4613	32	0	1	Random	
8	53	1991	6/7/1991	4613	33	0	1	Random	
8	53	1991	6/7/1991	4613	33	0	1	Random	
8	53	1991	6/7/1991	4613	34	0	1	Random	
8	53	1991	6/7/1991	4613	34	0	1	Random	
8	53	1991	6/7/1991	4613	35	0	1	Random	
8	53	1991	6/7/1991	4613	38	0	2	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
8	46	1991	6/8/1991	4642	26	0	0	Random	
8	46	1991	6/8/1991	4642	26	0	0	Random	
8	46	1991	6/8/1991	4642	27	0	0	Random	
8	46	1991	6/8/1991	4642	28	0	0	Random	
8	46	1991	6/8/1991	4642	29	0	0	Random	
8	46	1991	6/8/1991	4642	29	0	0	Random	
8	46	1991	6/8/1991	4642	29	0	0	Random	
8	46	1991	6/8/1991	4642	30	0	1	Random	
8	46	1991	6/8/1991	4642	30	0	0	Random	
8	46	1991	6/8/1991	4642	31	0	0	Random	
8	46	1991	6/8/1991	4642	31	0	0	Random	
8	46	1991	6/8/1991	4642	31	0	0	Random	
8	46	1991	6/8/1991	4642	31	0	0	Random	
8	46	1991	6/8/1991	4642	31	0	0	Random	
8	46	1991	6/8/1991	4642	31	0	0	Random	
8	46	1991	6/8/1991	4642	31	0	1	Random	
8	46	1991	6/8/1991	4642	32	0	0	Random	
8	46	1991	6/8/1991	4642	32	0	1	Random	
8	46	1991	6/8/1991	4642	32	0	0	Random	
8	46	1991	6/8/1991	4642	32	0	0	Random	
8	46	1991	6/8/1991	4642	33	0	1	Random	
8	46	1991	6/8/1991	4642	33	0	2	Random	
8	46	1991	6/8/1991	4642	38	0	1	Random	
8	47	1991	6/8/1991	4637	22	0	0	Random	
8	47	1991	6/8/1991	4637	24	0	0	Random	
8	47	1991	6/8/1991	4637	24	0	0	Random	
8	47	1991	6/8/1991	4637	25	0	0	Random	
8	47	1991	6/8/1991	4637	25	0	0	Random	
8	47	1991	6/8/1991	4637	27	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
8	47	1991	6/8/1991	4637	27	0	0	Random	
8	47	1991	6/8/1991	4637	28	0	0	Random	
8	47	1991	6/8/1991	4637	28	0	0	Random	
8	47	1991	6/8/1991	4637	28	0	0	Random	
8	47	1991	6/8/1991	4637	28	0	0	Random	
8	47	1991	6/8/1991	4637	28	0	0	Random	
8	47	1991	6/8/1991	4637	29	0	0	Random	
8	47	1991	6/8/1991	4637	29	0	0	Random	
8	47	1991	6/8/1991	4637	29	0	0	Random	
8	47	1991	6/8/1991	4637	30	0	0	Random	
8	47	1991	6/8/1991	4637	30	0	0	Random	
8	47	1991	6/8/1991	4637	30	0	1	Random	
8	47	1991	6/8/1991	4637	31	0	1	Random	
8	47	1991	6/8/1991	4637	31	0	0	Random	
8	47	1991	6/8/1991	4637	31	0	1	Random	
8	47	1991	6/8/1991	4637	31	0	1	Random	
8	47	1991	6/8/1991	4637	31	0	0	Random	
8	47	1991	6/8/1991	4637	31	0	0	Random	
8	47	1991	6/8/1991	4637	32	0	1	Random	
8	47	1991	6/8/1991	4637	32	0	1	Random	
8	47	1991	6/8/1991	4637	33	0	1	Random	
8	47	1991	6/8/1991	4637	33	0	0	Random	
8	47	1991	6/8/1991	4637	33	0	1	Random	
8	47	1991	6/8/1991	4637	34	0	1	Random	
8	47	1991	6/8/1991	4637	35	0	1	Random	
9	85	1991	6/11/1991	4691	28	0	0	Random	
9	85	1991	6/11/1991	4691	31	0	0	Random	
9	85	1991	6/11/1991	4691	31	0	0	Random	
9	71	1991	6/12/1991	4715	35	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
9	41	1991	6/14/1991	4801	33	0	0	Random	
9	41	1991	6/14/1991	4801	34	0	0	Random	
9	41	1991	6/14/1991	4801	35	0	1	Random	
9	41	1991	6/14/1991	4801	35	0	1	Random	
9	41	1991	6/14/1991	4801	36	0	1	Random	
9	41	1991	6/14/1991	4801	37	0	1	Random	
10	57	1991	6/20/1991	4997	35	0	1	Random	
10	57	1991	6/20/1991	4997	36	0	1	Random	
10	57	1991	6/20/1991	4997	37	0	1	Random	
10	57	1991	6/20/1991	4997	38	0	2	Random	
10	57	1991	6/20/1991	4997	39	0	2	Random	
10	59	1991	6/20/1991	4980	34	0	1	Random	
10	13	1991	6/21/1991	5057	37	0	0	Random	
10	13	1991	6/21/1991	5057	39	0	1	Random	
10	33	1991	6/22/1991	5085	35	0	1	Random	
10	33	1991	6/22/1991	5085	37	0	1	Random	
10	33	1991	6/22/1991	5085	38	0	1	Random	
10	33	1991	6/22/1991	5085	40	0	1	Random	
10	33	1991	6/22/1991	5085	44	0	3	Random	
10	39	1991	6/23/1991	5111	44	0	2	Random	
11	14	1991	6/27/1991	5263	37	0	1	Random	
11	14	1991	6/27/1991	5263	40	0	1	Random	
11	14	1991	6/27/1991	5263	42	0	1	Random	
11	14	1991	6/27/1991	5263	43	0	1	Random	
11	14	1991	6/27/1991	5263	43	0	2	Random	
11	14	1991	6/27/1991	5263	45	0	2	Random	
11	17	1991	6/27/1991	5271	41	0	1	Random	
11	17	1991	6/27/1991	5272	38	0	1	Random	
11	17	1991	6/27/1991	5272	42	0	1	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
11	35	1991	6/27/1991	5251	39	0	1	Random	
11	35	1991	6/27/1991	5251	40	0	1	Random	
11	35	1991	6/27/1991	5251	45	0	2	Random	
11	30	1991	6/28/1991	5285	40	0	1	Random	
11	30	1991	6/28/1991	5285	42	0	1	Random	
11	30	1991	6/28/1991	5285	44	0	2	Random	
11	30	1991	6/28/1991	5285	45	0	2	Random	
12	20	1991	7/1/1991	5391	38	0	1	Random	
12	20	1991	7/1/1991	5391	39	0	1	Random	
12	20	1991	7/1/1991	5391	39	0	1	Random	
12	20	1991	7/1/1991	5391	39	0	1	Random	
12	20	1991	7/1/1991	5391	41	0	1	Random	
12	20	1991	7/1/1991	5391	41	0	1	Random	
12	20	1991	7/1/1991	5391	41	0	1	Random	
12	20	1991	7/1/1991	5391	41	0	2	Random	
12	20	1991	7/1/1991	5391	42	0	1	Random	
12	20	1991	7/1/1991	5391	42	0	2	Random	
12	20	1991	7/1/1991	5391	42	0	1	Random	
12	20	1991	7/1/1991	5391	43	0	1	Random	
12	20	1991	7/1/1991	5391	43	0	2	Random	
12	20	1991	7/1/1991	5391	43	0	2	Random	
12	20	1991	7/1/1991	5391	43	0	2	Random	
12	20	1991	7/1/1991	5391	44	0	2	Random	
12	20	1991	7/1/1991	5391	45	0	2	Random	
12	20	1991	7/1/1991	5391	45	0	2	Random	
12	20	1991	7/1/1991	5391	47	0	3	Random	
12	45	1991	7/2/1991	5439	41	0	2	Random	
12	43	1991	7/3/1991	5563	37	0	1	Random	
12	43	1991	7/3/1991	5563	40	0	1	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
12	43	1991	7/3/1991	5563	43	0	2	Random	
12	43	1991	7/3/1991	5563	44	0	2	Random	
12	51	1991	7/4/1991	5715	44	0	1	Random	
12	55	1991	7/5/1991	5731	42	0	3	Random	
13	17	1991	7/8/1991	5642	43	0	2	Random	
13	17	1991	7/8/1991	5642	44	0	2	Random	
13	45	1991	7/10/1991	5765	38	0	2	Random	
13	49	1991	7/13/1991	5908	41	0	1	Random	
13	50	1991	7/13/1991	5902	48	0	3	Random	
13	54	1991	7/13/1991	5889	42	0	1	Random	
13	54	1991	7/13/1991	5889	45	0	2	Random	
13	55	1991	7/13/1991	5881	37	0	1	Random	
13	55	1991	7/13/1991	5881	42	0	2	Random	
13	55	1991	7/13/1991	5881	46	0	2	Random	
13	55	1991	7/13/1991	5881	48	0	3	Random	
13	55	1991	7/13/1991	5881	49	0	3	Random	
13	55	1991	7/13/1991	5881	49	0	3	Random	
14	54	1991	7/24/1991	5955	47	0	4	Random	
15	14	1991	8/6/1991	6024	50	0	3	Random	
15	58	1991	8/7/1991	6073	46	0	2	Random	
15	58	1991	8/7/1991	6075	47	0	4	Random	
15	58	1991	8/7/1991	6075	48	0	3	Random	
15	59	1991	8/7/1991	6072	44	0	1	Random	
15	59	1991	8/7/1991	6072	50	0	3	Random	
15	71	1991	8/7/1991	6065	42	0	1	Random	
15	56	1991	8/8/1991	6078	42	0	1	Random	
15	56	1991	8/8/1991	6078	43	0	1	Random	
17	17	1991	6/27/1991	5271	40	0	2	Random	
17	17	1991	6/27/1991	5271	40	0	1	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
17	17	1991	6/27/1991	5271	43	0	3	Random	
19	69	1991	10/2/1991	6422	104	0	5	Random	
13	16	1992	7/6/1992	9148	40	0	1	Systematic	
13	16	1992	7/6/1992	9148	40	0	2	Systematic	
13	16	1992	7/6/1992	9148	41	0	1	Systematic	
13	16	1992	7/6/1992	9148	41	0	2	Systematic	
13	16	1992	7/6/1992	9148	41	0	3	Systematic	
13	16	1992	7/6/1992	9148	42	0	2	Systematic	
13	16	1992	7/6/1992	9148	42	0	1	Systematic	
13	16	1992	7/6/1992	9148	43	0	2	Systematic	
13	16	1992	7/6/1992	9148	43	0	1	Systematic	
13	16	1992	7/6/1992	9148	43	0	2	Systematic	
13	16	1992	7/6/1992	9148	43	0	2	Systematic	
13	16	1992	7/6/1992	9148	44	0	1	Systematic	
13	16	1992	7/6/1992	9148	50	0	4	Systematic	
13	39	1992	7/7/1992	3491	43	N/A	N/A	N/A	sent to NHVDL for analysis
13	39	1992	7/7/1992	3491	45	N/A	N/A	N/A	sent to NHVDL for analysis
13	39	1992	7/7/1992	3491	40	0	5	Systematic	stomach & anterior gut
13	39	1992	7/7/1992	3491	42	0	5	Systematic	stomach & anterior gut
13	39	1992	7/7/1992	3491	43	0	5	Systematic	stomach & anterior gut
13	39	1992	7/7/1992	3491	44	0	5	Systematic	stomach & anterior gut
13	39	1992	7/7/1992	3491	46	0	5	Systematic	stomach & anterior gut
13	39	1992	7/7/1992	3491	47	0	5	Systematic	stomach & anterior gut
13	39	1992	7/7/1992	3491	47	0	5	Systematic	stomach & anterior gut
13	39	1992	7/7/1992	3491	47	0	5	Systematic	stomach & anterior gut
13	39	1992	7/7/1992	3491	48	0	5	Systematic	stomach & anterior gut
15	42	1992	8/5/1992	9464	46	0	2	Systematic	
15	42	1992	8/5/1992	9464	48	0	3	Systematic	
15	42	1992	8/5/1992	9464	48	0	4	Systematic	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
15	42	1992	8/5/1992	9464	49	0	3	Systematic	
15	42	1992	8/5/1992	9464	49	0	2	Systematic	
15	42	1992	8/5/1992	9464	50	0	4	Systematic	
15	42	1992	8/5/1992	9464	50	0	4	Systematic	
15	42	1992	8/5/1992	9464	50	0	3	Systematic	
15	42	1992	8/5/1992	9464	50	0	4	Systematic	
15	42	1992	8/5/1992	9464	50	0	4	Systematic	
15	42	1992	8/5/1992	9464	51	0	4	Systematic	
15	42	1992	8/5/1992	9464	51	0	4	Systematic	
15	42	1992	8/5/1992	9464	51	0	4	Systematic	
15	42	1992	8/5/1992	9464	51	0	5	Systematic	
15	42	1992	8/5/1992	9464	51	0	4	Systematic	
15	42	1992	8/5/1992	9464	52	0	5	Systematic	
15	42	1992	8/5/1992	9464	52	0	5	Systematic	
15	42	1992	8/5/1992	9464	52	0	5	Systematic	
15	42	1992	8/5/1992	9464	52	0	5	Systematic	
15	42	1992	8/5/1992	9464	52	0	4	Systematic	
15	42	1992	8/5/1992	9464	53	0	5	Systematic	
15	42	1992	8/5/1992	9464	54	0	4	Systematic	
15	42	1992	8/5/1992	9464	48	N/A	N/A	N/A	sent to NHVDL for analysis
15	42	1992	8/5/1992	9464	52	N/A	N/A	N/A	sent to NHVDL for analysis
17	59	1992	9/2/1992	9678	47	N/A	N/A	N/A	sent to NHVDL for analysis
17	59	1992	9/2/1992	9678	49	N/A	N/A	N/A	sent to NHVDL for analysis
17	59	1992	9/2/1992	9678	50	0	3	Systematic	stomach & anterior gut
17	59	1992	9/2/1992	9678	51	0	3	Systematic	stomach & anterior gut
17	59	1992	9/2/1992	9678	51	0	2	Systematic	stomach & anterior gut
17	59	1992	9/2/1992	9678	52	0	5	Systematic	stomach & anterior gut
17	59	1992	9/2/1992	9678	53	0	5	Systematic	stomach & anterior gut
17	59	1992	9/2/1992	9678	55	0	5	Systematic	stomach & anterior gut

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
19	52	1992	9/30/1992	9875	49	0	3	Systematic	50% stomach and 50% anterior
19	52	1992	9/30/1992	9875	52	0	2	Systematic	liver
19	52	1992	9/30/1992	9875	53	0	4	Systematic	stomach & anterior gut
19	52	1992	9/30/1992	9875	54	0	3	Systematic	stomach & anterior gut
19	52	1992	9/30/1992	9875	60	0	5	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	57	0	1	Systematic	anterior
20	51	1992	10/13/1992	9971	50	0	1	Systematic	little stomach
20	51	1992	10/13/1992	9971	47	0	0	Systematic	none
20	51	1992	10/13/1992	9971	50	0	0	Systematic	none
20	51	1992	10/13/1992	9971	53	N/A	N/A	N/A	sent to NHVDL for analysis
20	51	1992	10/13/1992	9971	60	N/A	N/A	N/A	sent to NHVDL for analysis
20	51	1992	10/13/1992	9971	49	0	1	Systematic	stomach
20	51	1992	10/13/1992	9971	52	0	1	Systematic	stomach
20	51	1992	10/13/1992	9971	48	0	2	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	49	0	2	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	50	0	3	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	50	0	3	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	51	0	1	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	51	0	3	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	52	0	3	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	52	0	3	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	52	0	2	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	53	0	3	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	53	0	3	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	53	0	3	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	54	0	2	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	55	0	5	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	56	0	3	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	56	0.	2	Systematic	stomach & anterior gut

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
20	51	1992	10/13/1992	9971	56	0	3	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	57	0	3	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	57	0	5	Systematic	stomach & anterior gut
20	51	1992	10/13/1992	9971	48	0	1	Systematic	trace amounts in pelvic area
4	25	1993	5/3/1993	1604	77	0	5	Random	
5	39	1993	5/11/1993	1837	71	0	5	Random	
6	40	1993	5/20/1993	2136	11	0	0	Random	
6	40	1993	5/20/1993	2136	11	0	0	Random	
6	40	1993	5/20/1993	2136	11	0	0	Random	
6	40	1993	5/20/1993	2136	12	0	0	Random	
6	40	1993	5/20/1993	2136	12	0	0	Random	
6	40	1993	5/20/1993	2136	13	0	0	Random	
6	40	1993	5/20/1993	2136	14	0	0	Random	
6	40	1993	5/20/1993	2136	18	0	0	Random	
6	40	1993	5/20/1993	2136	18	0	0	Random	
6	40	1993	5/20/1993	2136	18	0	0	Random	
6	40	1993	5/20/1993	2136	19	0	0	Random	
6	42	1993	5/20/1993	2146	6	0	0	Random	
6	42	1993	5/20/1993	2146	8	0	0	Random	
6	42	1993	5/20/1993	2146	8	0	0	Random	
6	42	1993	5/20/1993	2146	8	0	0	Random	
6	42	1993	5/20/1993	2146	9	0	0	Random	
6	42	1993	5/20/1993	2146	9	0	0	Random	
6	42	1993	5/20/1993	2146	9	0	0	Random	
6	42	1993	5/20/1993	2146	9	0	0	Random	
6	42	1993	5/20/1993	2146	9	0	0	Random	
6	42	1993	5/20/1993	2146	9	0	0	Random	
6	42	1993	5/20/1993	2146	9	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	10	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	11	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	12	0	0	Random	
6	42	1993	5/20/1993	2146	13	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
6	42	1993	5/20/1993	2146	13	0	0	Random	
6	42	1993	5/20/1993	2146	13	0	0	Random	
6	42	1993	5/20/1993	2146	13	0	0	Random	
6	42	1993	5/20/1993	2146	13	0	0	Random	
6	42	1993	5/20/1993	2146	13	0	0	Random	
6	42	1993	5/20/1993	2146	13	0	0	Random	
6	42	1993	5/20/1993	2146	13	0	0	Random	
6	42	1993	5/20/1993	2146	13	0	0	Random	
6	42	1993	5/20/1993	2146	13	0	0	Random	
6	42	1993	5/20/1993	2146	14	0	0	Random	
6	42	1993	5/20/1993	2146	14	0	0	Random	
6	42	1993	5/20/1993	2146	14	0	0	Random	
6	42	1993	5/20/1993	2146	14	0	0	Random	
6	42	1993	5/20/1993	2146	14	0	0	Random	
6	42	1993	5/20/1993	2146	15	0	0	Random	
6	42	1993	5/20/1993	2146	15	0	0	Random	
6	42	1993	5/20/1993	2146	15	0	0	Random	
6	42	1993	5/20/1993	2146	16	0	0	Random	
6	42	1993	5/20/1993	2146	16	0	0	Random	
6	42	1993	5/20/1993	2146	17	0	0	Random	
6	42	1993	5/20/1993	2146	17	0	0	Random	
6	42	1993	5/20/1993	2146	18	0	0	Random	
6	42	1993	5/20/1993	2146	18	0	0	Random	
6	42	1993	5/20/1993	2146	19	0	0	Random	
6	42	1993	5/20/1993	2146	20	0	0	Random	
6	42	1993	5/20/1993	2146	20	0	0	Random	
6	43	1993	5/20/1993	2147	8	0	0	Random	
6	43	1993	5/20/1993	2147	8	0	0	Random	
6	43	1993	5/20/1993	2147	10	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
6	43	1993	5/20/1993	2147	10	0	0	Random	
6	43	1993	5/20/1993	2147	10	0	0	Random	
6	43	1993	5/20/1993	2147	10	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	11	0	0	Random	
6	43	1993	5/20/1993	2147	12	0	0	Random	
6	43	1993	5/20/1993	2147	12	0	0	Random	
6	43	1993	5/20/1993	2147	12	0	0	Random	
6	43	1993	5/20/1993	2147	12	0	0	Random	
6	43	1993	5/20/1993	2147	12	0	0	Random	
6	43	1993	5/20/1993	2147	12	0	0	Random	
6	43	1993	5/20/1993	2147	12	0	0	Random	
6	43	1993	5/20/1993	2147	12	0	0	Random	
6	43	1993	5/20/1993	2147	12	0	0	Random	
6	43	1993	5/20/1993	2147	13	0	0	Random	
6	43	1993	5/20/1993	2147	13	0	0	Random	
6	43	1993	5/20/1993	2147	13	0	0	Random	
6	43	1993	5/20/1993	2147	13	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
6	43	1993	5/20/1993	2147	13	0	0	Random	
6	43	1993	5/20/1993	2147	13	0	0	Random	
6	43	1993	5/20/1993	2147	13	0	0	Random	
6	43	1993	5/20/1993	2147	13	0	0	Random	
6	43	1993	5/20/1993	2147	13	0	0	Random	
6	43	1993	5/20/1993	2147	13	0	0	Random	
6	43	1993	5/20/1993	2147	14	0	0	Random	
6	43	1993	5/20/1993	2147	15	0	0	Random	
6	43	1993	5/20/1993	2147	16	0	0	Random	
6	43	1993	5/20/1993	2147	16	0	0	Random	
6	43	1993	5/20/1993	2147	16	0	0	Random	
6	43	1993	5/20/1993	2147	17	0	0	Random	
6	43	1993	5/20/1993	2147	18	0	0	Random	
6	43	1993	5/20/1993	2147	18	0	0	Random	
6	43	1993	5/20/1993	2147	18	0	0	Random	
6	43	1993	5/20/1993	2147	18	0	0	Random	
6	43	1993	5/20/1993	2147	18	0	0	Random	
6	43	1993	5/20/1993	2147	18	0	0	Random	
6	43	1993	5/20/1993	2147	19	0	0	Random	
6	55	1993	5/21/1993	2180	81	0	4	Random	
8	40	1993	6/1/1993	2464	16	0	0	Random	
8	40	1993	6/1/1993	2464	16	0	0	Random	
8	40	1993	6/1/1993	2464	17	0	0	Random	
8	40	1993	6/1/1993	2464	18	0	0	Random	
8	40	1993	6/1/1993	2464	20	0	0	Random	
8	40	1993	6/1/1993	2464	20	0	0	Random	
8	40	1993	6/1/1993	2464	22	0	0	Random	
8	40	1993	6/1/1993	2464	22	0	0	Random	
8	40	1993	6/1/1993	2464	25	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
8	40	1993	6/1/1993	2464	25	0	0	Random	
9	25	1993	6/10/1993	2755	19	0	0	Random	
9	25	1993	6/10/1993	2755	20	0	0	Random	
9	25	1993	6/10/1993	2755	21	0	0	Random	
9	25	1993	6/10/1993	2755	21	0	0	Random	
9	25	1993	6/10/1993	2755	22	0	0	Random	
9	25	1993	6/10/1993	2755	22	0	0	Random	
9	25	1993	6/10/1993	2755	22	0	0	Random	
9	25	1993	6/10/1993	2755	23	0	0	Random	
9	25	1993	6/10/1993	2755	23	0	0	Random	
9	25	1993	6/10/1993	2755	23	0	0	Random	
9	25	1993	6/10/1993	2755	23	0	0	Random	
9	25	1993	6/10/1993	2755	23	0	0	Random	
9	25	1993	6/10/1993	2755	24	0	0	Random	
9	25	1993	6/10/1993	2755	24	0	0	Random	
9	25	1993	6/10/1993	2755	24	0	0	Random	
9	25	1993	6/10/1993	2755	24	0	0	Random	
9	25	1993	6/10/1993	2755	24	0	0	Random	
9	25	1993	6/10/1993	2755	24	0	0	Random	
9	25	1993	6/10/1993	2755	24	0	0	Random	
9	25	1993	6/10/1993	2755	25	0	0	Random	
9	25	1993	6/10/1993	2755	25	0	0	Random	
9	25	1993	6/10/1993	2755	25	0	0	Random	
9	25	1993	6/10/1993	2755	25	0	0	Random	
9	25	1993	6/10/1993	2755	25	0	0	Random	
9	25	1993	6/10/1993	2755	25	0	0	Random	
9	25	1993	6/10/1993	2755	25	0	0	Random	
9	25	1993	6/10/1993	2755	26	0	0	Random	
9	25	1993	6/10/1993	2755	27	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
9	25	1993	6/10/1993	2755	27	0	0	Random	
9	25	1993	6/10/1993	2755	27	0	0	Random	
9	25	1993	6/10/1993	2755	29	0	0	Random	
9	25	1993	6/10/1993	2755	30	0	0	Random	
9	25	1993	6/10/1993	2755	31	0	1	Random	
9	25	1993	6/10/1993	2755	31	0	1	Random	
10	74	1993	6/15/1993	2911	24	0	0	Random	
10	74	1993	6/15/1993	2911	26	0	0	Random	
10	74	1993	6/15/1993	2911	31	0	0	Random	
10	85	1993	6/15/1993	2895	26	0	0	Random	
10	85	1993	6/15/1993	2895	26	0	0	Random	
10	85	1993	6/15/1993	2895	28	0	0	Random	
10	61	1993	6/16/1993	2934	82	0	5	Random	
10	61	1993	6/16/1993	2935	20	0	0	Random	
10	61	1993	6/16/1993	2935	22	0	0	Random	
10	61	1993	6/16/1993	2935	23	0	0	Random	
10	61	1993	6/16/1993	2935	24	0	0	Random	
10	61	1993	6/16/1993	2935	24	0	0	Random	
10	61	1993	6/16/1993	2935	24	0	0	Random	
10	61	1993	6/16/1993	2935	24	0	0	Random	
10	61	1993	6/16/1993	2935	25	0	0	Random	
10	61	1993	6/16/1993	2935	25	0	0	Random	
10	61	1993	6/16/1993	2935	25	0	0	Random	
10	61	1993	6/16/1993	2935	25	0	0	Random	
10	61	1993	6/16/1993	2935	25	0	0	Random	
10	61	1993	6/16/1993	2935	26	0	0	Random	
10	61	1993	6/16/1993	2935	28	0	0	Random	
10	69	1993	6/16/1993	2921	22	0	0	Random	
10	69	1993	6/16/1993	2921	23	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
10	69	1993	6/16/1993	2921	24	0	0	Random	
10	69	1993	6/16/1993	2921	24	0	0	Random	
10	69	1993	6/16/1993	2921	25	0	0	Random	
10	69	1993	6/16/1993	2921	25	0	0	Random	
10	69	1993	6/16/1993	2921	25	0	0	Random	
10	69	1993	6/16/1993	2921	26	0	0	Random	
10	69	1993	6/16/1993	2921	31	0	0	Random	
10	22	1993	6/17/1993	2970	24	0	0	Random	
10	22	1993	6/17/1993	2970	24	0	0	Random	
10	22	1993	6/17/1993	2970	24	0	0	Random	
10	22	1993	6/17/1993	2970	25	0	0	Random	
10	22	1993	6/17/1993	2970	25	0	1	Random	
10	22	1993	6/17/1993	2970	26	0	0	Random	
10	22	1993	6/17/1993	2970	26	0	0	Random	
10	22	1993	6/17/1993	2970	26	0	1	Random	
10	22	1993	6/17/1993	2970	27	0	1	Random	
10	22	1993	6/17/1993	2970	27	0	0	Random	
10	22	1993	6/17/1993	2970	28	0	1	Random	
10	22	1993	6/17/1993	2970	28	0	1	Random	
10	22	1993	6/17/1993	2970	28	0	0	Random	
10	22	1993	6/17/1993	2970	28	0	1	Random	
10	22	1993	6/17/1993	2970	28	0	0	Random	
10	22	1993	6/17/1993	2970	28	0	0	Random	
10	22	1993	6/17/1993	2970	28	0	1	Random	
10	22	1993	6/17/1993	2970	28	0	1	Random	
10	22	1993	6/17/1993	2970	28	0	1	Random	
10	22	1993	6/17/1993	2970	29	0	1	Random	
10	22	1993	6/17/1993	2970	29	0	1	Random	
10	22	1993	6/17/1993	2970	29	0	1	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
10	22	1993	6/17/1993	2970	29	0	1	Random	
10	22	1993	6/17/1993	2970	29	0	1	Random	
10	22	1993	6/17/1993	2970	29	0	1	Random	
10	22	1993	6/17/1993	2970	29	0	0	Random	
10	22	1993	6/17/1993	2970	30	0	1	Random	
10	22	1993	6/17/1993	2970	30	0	1	Random	
10	22	1993	6/17/1993	2970	30	0	1	Random	
10	22	1993	6/17/1993	2970	31	0	1	Random	
10	22	1993	6/17/1993	2970	31	0	1	Random	
10	22	1993	6/17/1993	2970	31	0	1	Random	
10	22	1993	6/17/1993	2970	31	0	1	Random	
10	22	1993	6/17/1993	2970	31	0	1	Random	
10	22	1993	6/17/1993	2970	31	0	1	Random	
10	22	1993	6/17/1993	2970	32	0	1	Random	
10	22	1993	6/17/1993	2970	34	0	1	Random	
10	22	1993	6/17/1993	2970	34	0	1	Random	
10	22	1993	6/17/1993	2970	36	0	1	Random	
10	25	1993	6/17/1993	2974	27	0	0	Random	
10	25	1993	6/17/1993	2974	28	0	0	Random	
10	31	1993	6/17/1993	2983	24	0	0	Random	
10	31	1993	6/17/1993	2983	27	0	0	Random	
10	31	1993	6/17/1993	2983	27	0	0	Random	
10	31	1993	6/17/1993	2983	28	0	0	Random	
10	31	1993	6/17/1993	2983	29	0	1	Random	
10	31	1993	6/17/1993	2983	29	0	0	Random	
10	31	1993	6/17/1993	2983	29	0	1	Random	
10	31	1993	6/17/1993	2983	30	0	1	Random	
10	31	1993	6/17/1993	2983	30	0	1	Random	
10	31	1993	6/17/1993	2983	30	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
10	31	1993	6/17/1993	2983	31	0	1	Random	
10	31	1993	6/17/1993	2983	35	0	1	Random	
10	31	1993	6/17/1993	2983	37	0	1	Random	
10	31	1993	6/17/1993	2984	22	0	0	Random	
10	31	1993	6/17/1993	2984	23	0	0	Random	
10	31	1993	6/17/1993	2984	24	0	0	Random	
10	31	1993	6/17/1993	2984	26	0	0	Random	
10	31	1993	6/17/1993	2984	27	0	0	Random	
10	31	1993	6/17/1993	2984	28	0	0	Random	
10	31	1993	6/17/1993	2984	28	0	0	Random	
10	31	1993	6/17/1993	2984	29	0	0	Random	
10	31	1993	6/17/1993	2984	30	0	0	Random	
10	35	1993	6/17/1993	2996	24	0	0	Random	
10	35	1993	6/17/1993	2996	25	0	0	Random	
10	35	1993	6/17/1993	2996	25	0	0	Random	
10	35	1993	6/17/1993	2996	26	0	0	Random	
10	35	1993	6/17/1993	2996	26	0	0	Random	
10	35	1993	6/17/1993	2996	26	0	0	Random	
10	35	1993	6/17/1993	2996	27	0	0	Random	
10	35	1993	6/17/1993	2996	29	0	0	Random	
10	35	1993	6/17/1993	2996	30	0	0	Random	
10	35	1993	6/17/1993	2996	31	0	0	Random	
10	35	1993	6/17/1993	2996	31	0	0	Random	
10	35	1993	6/17/1993	2996	34	0	1	Random	
10	35	1993	6/17/1993	2996	35	0	1	Random	
10	35	1993	6/17/1993	2996	36	0	1	Random	
10	35	1993	6/17/1993	2996	37	0	1	Random	
10	35	1993	6/17/1993	2996	38	0	1	Random	
10	35	1993	6/17/1993	2997	26	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
10	35	1993	6/17/1993	2997	26	0	0	Random	
10	35	1993	6/17/1993	2997	28	0	0	Random	
10	35	1993	6/17/1993	2997	29	0	1	Random	
10	35	1993	6/17/1993	2997	29	0	0	Random	
10	35	1993	6/17/1993	2997	30	0	1	Random	
10	35	1993	6/17/1993	2997	30	0	1	Random	
10	35	1993	6/17/1993	2997	30	0	1	Random	
10	35	1993	6/17/1993	2997	30	0	1	Random	
10	35	1993	6/17/1993	2997	31	0	1	Random	
10	35	1993	6/17/1993	2997	31	0	1	Random	
10	35	1993	6/17/1993	2997	31	0	1	Random	
10	35	1993	6/17/1993	2997	31	0	1	Random	
10	35	1993	6/17/1993	2997	31	0	0	Random	
10	35	1993	6/17/1993	2997	31	0	1	Random	
10	35	1993	6/17/1993	2997	32	0	1	Random	
10	35	1993	6/17/1993	2997	32	0	1	Random	
10	35	1993	6/17/1993	2997	33	0	1	Random	
10	35	1993	6/17/1993	2997	33	0	1	Random	
10	35	1993	6/17/1993	2997	33	0	1	Random	
10	35	1993	6/17/1993	2997	34	0	1	Random	
10	35	1993	6/17/1993	2997	34	0	1	Random	
10	35	1993	6/17/1993	2997	34	0	1	Random	
10	35	1993	6/17/1993	2997	36	0	1	Random	
11	60	1993	6/25/1993	3271	27	0	0	Random	
11	60	1993	6/25/1993	3271	27	0	0	Random	
11	60	1993	6/25/1993	3271	29	0	0	Random	
11	60	1993	6/25/1993	3271	29	0	0	Random	
11	60	1993	6/25/1993	3271	29	0	0	Random	
11	60	1993	6/25/1993	3271	30	0	1	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
11	60	1993	6/25/1993	3271	30	0	0	Random	
11	60	1993	6/25/1993	3271	32	0	1	Random	
11	60	1993	6/25/1993	3271	32	0	0	Random	
11	60	1993	6/25/1993	3271	33	0	1	Random	
11	60	1993	6/25/1993	3271	33	0	1	Random	
11	60	1993	6/25/1993	3271	33	0	1	Random	
11	60	1993	6/25/1993	3271	33	0	1	Random	
11	60	1993	6/25/1993	3271	34	0	1	Random	
11	60	1993	6/25/1993	3271	34	0	1	Random	
11	60	1993	6/25/1993	3271	34	0	1	Random	
11	60	1993	6/25/1993	3271	35	0	1	Random	
11	60	1993	6/25/1993	3271	35	0	1	Random	
11	60	1993	6/25/1993	3271	35	0	0	Random	
11	60	1993	6/25/1993	3271	36	0	1	Random	
11	60	1993	6/25/1993	3271	37	0	1	Random	
12	16	1993	6/30/1993	3418	30	0	0	Random	
12	16	1993	6/30/1993	3418	31	0	1	Random	
12	16	1993	6/30/1993	3418	31	0	0	Random	
12	16	1993	6/30/1993	3418	32	0	0	Random	
12	16	1993	6/30/1993	3418	33	0	0	Random	
12	16	1993	6/30/1993	3418	34	0	0	Random	
12	16	1993	6/30/1993	3418	35	0	1	Random	
12	16	1993	6/30/1993	3418	37	0	1	Random	
12	61	1993	6/30/1993	3394	18	0	0	Random	
12	61	1993	6/30/1993	3394	20	0	0	Random	
12	61	1993	6/30/1993	3394	21	0	0	Random	
12	61	1993	6/30/1993	3394	34	0	1	Random	
12	61	1993	6/30/1993	3394	35	0	1	Random	
12	61	1993	6/30/1993	3394	38	0	1	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
12	58	1993	7/1/1993	3465	28	0	0	Random	
12	58	1993	7/1/1993	3465	31	0	0	Random	
12	58	1993	7/1/1993	3465	34	0	1	Random	
12	58	1993	7/1/1993	3465	35	0	1	Random	
12	58	1993	7/1/1993	3465	36	0	1	Random	
12	58	1993	7/1/1993	3465	37	0	1	Random	
12	58	1993	7/1/1993	3465	38	0	1	Random	
12	49	1993	7/2/1993	3509	34	0	0	Random	
12	49	1993	7/2/1993	3509	35	0	0	Random	
12	49	1993	7/2/1993	3509	39	0	1	Random	
13	8	1993	7/8/1993	3650	34	0	0	Random	
13	8	1993	7/8/1993	3650	35	0	0	Random	
13	8	1993	7/8/1993	3650	36	0	1	Random	
13	8	1993	7/8/1993	3650	37	0	1	Random	
13	8	1993	7/8/1993	3650	38	0	1	Random	
13	8	1993	7/8/1993	3650	38	0	1	Random	
13	8	1993	7/8/1993	3650	40	0	1	Random	
13	8	1993	7/8/1993	3650	42	0	2	Random	
13	11	1993	7/8/1993	3652	33	0	0	Random	
13	44	1993	7/8/1993	3735	41	0	2	Random	
13	36	1993	7/9/1993	3781	44	0	3	Random	
14	58	1993	7/13/1993	3820	36	0	0	Random	
14	58	1993	7/13/1993	3820	39	0	1	Random	
14	58	1993	7/13/1993	3820	39	0	1	Random	
14	58	1993	7/13/1993	3820	41	0	1	Random	
14	53	1993	7/14/1993	3832	38	0	1	Random	
14	57	1993	7/14/1993	3826	30	0	0	Random	
14	57	1993	7/14/1993	3826	33	0	0	Random	
14	57	1993	7/14/1993	3826	35	0	0	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
14	57	1993	7/14/1993	3826	35	0	1	Random	
14	57	1993	7/14/1993	3826	36	0	1	Random	
14	57	1993	7/14/1993	3826	37	0	1	Random	
14	57	1993	7/14/1993	3826	38	0	1	Random	
14	57	1993	7/14/1993	3826	38	0	1	Random	
14	57	1993	7/14/1993	3826	39	0	1	Random	
14	57	1993	7/14/1993	3826	39	0	1	Random	
14	57	1993	7/14/1993	3826	39	0	1	Random	
14	57	1993	7/14/1993	3826	39	0	1	Random	
14	57	1993	7/14/1993	3826	40	0	1	Random	
14	57	1993	7/14/1993	3826	40	0	1	Random	
14	57	1993	7/14/1993	3826	41	0	1	Random	
14	57	1993	7/14/1993	3826	41	0	1	Random	
14	57	1993	7/14/1993	3826	41	0	1	Random	
14	57	1993	7/14/1993	3826	41	0	1	Random	
14	57	1993	7/14/1993	3826	41	0	1	Random	
14	57	1993	7/14/1993	3826	41	0	1	Random	
14	57	1993	7/14/1993	3826	42	0	2	Random	
14	57	1993	7/14/1993	3826	42	0	2	Random	
14	57	1993	7/14/1993	3826	42	0	2	Random	
14	57	1993	7/14/1993	3826	44	0	2	Random	
14	57	1993	7/14/1993	3826	47	0	5	Random	
14	57	1993	7/14/1993	3826	47	0	3	Random	
14	57	1993	7/14/1993	3826	48	0	3	Random	
14	57	1993	7/14/1993	3826	50	0	5	Random	
15	59	1993	7/26/1993	3913	38	0	1	Random	
15	59	1993	7/26/1993	3913	39	0	0	Random	
15	59	1993	7/26/1993	3913	40	0	1	Random	
15	59	1993	7/26/1993	3913	41	0	1	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
15	59	1993	7/26/1993	3913	42	0	2	Random	
15	59	1993	7/26/1993	3913	42	0	1	Random	
15	59	1993	7/26/1993	3913	43	0	2	Random	
15	59	1993	7/26/1993	3913	44	0	2	Random	
15	59	1993	7/26/1993	3913	48	0	3	Random	
15	60	1993	7/26/1993	3911	35	0	0	Random	
15	60	1993	7/26/1993	3911	36	0	0	Random	
15	60	1993	7/26/1993	3911	37	0	1	Random	
15	60	1993	7/26/1993	3911	38	0	1	Random	
15	60	1993	7/26/1993	3911	38	0	1	Random	
15	60	1993	7/26/1993	3911	39	0	1	Random	
15	60	1993	7/26/1993	3911	39	0	1	Random	
15	60	1993	7/26/1993	3911	39	0	1	Random	
15	60	1993	7/26/1993	3911	40	0	1	Random	
15	60	1993	7/26/1993	3911	40	0	1	Random	
15	60	1993	7/26/1993	3911	40	0	1	Random	
15	60	1993	7/26/1993	3911	41	0	1	Random	
15	60	1993	7/26/1993	3911	41	0	1	Random	
15	60	1993	7/26/1993	3911	41	0	2	Random	
15	60	1993	7/26/1993	3911	41	0	2	Random	
15	60	1993	7/26/1993	3911	41	0	1	Random	
15	60	1993	7/26/1993	3911	41	0	1	Random	
15	60	1993	7/26/1993	3911	42	0	3	Random	
15	60	1993	7/26/1993	3911	42	0	2	Random	
15	60	1993	7/26/1993	3911	42	0	2	Random	
15	60	1993	7/26/1993	3911	43	0	2	Random	
15	60	1993	7/26/1993	3911	43	0	2	Random	
15	60	1993	7/26/1993	3911	43	0	2	Random	
15	60	1993	7/26/1993	3911	43	0	3	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
15	60	1993	7/26/1993	3911	43	0	2	Random	
15	60	1993	7/26/1993	3911	44	0	2	Random	
15	60	1993	7/26/1993	3911	44	0	3	Random	
15	60	1993	7/26/1993	3911	44	0	4	Random	
15	60	1993	7/26/1993	3911	46	0	3	Random	
15	60	1993	7/26/1993	3911	46	0	3	Random	
16	55	1993	8/12/1993	4070	35	0	0	Random	
16	55	1993	8/12/1993	4070	36	0	1	Random	
16	55	1993	8/12/1993	4070	36	0	0	Random	
16	55	1993	8/12/1993	4070	37	0	1	Random	
16	55	1993	8/12/1993	4070	38	0	1	Random	
16	55	1993	8/12/1993	4070	38	0	1	Random	
16	55	1993	8/12/1993	4070	39	0	1	Random	
16	55	1993	8/12/1993	4070	40	0	1	Random	
16	55	1993	8/12/1993	4070	40	0	1	Random	
16	55	1993	8/12/1993	4070	40	0	1	Random	
16	55	1993	8/12/1993	4070	40	0	1	Random	
16	55	1993	8/12/1993	4070	41	0	1	Random	
16	55	1993	8/12/1993	4070	41	0	2	Random	
16	55	1993	8/12/1993	4070	41	0	1	Random	
16	55	1993	8/12/1993	4070	41	0	2	Random	
16	55	1993	8/12/1993	4070	41	0	1	Random	
16	55	1993	8/12/1993	4070	42	0	1	Random	
16	55	1993	8/12/1993	4070	42	0	3	Random	
16	55	1993	8/12/1993	4070	42	0	2	Random	
16	55	1993	8/12/1993	4070	43	0	3	Random	
16	55	1993	8/12/1993	4070	43	0	2	Random	
16	55	1993	8/12/1993	4070	43	0	2	Random	
16	55	1993	8/12/1993	4070	43	0	3	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
16	55	1993	8/12/1993	4070	44	0	2	Random	
16	55	1993	8/12/1993	4070	44	0	3	Random	
16	55	1993	8/12/1993	4070	44	0	1	Random	
16	55	1993	8/12/1993	4070	45	0	4	Random	
16	55	1993	8/12/1993	4070	45	0	3	Random	
16	55	1993	8/12/1993	4070	49	0	4	Random	
17	53	1993	7/14/1993	3832	37	0	1	Random	
17	53	1993	7/14/1993	3832	38	0	2	Random	
17	53	1993	7/14/1993	3832	40	0	1	Random	
17	53	1993	7/14/1993	3832	41	0	1	Random	
17	53	1993	7/14/1993	3832	43	0	3	Random	
17	53	1993	7/14/1993	3832	43	0	3	Random	
17	53	1993	7/14/1993	3832	43	0	3	Random	
17	53	1993	7/14/1993	3832	43	0	4	Random	
17	53	1993	7/14/1993	3832	44	0	2	Random	
17	53	1993	7/14/1993	3832	44	0	3	Random	
17	53	1993	7/14/1993	3832	45	0	3	Random	
17	53	1993	7/14/1993	3832	46	0	3	Random	
17	53	1993	7/14/1993	3832	46	0	4	Random	
17	53	1993	7/14/1993	3832	46	0	4	Random	
17	53	1993	7/14/1993	3832	50	0	4	Random	
17	49	1993	8/25/1993	4148	38	0	1	Random	
17	49	1993	8/25/1993	4148	41	0	0	Random	
17	49	1993	8/25/1993	4148	42	0	1	Random	
17	49	1993	8/25/1993	4148	43	0	1	Random	
17	49	1993	8/25/1993	4148	44	0	2	Random	
17	49	1993	8/25/1993	4148	48	0	2	Random	
17	50	1993	8/25/1993	4150	39	0	0	Random	
17	50	1993	8/25/1993	4150	40	0	1	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
17	50	1993	8/25/1993	4150	41	0	1	Random	
17	50	1993	8/25/1993	4150	41	0	1	Random	
17	50	1993	8/25/1993	4150	42	0	1	Random	
17	50	1993	8/25/1993	4150	42	0	2	Random	
17	50	1993	8/25/1993	4150	43	0	2	Random	
17	50	1993	8/25/1993	4150	43	0	3	Random	
17	50	1993	8/25/1993	4150	44	0	2	Random	
17	50	1993	8/25/1993	4150	45	0	1	Random	
17	50	1993	8/25/1993	4150	45	0	1	Random	
17	50	1993	8/25/1993	4150	45	0	2	Random	
17	50	1993	8/25/1993	4150	48	0	4	Random	
17	50	1993	8/25/1993	4150	50	0	3	Random	
18	11	1993	9/7/1993	4179	46	0	2	Random	
18	55	1993	9/8/1993	4244	88	0	5	Random	
18	55	1993	9/8/1993	4244	90	0	5	Random	
18	55	1993	9/8/1993	4244	90	0	5	Random	
18	55	1993	9/8/1993	4244	91	0	5	Random	
18	55	1993	9/8/1993	4244	91	0	5	Random	
18	55	1993	9/8/1993	4244	93	0	5	Random	
18	55	1993	9/8/1993	4244	93	0	5	Random	
18	55	1993	9/8/1993	4244	93	0	5	Random	
18	55	1993	9/8/1993	4244	95	0	5	Random	
18	58	1993	9/8/1993	4239	46	0	2	Random	
18	61	1993	9/8/1993	4234	82	0	5	Random	
18	61	1993	9/8/1993	4234	88	0	5	Random	
18	61	1993	9/8/1993	4234	96	0	5	Random	
18	61	1993	9/8/1993	4234	98	0	5	Random	
18	72	1993	9/8/1993	4229	42	0	0	Random	
18	72	1993	9/8/1993	4229	43	0	1	Random	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
18	55	1993	9/9/1993	4248	46	0	2	Random	
18	55	1993	9/9/1993	4248	97	0	5	Random	
20	60	1993	10/5/1993	4431	92	0	5	Random	
11	19	1994	6/21/1994	6478	27	0	0	Systematic	
11	19	1994	6/21/1994	6478	30	0	0	Systematic	
11	19	1994	6/21/1994	6478	30	0	0	Systematic	
11	19	1994	6/21/1994	6478	31	0	0	Systematic	
11	26	1994	6/21/1994	6487	35	0	1	Systematic	mid gut
11	26	1994	6/21/1994	6487	37	0	1	Systematic	mid gut
11	26	1994	6/21/1994	6487	36	N/A	N/A	N/A	sent to NHVDL for analysis
11	26	1994	6/21/1994	6487	32	0	0	Systematic	
11	61	1994	6/23/1994	6612	33	0	1	Systematic	mid gut
11	61	1994	6/23/1994	6612	33	0	1	Systematic	mid gut
11	61	1994	6/23/1994	6612	34	0	1	Systematic	mid gut
11	61	1994	6/23/1994	6612	36	0	1	Systematic	mid gut
11	61	1994	6/23/1994	6614	32	0	1	Systematic	mid gut
11	61	1994	6/23/1994	6614	34	0	1	Systematic	pelvic area
11	61	1994	6/23/1994	6612	30	0	0	Systematic	
11	61	1994	6/23/1994	6612	31	0	0	Systematic	
11	61	1994	6/23/1994	6612	32	0	0	Systematic	
11	61	1994	6/23/1994	6612	35	0	0	Systematic	
11	61	1994	6/23/1994	6614	34	0	0	Systematic	
12	54	1994	6/29/1994	6880	38	0	0	Systematic	
12	55	1994	6/29/1994	6918	39	0	1	Systematic	anterior & pelvic area
12	57	1994	6/29/1994	6860	36	0	1	Systematic	mid gut
12	57	1994	6/29/1994	6860	35	0	1	Systematic	pelvic area
12	57	1994	6/29/1994	6860	36	0	1	Systematic	pelvic area
12	26	1994	6/30/1994	6718	34	0	1	Systematic	mid gut
12	26	1994	6/30/1994	6718	38	0	1	Systematic	mid gut

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
12	26	1994	6/30/1994	6718	38	0	1	Systematic	mid gut
12	26	1994	6/30/1994	6718	31	0	0	Systematic	
12	26	1994	6/30/1994	6718	32	0	0	Systematic	
12	26	1994	6/30/1994	6718	38	0	0	Systematic	
12	29	1994	6/30/1994	6726	41	0	1	Systematic	mid gut
12	29	1994	6/30/1994	6726	41	N/A	N/A	N/A	sent to NHVDL for analysis
12	85	1994	6/28/1994	6648	35	N/A	N/A	N/A	sent to NHVDL for analysis
12	85	1994	6/28/1994	6648	32	N/A	N/A	N/A	sent to NHVDL for analysis
13	53	1994	7/6/1994	7007	37	0	1	Systematic	stomach & anterior gut
13	53	1994	7/6/1994	7007	37	0	1	Systematic	stomach & anterior gut
13	53	1994	7/6/1994	7007	39	0	1	Systematic	stomach & anterior gut
13	53	1994	7/6/1994	7007	39	0	1	Systematic	stomach & anterior gut
13	54	1994	7/6/1994	7005	30	0	0	Systematic	
13	54	1994	7/6/1994	7005	35	0	0	Systematic	
13	54	1994	7/6/1994	7005	41	0	2	Systematic	
13	55	1994	7/6/1994	6990	40	0	1	Systematic	stomach & anterior gut
13	18	1994	7/7/1994	7160	39	0	1	Systematic	stomach & anterior gut
13	18	1994	7/7/1994	7160	35	0	0	Systematic	
13	18	1994	7/7/1994	7160	36	0	0	Systematic	
13	25	1994	7/8/1994	7181	39	0	1	Systematic	mid gut
13	25	1994	7/8/1994	7181	36	0	0	Systematic	
14	8	1994	7/12/1994	7076	31	0	1	Systematic	stomach & anterior gut
14	8	1994	7/12/1994	7076	32	0	1	Systematic	stomach & anterior gut
14	8	1994	7/12/1994	7076	35	0	1	Systematic	stomach & anterior gut
14	8	1994	7/12/1994	7076	42	0	1	Systematic	stomach & anterior gut
14	8	1994	7/12/1994	7076	31	0	0	Systematic	
14	8	1994	7/12/1994	7076	33	0	0	Systematic	
14	8	1994	7/12/1994	7076	36	0	0	Systematic	
14	8	1994	7/12/1994	7076	36	0	0	Systematic	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
14	9	1994	7/12/1994	7078	34	0	0	Systematic	
14	9	1994	7/12/1994	7078	36	0	0	Systematic	
14	13	1994	7/12/1994	7082	30	0	0	Systematic	
14	13	1994	7/12/1994	7082	33	0	0	Systematic	
14	18	1994	7/13/1994	7088	37	0	1	Systematic	stomach & anterior gut
14	18	1994	7/13/1994	7089	35	0	1	Systematic	stomach & anterior gut
14	18	1994	7/13/1994	7089	36	0	1	Systematic	stomach & anterior gut
14	21	1994	7/13/1994	7093	35	0	2	Systematic	stomach & anterior gut
14	21	1994	7/13/1994	7093	35	0	1	Systematic	stomach & anterior gut
14	21	1994	7/13/1994	7093	32	0	0	Systematic	
14	61	1994	7/13/1994	7219	33	0	1	Systematic	stomach & anterior gut
14	61	1994	7/13/1994	7219	34	0	1	Systematic	stomach & anterior gut
14	61	1994	7/13/1994	7219	36	0	1	Systematic	stomach & anterior gut
14	61	1994	7/13/1994	7219	36	0	1	Systematic	stomach & anterior gut
14	61	1994	7/13/1994	7219	33	0	0	Systematic	
14	61	1994	7/13/1994	7219	34	0	0	Systematic	
14	54	1994	7/14/1994	7231	35	0	1	Systematic	stomach & anterior gut
14	54	1994	7/14/1994	7231	36	0	1	Systematic	stomach & anterior gut
15	8	1994	7/26/1994	7302	35	0	2	Systematic	anterior gut
15	8	1994	7/26/1994	7302	34	0	1	Systematic	stomach & anterior gut
15	8	1994	7/26/1994	7302	38	0	1	Systematic	stomach & anterior gut
15	8	1994	7/26/1994	7302	42	0	2	Systematic	stomach & anterior gut
15	8	1994	7/26/1994	7302	33	0	0	Systematic	
15	8	1994	7/26/1994	7302	35	0	0	Systematic	
15	8	1994	7/26/1994	7302	38	0	0	Systematic	
15	8	1994	7/26/1994	7302	40	0	0	Systematic	
15	55	1994	7/28/1994	7368	42	0	1	Systematic	stomach & anterior gut
15	55	1994	7/28/1994	7368	38	0	0	Systematic	
16	42	1994	8/10/1994	7467	42	0	1	Systematic	mid gut

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
16	43	1994	8/10/1994	7465	39	0	1	Systematic	small amt pelvic fin area
16	43	1994	8/10/1994	7465	40	0	1	Systematic	small amt pelvic fin area
16	43	1994	8/10/1994	7465	27	0	0	Systematic	
16	43	1994	8/10/1994	7465	28	0	0	Systematic	
16	43	1994	8/10/1994	7465	31	0	0	Systematic	
16	43	1994	8/10/1994	7465	31	0	0	Systematic	
16	43	1994	8/10/1994	7465	31	0	0	Systematic	
16	43	1994	8/10/1994	7465	33	0	0	Systematic	
16	43	1994	8/10/1994	7465	35	0	0	Systematic	
16	43	1994	8/10/1994	7465	36	0	0	Systematic	
16	52	1994	8/10/1994	7461	42	0	1	Systematic	mid gut
17	11	1994	8/22/1994	7268	42	0	1	Systematic	mid gut
17	46	1994	8/24/1994	7509	40	0	0	Systematic	
18	55	1994	9/7/1994	7594	44	0	1	Systematic	anterior gut
18	55	1994	9/7/1994	7594	37	0	0	Systematic	
18	55	1994	9/7/1994	7594	39	0	0	Systematic	
18	55	1994	9/7/1994	7594	42	0	0	Systematic	
20	58	1994	10/4/1994	7783	41	0	0	Systematic	
20	58	1994	10/4/1994	7783	43	0	0	Systematic	
20	58	1994	10/4/1994	7783	43	0	0	Systematic	
11	82	1995	5/31/1995	1695	17	0	0	Systematic	
11	82	1995	5/31/1995	1695	21	0	0	Systematic	
11	82	1995	5/31/1995	1695	21	0	0	Systematic	
11	85	1995	5/31/1995	1687	18	0	0	Systematic	
11	85	1995	5/31/1995	1687	18	0	0	Systematic	
11	85	1995	5/31/1995	1687	19	0	0	Systematic	
11	85	1995	5/31/1995	1687	19	0	0	Systematic	
11	85	1995	5/31/1995	1687	19	0	0	Systematic	
11	85	1995	5/31/1995	1687	19	0	0	Systematic	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
11	85	1995	5/31/1995	1687	19	0	0	Systematic	
11	85	1995	5/31/1995	1687	19	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	20	0	0	Systematic	
11	85	1995	5/31/1995	1687	21	0	0	Systematic	
11	85	1995	5/31/1995	1687	21	0	0	Systematic	
11	85	1995	5/31/1995	1687	21	0	0	Systematic	
11	85	1995	5/31/1995	1687	21	0	0	Systematic	
11	85	1995	5/31/1995	1687	21	0	0	Systematic	
11	85	1995	5/31/1995	1687	21	0	0	Systematic	
11	85	1995	5/31/1995	1687	21	0	0	Systematic	
11	85	1995	5/31/1995	1687	21	0	0	Systematic	
11	85	1995	5/31/1995	1687	21	0	0	Systematic	
11	85	1995	5/31/1995	1687	21	0	0	Systematic	
11	85	1995	5/31/1995	1687	21	0	0	Systematic	
11	85	1995	5/31/1995	1687	22	0	0	Systematic	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
11	85	1995	5/31/1995	1687	22	0	0	Systematic	
11	85	1995	5/31/1995	1687	22	0	0	Systematic	
11	85	1995	5/31/1995	1687	22	0	0	Systematic	
11	85	1995	5/31/1995	1687	22	0	0	Systematic	
11	85	1995	5/31/1995	1687	22	0	0	Systematic	
11	85	1995	5/31/1995	1687	22	0	0	Systematic	
11	85	1995	5/31/1995	1687	22	0	0	Systematic	
11	85	1995	5/31/1995	1687	22	0	0	Systematic	
11	85	1995	5/31/1995	1687	22	0	0	Systematic	
11	85	1995	5/31/1995	1687	23	0	0	Systematic	
11	85	1995	5/31/1995	1687	23	0	0	Systematic	
11	85	1995	5/31/1995	1687	23	0	0	Systematic	
11	85	1995	5/31/1995	1687	24	0	0	Systematic	
11	85	1995	5/31/1995	1687	24	0	0	Systematic	
11	85	1995	5/31/1995	1687	24	0	0	Systematic	
11	92	1995	5/31/1995	1678	15	0	0	Systematic	
11	92	1995	5/31/1995	1678	19	0	0	Systematic	
11	92	1995	5/31/1995	1678	19	0	0	Systematic	
11	92	1995	5/31/1995	1678	20	0	0	Systematic	
11	92	1995	5/31/1995	1678	22	0	0	Systematic	
11	92	1995	5/31/1995	1678	22	0	0	Systematic	
11	92	1995	5/31/1995	1678	23	0	0	Systematic	
11	92	1995	5/31/1995	1679	18	0	0	Systematic	
11	92	1995	5/31/1995	1679	19	0	0	Systematic	
11	92	1995	5/31/1995	1679	19	0	0	Systematic	
11	92	1995	5/31/1995	1679	19	0	0	Systematic	
11	92	1995	5/31/1995	1679	20	0	0	Systematic	
11	92	1995	5/31/1995	1679	20	0	0	Systematic	
11	92	1995	5/31/1995	1679	20	0	0	Systematic	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
11	92	1995	5/31/1995	1679	20	0	0	Systematic	
11	92	1995	5/31/1995	1679	20	0	0	Systematic	
11	93	1995	5/31/1995	1677	20	0	0	Systematic	
11	93	1995	5/31/1995	1677	21	0	0	Systematic	
11	96	1995	5/31/1995	1674	19	0	0	Systematic	
11	96	1995	5/31/1995	1674	20	0	0	Systematic	
11	72	1995	6/1/1995	1716	23	0	0	Systematic	
11	73	1995	6/1/1995	1713	16	0	0	Systematic	
11	73	1995	6/1/1995	1713	17	0	0	Systematic	
11	74	1995	6/1/1995	1711	18	0	0	Systematic	
11	74	1995	6/1/1995	1711	18	0	0	Systematic	
11	74	1995	6/1/1995	1711	18	0	0	Systematic	
11	74	1995	6/1/1995	1711	18	0	0	Systematic	
11	74	1995	6/1/1995	1711	18	0	0	Systematic	
11	74	1995	6/1/1995	1711	19	0	0	Systematic	
11	74	1995	6/1/1995	1711	19	0	0	Systematic	
11	74	1995	6/1/1995	1711	19	0	0	Systematic	
11	74	1995	6/1/1995	1711	19	0	0	Systematic	
11	74	1995	6/1/1995	1711	19	0	0	Systematic	
11	58	1995	6/2/1995	1798	14	0	0	Systematic	
11	58	1995	6/2/1995	1798	16	0	0	Systematic	
11	58	1995	6/2/1995	1798	16	0	0	Systematic	
11	58	1995	6/2/1995	1798	20	0	0	Systematic	
11	58	1995	6/2/1995	1798	20	0	0	Systematic	
11	58	1995	6/2/1995	1799	17	0	0	Systematic	
11	58	1995	6/2/1995	1799	23	0	0	Systematic	
11	58	1995	6/2/1995	1799	23	0	0	Systematic	
11	58	1995	6/2/1995	1802	21	0	0	Systematic	
11	58	1995	6/2/1995	1805	18	0	0	Systematic	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
11	58	1995	6/2/1995	1805	18	0	0	Systematic	
11	58	1995	6/2/1995	1805	19	0	0	Systematic	
11	58	1995	6/2/1995	1805	20	0	0	Systematic	
11	58	1995	6/2/1995	1805	20	0	0	Systematic	
11	60	1995	6/2/1995	1791	20	0	0	Systematic	
11	60	1995	6/2/1995	1795	17	0	0	Systematic	
11	60	1995	6/2/1995	1795	18	0	0	Systematic	
11	60	1995	6/2/1995	1795	19	0	0	Systematic	
11	60	1995	6/2/1995	1795	19	0	0	Systematic	
11	60	1995	6/2/1995	1795	20	0	0	Systematic	
11	60	1995	6/2/1995	1795	21	0	0	Systematic	
11	60	1995	6/2/1995	1795	21	0	0	Systematic	
11	60	1995	6/2/1995	1795	22	0	0	Systematic	
11	36	1995	6/3/1995	1839	21	0	0	Systematic	
11	36	1995	6/3/1995	1839	22	0	0	Systematic	
11	38	1995	6/3/1995	1842	22	0	0	Systematic	
11	39	1995	6/3/1995	1844	23	0	0	Systematic	
11	39	1995	6/3/1995	1850	20	0	0	Systematic	
11	39	1995	6/3/1995	1850	23	0	0	Systematic	
11	39	1995	6/3/1995	1850	26	0	0	Systematic	
11	42	1995	6/3/1995	1857	19	0	0	Systematic	
11	51	1995	6/3/1995	1829	21	0	0	Systematic	
11	44	1995	6/4/1995	1866	20	0	0	Systematic	
11	44	1995	6/4/1995	1866	20	0	0	Systematic	
13	74	1995	6/14/1995	2178	33	0	1	Systematic	
13	74	1995	6/14/1995	2178	34	0	2	Systematic	
13	90	1995	6/14/1995	2153	24	0	0	Systematic	
13	90	1995	6/14/1995	2153	30	0	1	Systematic	
13	90	1995	6/14/1995	2153	35	0	2	Systematic	

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
13	57	1995	6/15/1995	2214	30	0	1	Systematic	
13	57	1995	6/15/1995	2217	31	0	1	Systematic	
13	58	1995	6/15/1995	2224	25	0	0	Systematic	
13	58	1995	6/15/1995	2224	25	0	0	Systematic	
13	58	1995	6/15/1995	2224	26	0	0	Systematic	
13	58	1995	6/15/1995	2224	26	0	0	Systematic	
13	58	1995	6/15/1995	2224	27	0	0	Systematic	
13	58	1995	6/15/1995	2224	28	0	1	Systematic	
13	58	1995	6/15/1995	2224	28	0	1	Systematic	
13	58	1995	6/15/1995	2224	28	0	1	Systematic	
13	58	1995	6/15/1995	2224	29	0	1	Systematic	
13	58	1995	6/15/1995	2224	30	0	1	Systematic	
13	58	1995	6/15/1995	2224	32	0	1	Systematic	
13	59	1995	6/15/1995	2207	29	0	1	Systematic	
13	59	1995	6/15/1995	2207	30	0	1	Systematic	
13	61	1995	6/15/1995	2202	26	0	0	Systematic	
13	64	1995	6/15/1995	2196	30	0	1	Systematic	
13	35	1995	6/16/1995	2276	26	0	1	Systematic	
13	35	1995	6/16/1995	2276	26	0	0	Systematic	
13	35	1995	6/16/1995	2276	28	0	1	Systematic	
13	35	1995	6/16/1995	2276	29	0	1	Systematic	
13	35	1995	6/16/1995	2276	31	0	1	Systematic	
13	35	1995	6/16/1995	2276	33	0	1	Systematic	
13	54	1995	6/16/1995	2243	28	0	0	Systematic	
13	43	1995	6/17/1995	2310	23	0	0	Systematic	
15	61	1995	6/28/1995	2626	34	0	1	Systematic	mid gut
15	61	1995	6/28/1995	2626	34	0	1	Systematic	mid gut
15	61	1995	6/28/1995	2626	36	0	1	Systematic	mid gut
15	58	1995	6/29/1995	2680	38	0	1	Systematic	stomach & anterior gut

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
15	58	1995	6/29/1995	2680	39	0	1	Systematic	stomach & anterior gut
15	58	1995	6/29/1995	2680	40	0	2	Systematic	stomach & anterior gut
15	58	1995	6/29/1995	2680	41	0	2	Systematic	stomach & anterior gut
15	58	1995	6/29/1995	2680	42	0	3	Systematic	stomach & anterior gut
15	58	1995	6/29/1995	2681	41	0	1	Systematic	stomach and pelvic fin area
15	50	1995	6/30/1995	2718	36	0	1	Systematic	mid gut
15	51	1995	6/30/1995	2713	38	0	1	Systematic	stomach & anterior gut
15	51	1995	6/30/1995	2713	42	0	1	Systematic	stomach & anterior gut
15	54	1995	6/30/1995	2704	35	0	1	Systematic	mid gut
15	54	1995	6/30/1995	2704	37	0	1	Systematic	mid gut
15	54	1995	6/30/1995	2704	39	0	1	Systematic	mid gut
15	54	1995	6/30/1995	2704	39	0	1	Systematic	mid gut
15	54	1995	6/30/1995	2704	40	0	1	Systematic	mid gut
15	54	1995	6/30/1995	2704	40	0	1	Systematic	mid gut
15	54	1995	6/30/1995	2704	39	0	2	Systematic	mid gut to anus
15	54	1995	6/30/1995	2704	41	0	2	Systematic	mid gut to anus
15	54	1995	6/30/1995	2704	45	0	2	Systematic	mid gut to anus
15	54	1995	6/30/1995	2706	35	0	1	Systematic	stomach & anterior gut
15	54	1995	6/30/1995	2706	38	0	1	Systematic	stomach & anterior gut
15	54	1995	6/30/1995	2706	39	0	1	Systematic	stomach & anterior gut
15	54	1995	6/30/1995	2706	40	0	1	Systematic	stomach & anterior gut
15	54	1995	6/30/1995	2706	40	0	2	Systematic	stomach & anterior gut
15	54	1995	6/30/1995	2706	35	0	0	Systematic	
15	36	1995	7/1/1995	2745	40	0	2	Systematic	stomach & anterior gut
15	42	1995	7/1/1995	2766	37	0	0	Systematic	
15	42	1995	7/1/1995	2766	39	0	2	Systematic	
15	42	1995	7/1/1995	2766	41	0	1	Systematic	
15	42	1995	7/1/1995	2766	42	0	2	Systematic	
17	29	1995	7/20/1995	3056	38	0	1	Systematic	stomach & anterior gut

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
17	57	1995	7/20/1995	3086	40	0	1	Systematic	mid gut
17	61	1995	7/20/1995	3080	42	0	1	Systematic	mid gut
17	61	1995	7/20/1995	3080	43	0	2	Systematic	mid gut to anus
17	62	1995	7/20/1995	3078	46	0	3	Systematic	stomach & anterior gut
17	48	1995	7/21/1995	3098	42	0	2	Systematic	stomach & anterior gut
17	48	1995	7/21/1995	3098	46	0	2	Systematic	stomach & anterior gut
17	48	1995	7/21/1995	3098	46	0	3	Systematic	stomach & anterior gut
17	48	1995	7/21/1995	3098	49	0	3	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3096	42	0	2	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3096	43	0	3	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	41	0	1	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	41	0	1	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	42	0	1	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	42	0	1	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	42	0	2	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	43	0	2	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	44	0	2	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	44	0	2	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	44	0	3	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	45	0	3	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	46	0	2	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	46	0	3	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	46	0	3	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	47	0	3	Systematic	stomach & anterior gut
17	51	1995	7/21/1995	3097	49	0	4	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3091	40	0	1	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3091	42	0	1	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3091	44	0	1	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3091	44	0	3	Systematic	stomach & anterior gut

River Run	River Mile	Year	Sample Date	Sample ID	Length (mm)	External Exam	Internal Exam	Selection Method	Comments
17	55	1995	7/21/1995	3091	45	0	2	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3091	45	0	3	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3091	45	0	4	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3091	45	0	2	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3091	45	0	2	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3091	46	0	2	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3091	47	0	2	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3091	48	0	3	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3091	49	0	3	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3093	41	0	1	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3093	42	0	2	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3093	43	0	2	Systematic	stomach & anterior gut
17	55	1995	7/21/1995	3093	47	0	3	Systematic	stomach & anterior gut

Appendix 2

New Hampshire Veterinary Diagnostic Laboratory Report

University of New Hampshire
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Final Report

DIRECT TO FARMERS
Dr. INGA SIDOR
NHVDL
21 Botanical Lane
Durham , NH 03824

UNH Case#: 16-852
Date Received: 02/02/16
Owner: Normandeau Associates

Case Id: 12 samples
Species: Fish Species

Pathology Report

Specimen:
Twelve formalin-fixed rainbow smelt (*Osmerus mordax*, project number 19998.008.9.085) from the Hudson River estuary, four each from three year classes (1992, 1994 and 1995), are submitted for examination. Fishes are trimmed separately into individual cassettes.

Histopathology:
1992 (slides 1A-B, 2, 3 and 4)
Saggital and transverse sections of four fish are examined, including integument, skeletal muscle, bone, cartilage, fin, brain, eye, gill, heart, spinal cord, kidney, liver, intestine, stomach, swim bladder and gonad. In two fish, there are sections through multiple, large, intracoelomic acanthocephalan parasites; these are characterized by a thick, muscular tegument, pseudocoelom, gonad, and lemnisci supporting a frequently invaginated, spined proboscis. These parasites are coated by a variably-thick layer of macrophages, with fibrous adhesions to other viscera. Mesenteric adipose is discolored yellow, with increased interstitial and serosal infiltrates of macrophages. Intestines of the fish frequently contain remnants of food items (arthropods with cuticle and skeletal muscle).

1994 (slides 1-4)
Saggital and transverse sections of four fish are examined, as above. There are no significant histologic lesions.

1995 (slides 1-4)
Saggital and transverse sections of four fish are examined, as above. A single, small, encysted trematode is present in the lens of one eye. A cestode is present within coelom of a second fish, with mild peripheral inflammation. A third fish has a large acanthocephalan in the coelom, as described above, with moderate cuffing by infiltrating macrophages. .

Comment:
Mixed parasitism is common in wild fish. The most consistent parasite in these fish (in 3/12) is an acanthocephalan (spiny-headed worm), named for the spined proboscis they use to attach to the host. The larval form of these parasites typically infect small insects or crustaceans (amphipods), and develop in liver or mesentery of the fish host. The location of these acanthocephalan parasites is similar to that described for microsporidia (e.g. *Glugea hertwigi*), but no compatible microsporidian parasites or xenomas are present.

A small number of acanthocephalan parasites have been described in the rainbow smelt, including *Echinorhynchus salmonis*, *Acanthocephalus dirus*, and various *Corynosoma* spp. Definitive identification of these parasites is performed by examination of the spines in intact, fixed specimens; we can arrange a consult with a parasitologist, if desired.

Diagnoses:
1992: Acanthocephalan parasites with moderate, chronic peritonitis (2/4 fish)
1994: No significant lesions (4 fish)
1995: Acanthocephalan parasites with moderate, chronic peritonitis (1/4 fish), ocular trematode parasite (1/4 fish), cestode parasite with mild, chronic peritonitis (1/4 fish)
Case No: 16-852

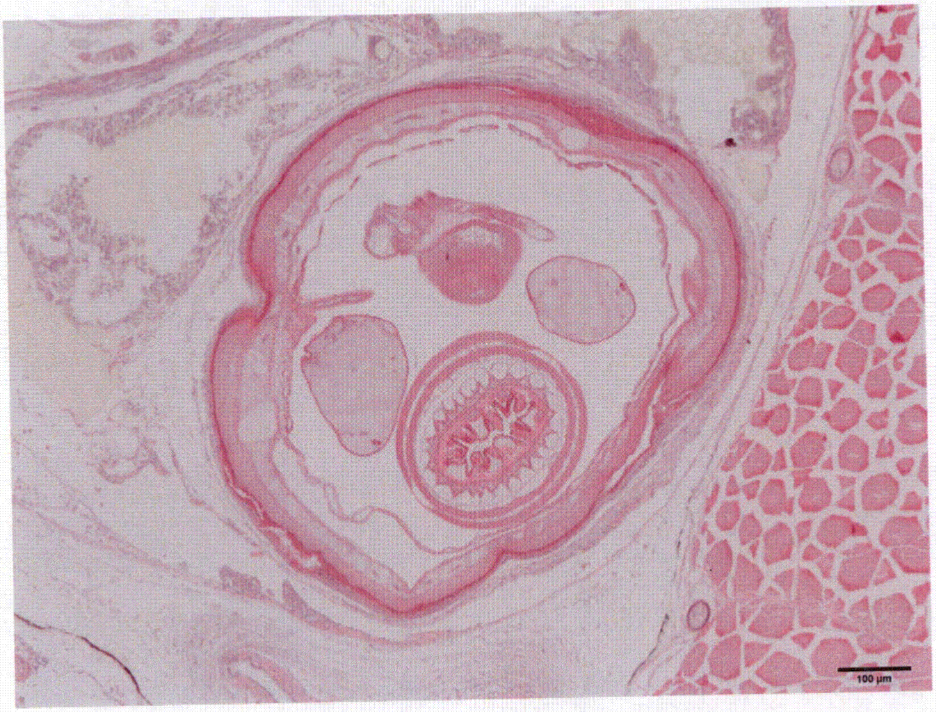

Photo 1: 16-852 Inverted Proboscsis 100x

Photo 2: 16-852 Parasite Adjacent to Gut 25x

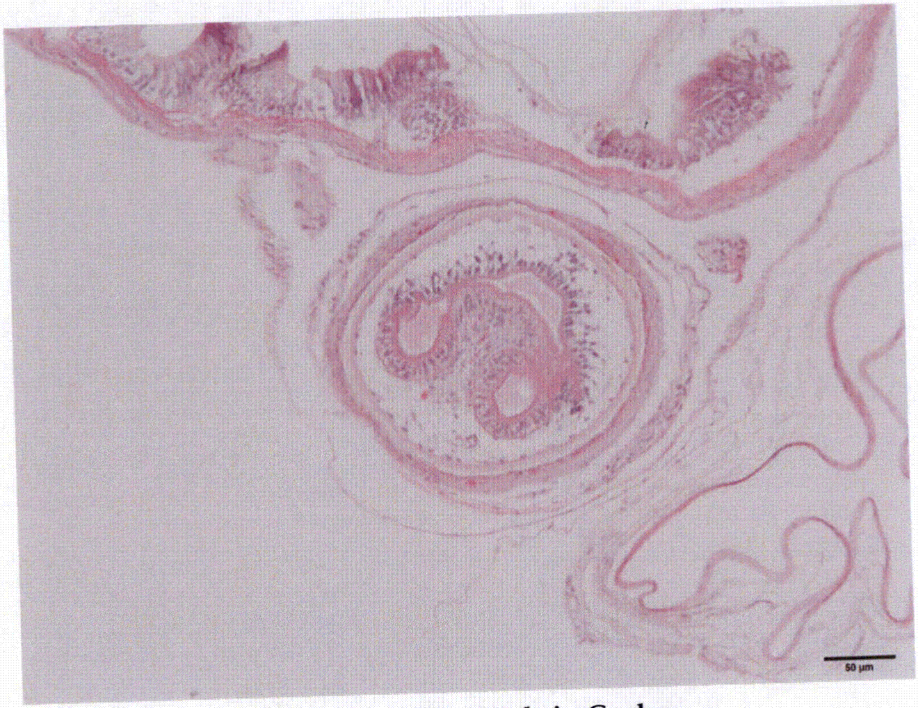

Photo 3: 16-852 Cestode in Coelom

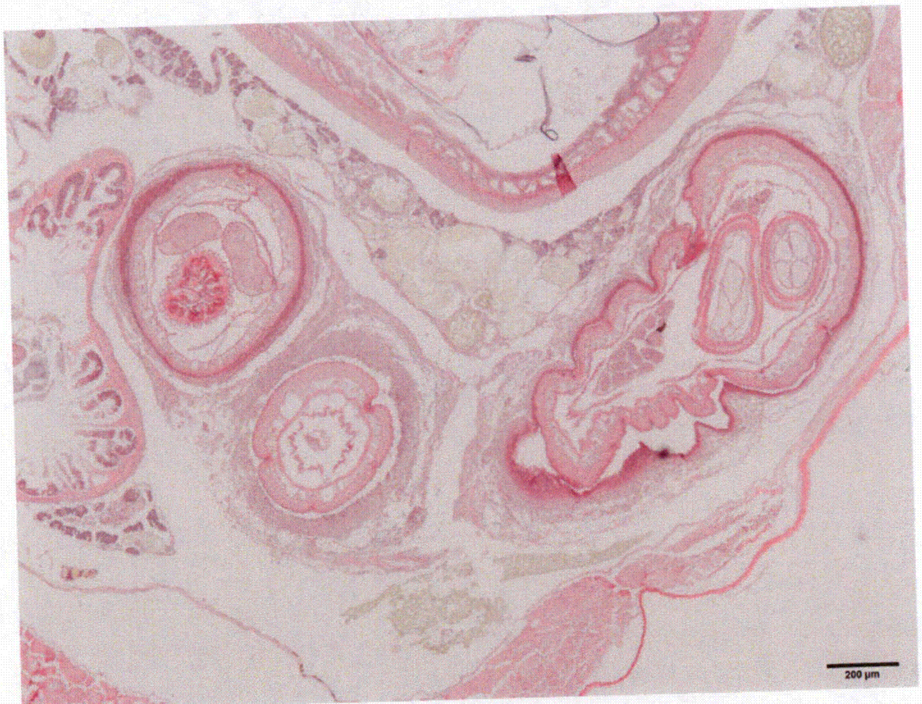

Photo 4: 16-852 Three Sections of Parasite

APPENDIX 2C

BIOLOGICAL EXAMINATION OF SPATIAL AND TEMPORAL DISTRIBUTION AND ABUNDANCE OF EARLY LIFE STAGES OF RIVER HERRING WITH RESPECT TO IPEC ENTRAINMENT IMPACTS

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March 2016

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1 INTRODUCTION

The December 2015 Final Supplemental Environmental Impact Statement ("FSEIS") to the Generic Environmental Impact Statement for License Renewal of Nuclear Plants Supplement 38 Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3 Draft Report for Comment (USNRC 2015) reached interim species-specific findings of "large" potential impacts for two species, blueback herring and rainbow smelt, of continued IP2 and IP3 cooling system operation during the license renewal period (USNRC 2015, Table A-18). For both species NRC Staff determined that a decline had been detected in the population trend, and that the Strength of Connection (SOC) between cooling system operation and population trend is high. These findings were based on an analysis methodology that NRC applied to the voluminous data collected on the distribution and abundance of Hudson River fishes over the last 40 years by the owners of IP2 and IP3. Over these four decades, I have provided expert technical oversight for the data collection and have been the primary analyst of that dataset.

The NRC staff's analysis methods were applied to three river sampling programs, plus entrainment and impingement sampling, for 17 species of fish and 1 crab species, using a broadly applicable methodology. However, no methodology is certain to work well for all species. Therefore, it is important that NRC consider information that indicates that additional methods or analyses are necessary to provide accurate conclusions for particular species.

This report presents analyses which demonstrate that the Strength of Connection between power plant operations and population trends is actually low for blueback herring, and therefore the overall impact conclusion for the species should be "small". The analyses used primarily, but not exclusively, information provided to NRC in 2007.

2 METHODOLOGY

The analyses presented here are based on the patterns of spatial and temporal distribution of eggs, larvae, and juvenile (young-of-year) fishes collected in the Long River Survey (LRS) from 1979 through 2005. These patterns were produced from the region x week densities (D_{rw}) provided to NRC, which were then multiplied by the regional volumes to produce an estimate of population presence[1]:

$$N_{yrw} = D_{yrw} \times V_r$$
$$P_y = \Sigma_{yrw} N_{yrw}$$

The N_{rw} values were then graphed for each year, and the patterns of spatial and temporal presence were related to freshwater inflow to the estuary as measured at the Federal Dam in Troy, NY.

Estimates of entrainment conditional mortality rate (CMRs), analogous to NRC's entrainment mortality rate (EMR) and based on riverwide abundance patterns with actual cooling water flows at IPEC from 1974-1997 and annual entrainment estimates, were also incorporated from the Hudson River DEIS (Central Hudson et al. 1999).

River herring (blueback herrings and alewife) spawn in the northern areas of the Hudson River Estuary, far upstream of the Indian Point Energy Center (IPEC), and early life stages of these species are also found predominantly upstream from IPEC (Central Hudson et al. 1999). Consequently, their susceptibility to entrainment and impingement is comparatively low. These facts have been known since the 1970s, and were noted by federal agency scientists, including NRC's own experts, in peer-reviewed articles published following the Hudson River Settlement Agreement (Boreman and Goodyear 1988; Barnthouse and Van Winkle 1988). Since the 1970s, nearly 40 years of monitoring has provided additional insights into the life history and distribution of river herring in the Hudson River, further demonstrating that IPEC operations have no significant impact on these populations.

NRC calculated an entrainment mortality rate (EMR) for blueback herring of 0.095 (9.5%), and an impingement mortality rate of 0.004 (0.4%) (NRC 2015, Table A-15), and used these values in its Monte Carlo analysis to determine that Strength of Connection was high. NRC's estimate of EMR is far higher than previous estimates of entrainment mortality rates for river herring at IPEC. In the 1999 DEIS, annual estimates of entrainment mortality (CMR) at IPEC over the years 1979-1997 ranged from 0.02% to 5.34% (Table 1). These estimates were closely related to the fraction of the larval population that occurred within region 4 where IPEC is located (Figure 1), with the average % of larvae in region 4 over the period of 1.13% and average CMR over the same period of 1.11% (Table 1). Based on CMR, between 1979 and 1997 entrainment mortality was less than 1% in 14 of 19 years, and exceeded 3% in only 2 years.

Examination of the CMR estimates from the DEIS, along with historical data on freshwater inflow to the estuary during the spawning season, indicates a strong relationship between the CMR and flow (Figure 2), which suggests the mechanism by which entrainment impacts at IPEC for this species are determined. Years with CMR of 3% or higher, e.g. 1983, 1984, 1990, experienced high freshwater inflow rates during the spawning and larval development period, May 1-June 15. Conversely, in years with low freshwater inflow rates, CMR was overwhelmingly below 1.5%, and often below 0.5%, e.g. 1985, 1987, and 1995. The spatial and temporal patterns of egg, larval,

[1] Presence is the sum of all region numeric abundances over weeks 18-26 in each year. This sampling window may or may not be an appropriate time to estimate an index of actual abundance for any life stage.

and juvenile fish distribution in these years are examined to provide insight into the influence of flow on IPEC entrainment impact on river herring.

Table 1 Total estimated presence of eggs, larvae, and YOY in regions 1-12, based on LRS sampling in weeks 18-26, annual percent of river population of early life stages within region 4, and entrainment CMR estimates (%) from the DEIS for river herring.

River Herring							
	Weeks 18-26 Population			Percent in Region 4			
Year	Eggs	Lar	YOY	Eggs	Lar	YOY	CMR_{IP}
1979	555	1,789	111.53	0.00	1.87	0.01	2.24
1980	220	1,618		0.00	0.11	0.02	0.48
1981	7,491	2,088	216.93	0.00	0.33	0.00	0.57
1982	5,318	2,699	32.54	0.00	1.09	0.58	0.81
1983	3,922	3,570	11.73	0.00	3.99	0.71	3.05
1984	3,915	2,181	71.62	0.00	4.87	0.03	5.34
1985	365	2,440	163.01	0.00	0.01	0.00	0.02
1986	238	3,307	25.56	0.00	1.15	0.16	0.92
1987	111	1,002	75.93	0.00	0.06	0.02	0.04
1988	462	1,357	34.90	0.00	0.29	0.00	0.51
1989	830	1,634	68.33	0.00	1.24	6.10	1.41
1990	3,392	1,686	0.00	0.00	3.17	0.00	2.94
1991	390	1,171	0.00	0.00	0.04	0.00	0.41
1992	489	1,977	5.86	0.00	0.53	0.00	0.41
1993	98	1,146	4.55	0.00	0.22	0.00	0.23
1994	280	1,197	0.13	0.00	0.51	1.56	0.49
1995	100	790	9.97	0.01	0.13	0.00	0.12
1996	1,297	2,419	9.33	0.00	0.23	0.72	0.49
1997	36	390	0.00	0.00	1.69	0.00	0.60
1998	53	624	0.00	0.01	0.77	0.00	NA
1999	14	663	0.00	0.00	2.54	0.00	NA
2000	135	1,829	0.86	0.99	4.28	0.00	NA
2001	28	1,100	0.00	0.00	1.32	0.00	NA
2002	28	848	0.00	0.17	4.34	0.00	NA
2003	121	724	0.00	0.03	1.86	0.00	NA
2004	69	718	0.00	0.44	1.19	0.00	NA
2005	8	613	0.03	0.00	1.54	0.00	NA
Ave 79-97	1,553	1,814	46.77	0.00	1.13	0.52	1.11
Ave 79-05	1,110	1,540	32.42	0.06	1.46	0.37	

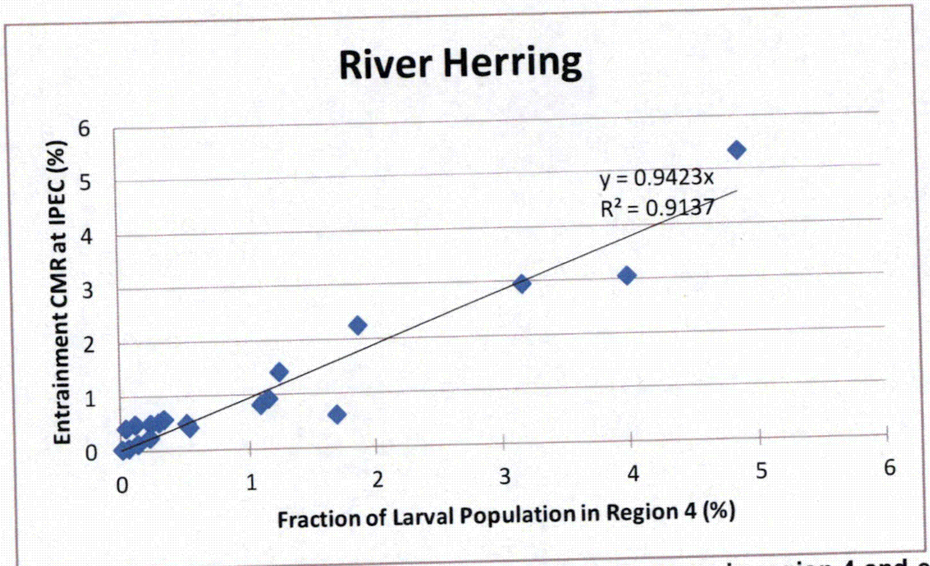

Figure 1 Relationship between fraction of larval population presence in region 4 and entrainment CMR.

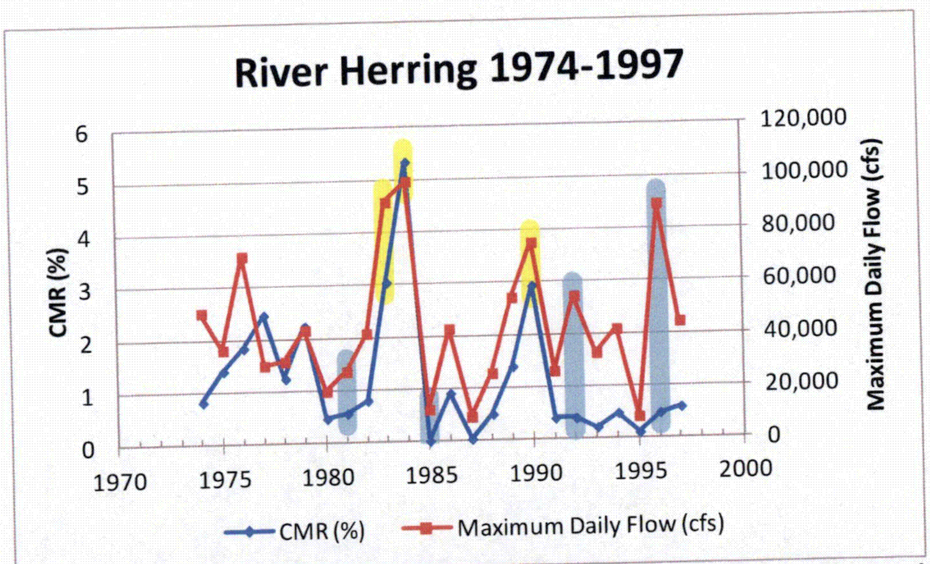

Figure 2 Annual CMR (%) for river herring at IPEC from 1974-1997, and maximum daily flow at Federal Dam between May 1 and June 15 of each year. The three years with highest CMR highlighted in yellow, and 4 selected years with low CMR and various levels of flow highlighted in blue.

3 RESULTS

3.1 SPATIAL-TEMPORAL DISTRIBUTION IN TYPICAL YEARS

Examination of the spatial-temporal patterns of the early life stages provides a strong qualitative, if not quantitative, demonstration that entrainment mortality rates for blueback herring (not distinguished from alewife in egg and larval stages) are typically low due to their occurrence far upstream of IPEC. Distributions for 1981, 1985, and 1992 provide clear examples that in years with stable and moderate to low freshwater inflow, river herring eggs occur only in the northern reaches of the estuary at a substantial distance from Indian Point, that larvae are dispersed downstream but nonetheless remain out of the influence of Indian Point (Tables 1 and 2), and the YOY resulting from the spawn, prior to emigration, are found in similar locations as the larvae (Figures 3-5).

Table 2 Estimated number of river herring entrained at IPEC based on in-plant sampling programs, 1981-1987. Source is DEIS Appendix VI-1-D-2 Table 2.

Year	Number Entrained (millions)
1981	110
1982	No Sampling
1983	547
1984	1,990
1985	2
1986	146
1987	2

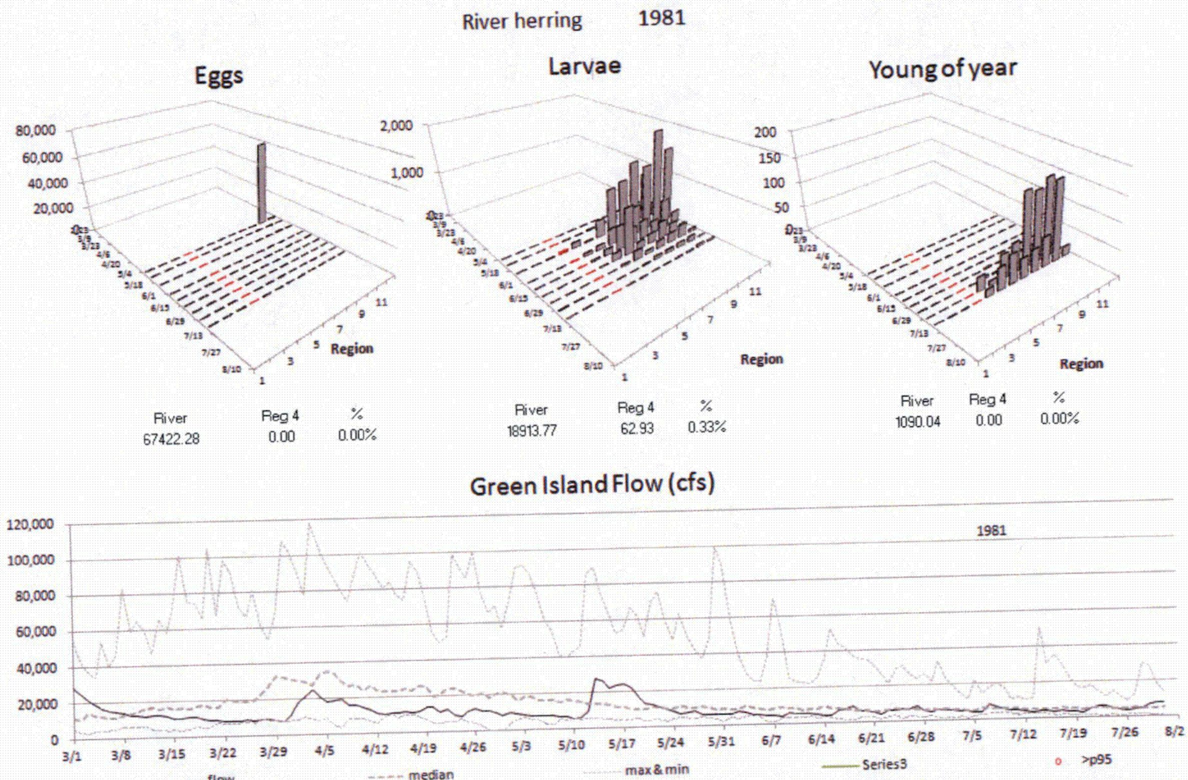

Figure 3 Spatial-temporal distribution of eggs, larvae, and YOY river herring from LRS sampling in 1981, with total river population and region 4 population summed across all sampling weeks. Red bars indicate region 4. Freshwater inflows for March-July, with actual flow for each date, and maximum, minimum and median for each calendar date for 1946-2005. Red circles indicate actual flow exceeding 95th percentile for the date.

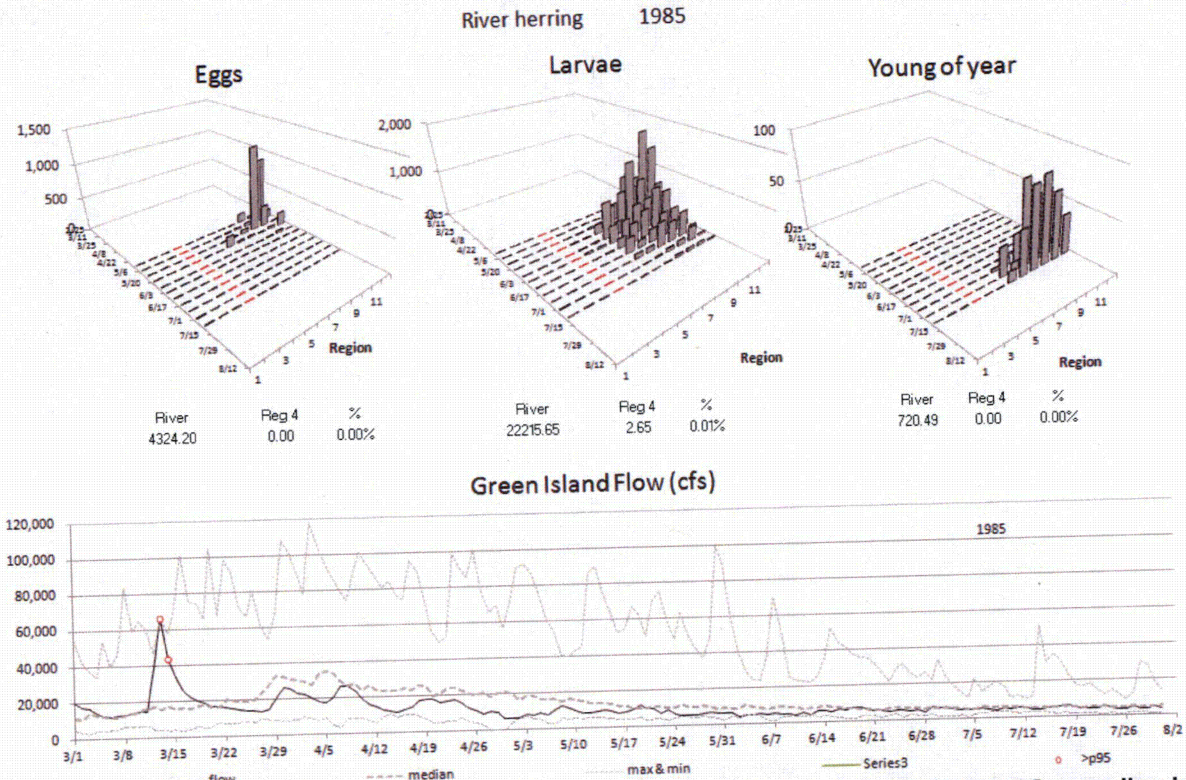

Figure 4 Spatial-temporal distribution of eggs, larvae, and YOY river herring from LRS sampling in 1985, with total river population and region 4 population summed across all sampling weeks. Red bars indicate region 4. Freshwater inflows for March-July, with actual flow for each date, and maximum, minimum and median for each calendar date for 1946-2005. Red circles indicate actual flow exceeding 95th percentile for the date.

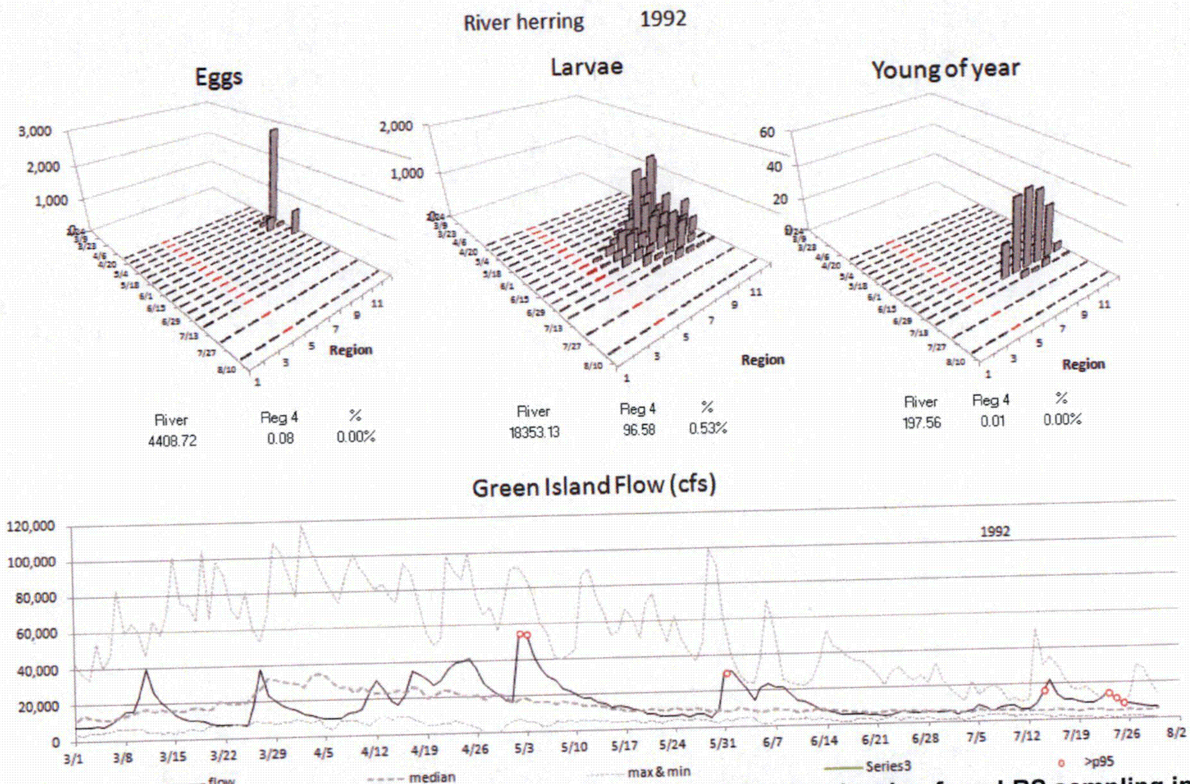

Figure 5 Spatial-temporal distribution of eggs, larvae, and YOY river herring from LRS sampling in 1992, with total river population and region 4 population summed across all sampling weeks. Red bars indicate region 4. Freshwater inflows for March-July, with actual flow for each date, and maximum, minimum and median for each calendar date for 1946-2005. Red circles indicate actual flow exceeding 95th percentile for the date.

3.2 SPATIAL-TEMPORAL DISTRIBUTION IN HIGH-FLOW YEARS

The pattern seen in years with a high flow event during the spawning season contrasts sharply with the spatial-temporal patterns in low-flow, low-CMR years. For example, in 1983, river flows were high during the last half of April and early May (Figure 6). Eggs were distributed further downstream than is typical. Larvae were dispersed throughout the upper and middle regions of the estuary and were present in regions 3 and 4 in late May and early June. The estimated CMR was 3.05%. Surviving YOY observed in July were mostly in regions 6-8, upstream of IPEC.

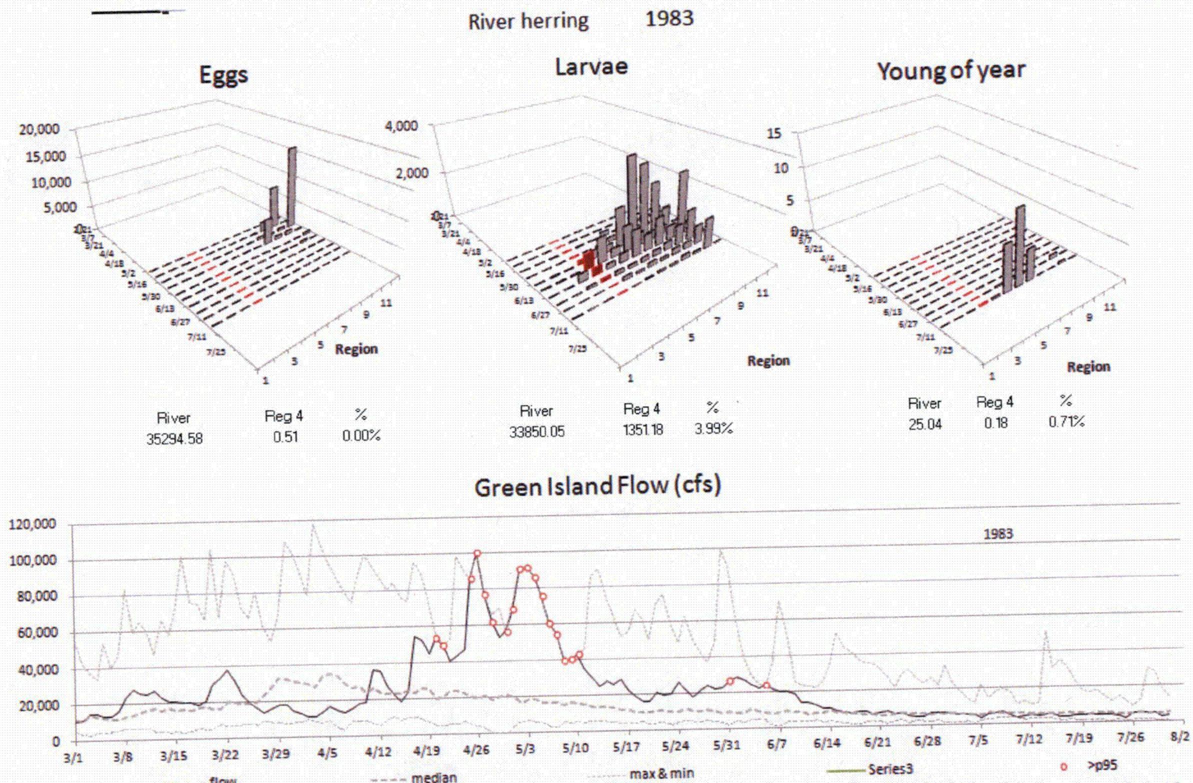

Figure 6 Spatial-temporal distribution of eggs, larvae, and YOY river herring from LRS sampling in 1983, with total river population and region 4 population summed across all sampling weeks. Red bars indicate region 4. Freshwater inflows for March-July, with actual flow for each date, and maximum, minimum and median for each calendar date for 1946-2005. Red circles indicate actual flow exceeding 95th percentile for the date.

In 1984, an extreme flow event occurred at the end of May, setting the period of record daily flow maximums from May 29 through June 4 (Figure 7). This event resulted in a cessation of spawning, and rapid and extreme downriver transport of larval stages to and well beyond region 4. The abundance of larvae in region 4 resulted in the highest annual number of river herring larvae entrained of 1,990 million (Table 2) and the highest estimated CMR of 5.34% (Table 1). After the high flow event, a second spawning bout produced additional larvae in the upriver regions where they are usually found. All surviving YOY were found in upriver regions where larvae from the second spawning were distributed. There were no YOY downstream indicating that the advected larvae did not survive.

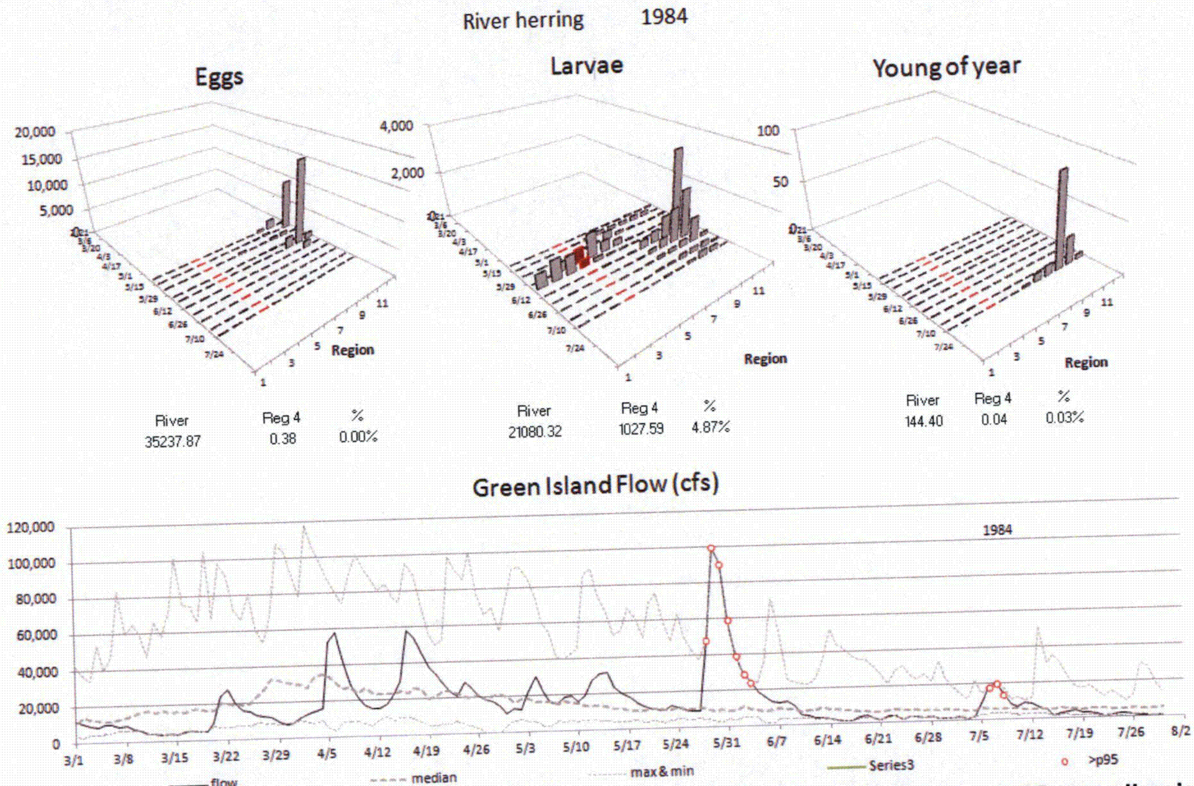

Figure 7 Spatial-temporal distribution of eggs, larvae, and YOY river herring from LRS sampling in 1984, with total river population and region 4 population summed across all sampling weeks. Red bars indicate region 4. Freshwater inflows for March-July, with actual flow for each date, and maximum, minimum and median for each calendar date for 1946-2005. Red circles indicate actual flow exceeding 95th percentile for the date.

Although the high flow event of 1990 occurred slightly earlier than in 1984, with calendar date maximum flows from May 17 through May 24, the spatial-temporal patterns of larval abundance were very similar to 1984 (Figure 8). The high flows of late May rapidly advected larvae downstream to and below region 4. Spawning after the high flow events produced additional larvae in upper regions of the estuary, which then produced the surviving young-of-year. The CMR estimate for 1990 was 2.94% (Table 1), the third highest estimate between 1979 and 1997.

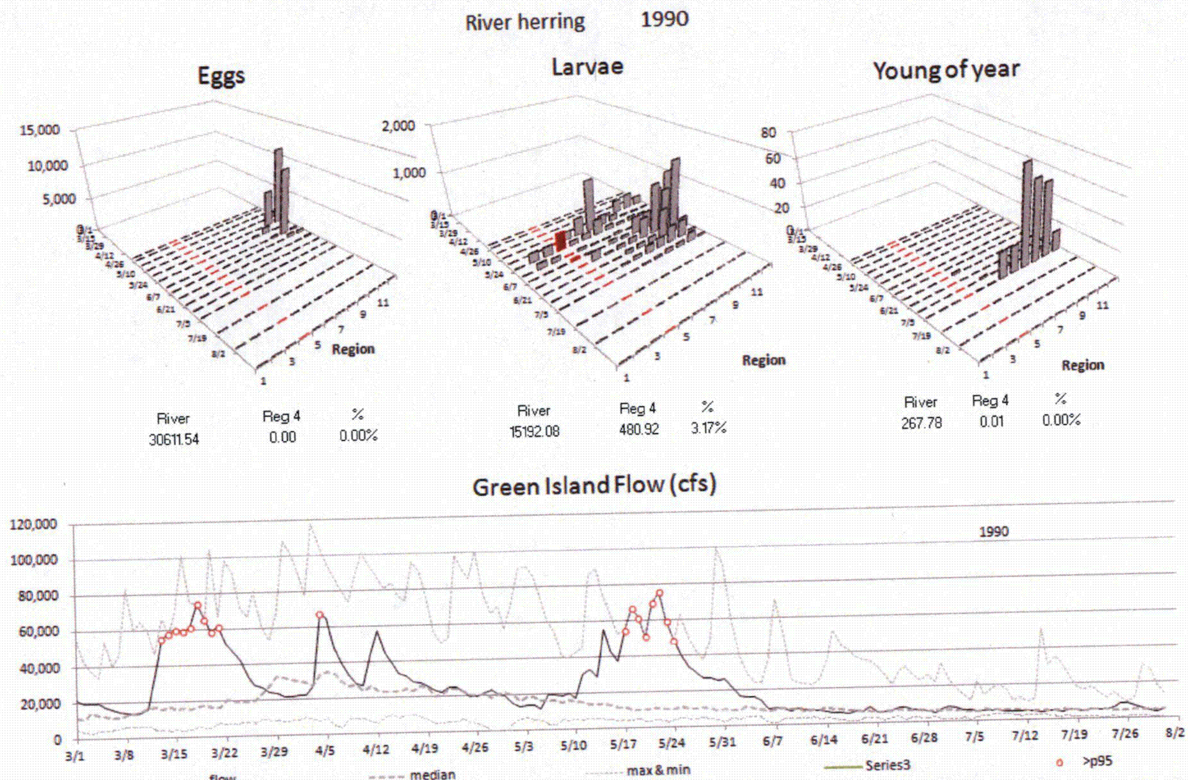

Figure 8 Spatial-temporal distribution of eggs, larvae, and YOY river herring from LRS sampling in 1990, with total river population and region 4 population summed across all sampling weeks. Red bars indicate region 4. Freshwater inflows for March-July, with actual flow for each date, and maximum, minimum and median for each calendar date for 1946-2005. Red circles indicate actual flow exceeding 95th percentile for the date.

Overall, the relationship of entrainment CMR with maximum daily flow demonstrates that entrainment mortality rate is strongly driven by extreme flow events, with the 3 years with highest entrainment CMR occurring during 3 of the 4 highest maximum flows (Figure 9). These high CMR values, although still generally less than ½ of the EMR used by NRC, occurred when maximum daily flow exceeded about 75,000 cfs, approximately the 90th percentile of maximum daily flow.

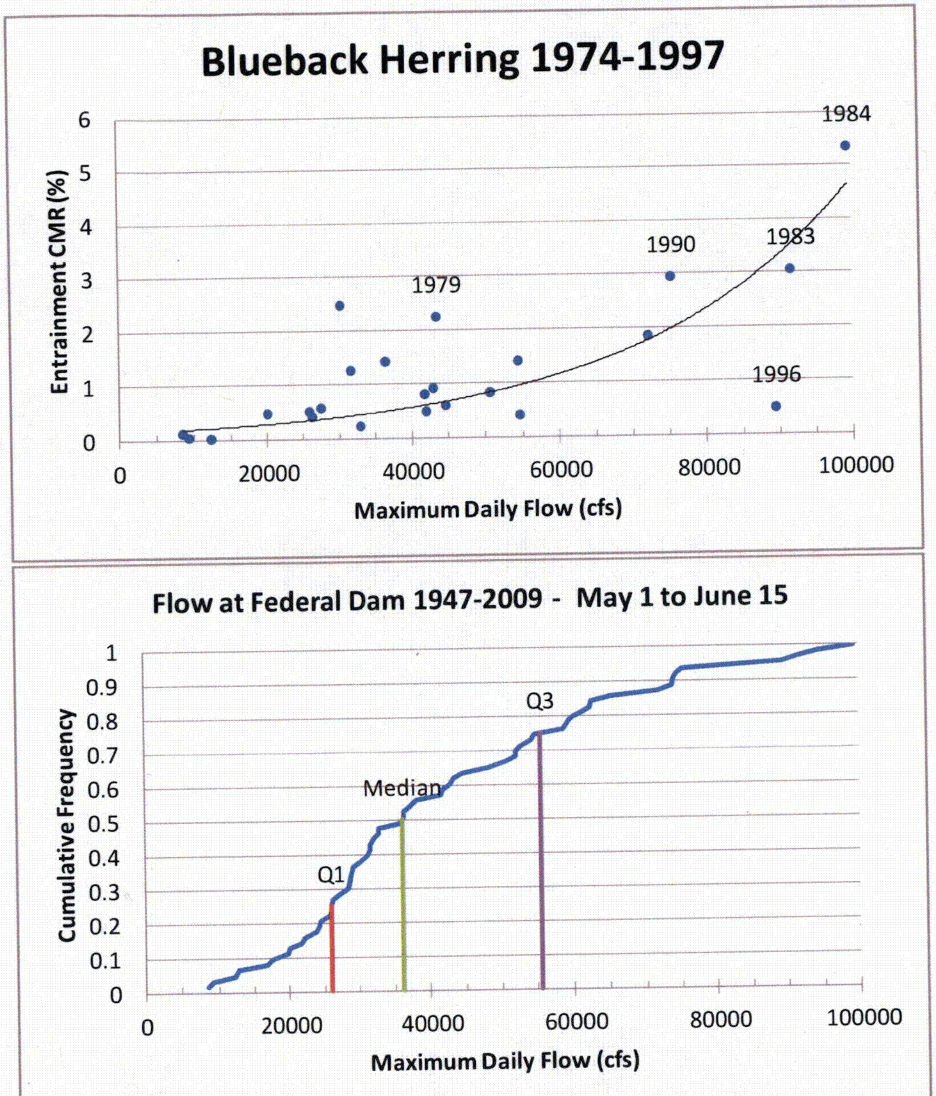

Figure 9 Top – Relationship between maximum daily flow at the Federal Dam between May 1 and June 15 each year and river herring entrainment CMR at IPEC (1974-1997). Bottom – Cumulative frequency of maximum daily flow at the Federal Dam between May 1 and June 15 each year, (1947-2009)

3.3 DEVIATIONS

There were exceptions to this general pattern, as evidenced by a much lower CMR than would have been expected in 1996, and a higher CMR than expected in 1979 (Figure 9). Although maximum daily flow in 1996 was the third highest observed in the 1974-1997 period, the flow peak was brief, and occurred prior to river herring spawning, and subsequently had little effect on the spatial distribution of larvae (Figure 10). In 1979, a period of higher, but not extreme, flows during the last week of May and first week of June advected larvae to the Indian Point region, and resulted in a CMR estimate of 2.47 percent (Figure 11).

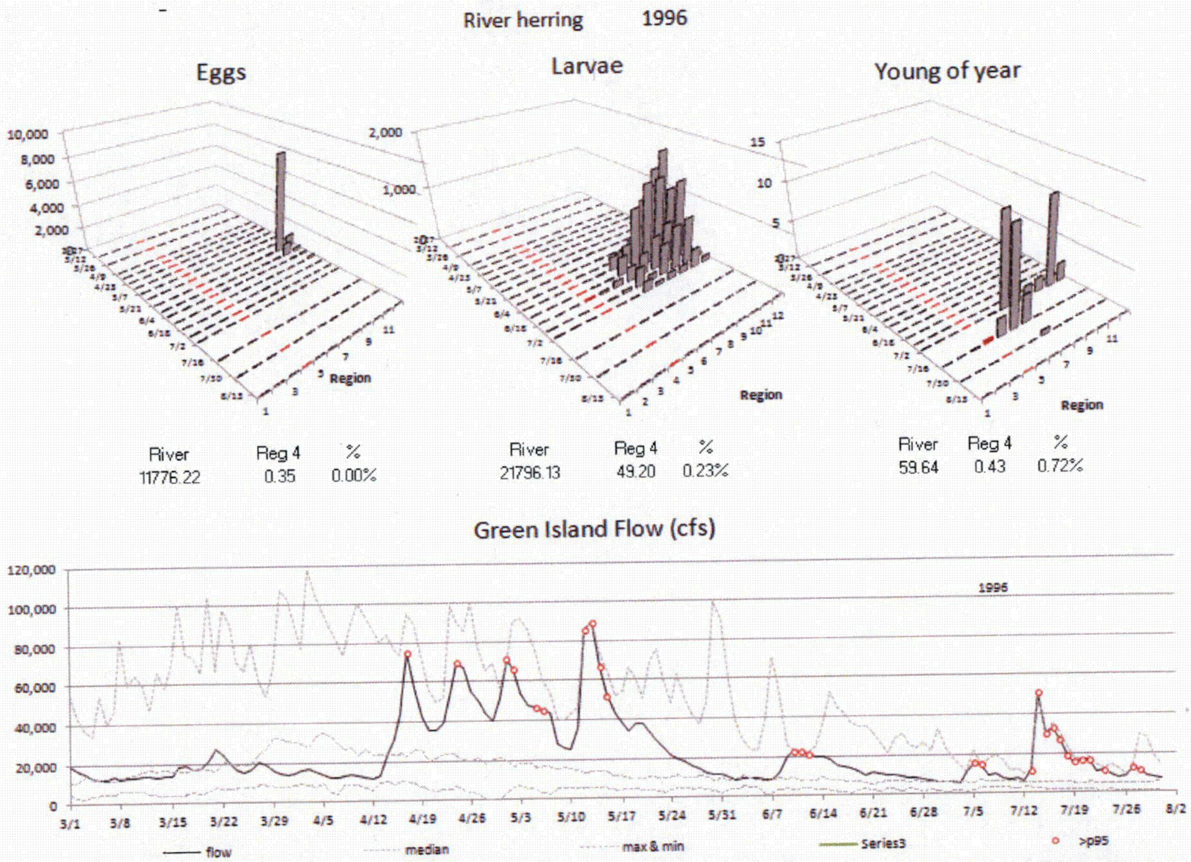

Figure 10 **Spatial-temporal distribution of eggs, larvae, and YOY river herring from LRS sampling in 1996, with total river population and region 4 population summed across all sampling weeks. Red bars indicate region 4. Freshwater inflows for March-July, with actual flow for each date, and maximum, minimum and median for each calendar date for 1946-2005. Red circles indicate actual flow exceeding 95th percentile for the date.**

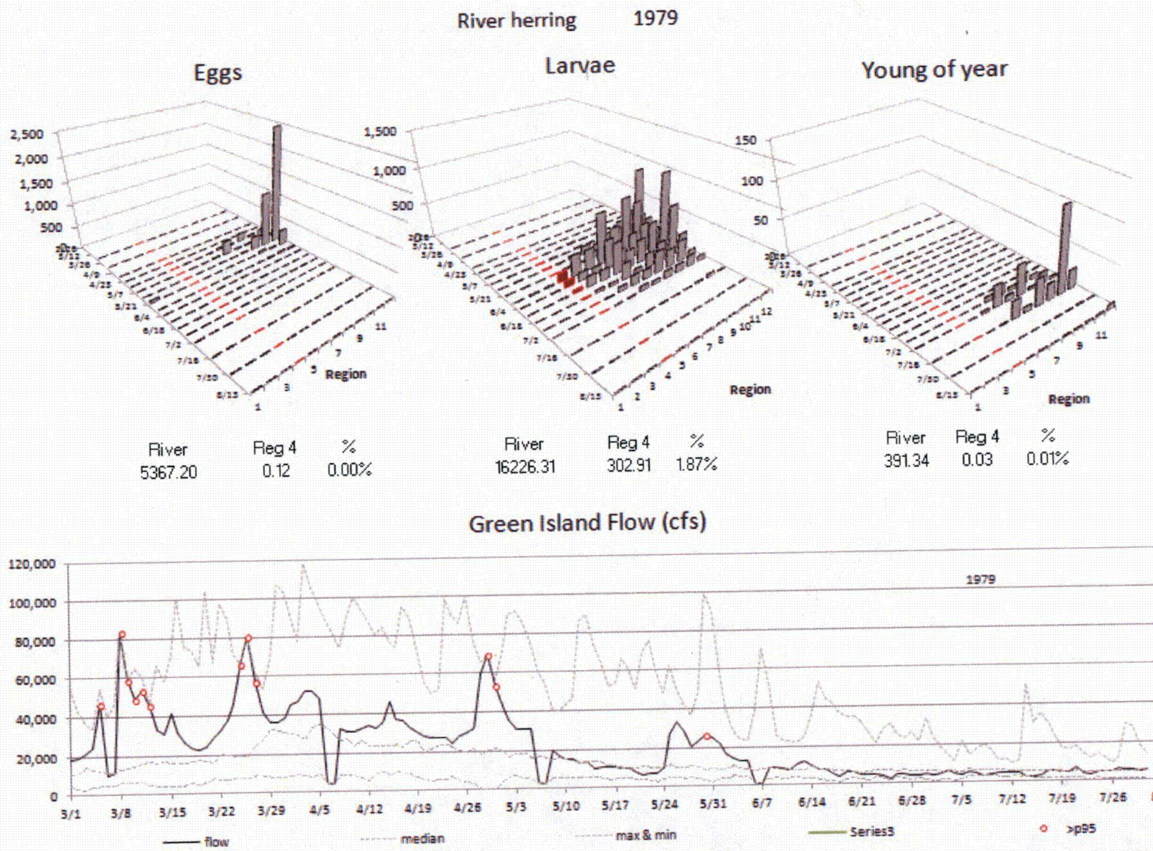

Figure 11 Spatial-temporal distribution of eggs, larvae, and YOY river herring from LRS sampling in 1979, with total river population and region 4 population summed across all sampling weeks. Red bars indicate region 4. Freshwater inflows for March-July, with actual flow for each date, and maximum, minimum and median for each calendar date for 1946-2005. Red circles indicate actual flow exceeding 95th percentile for the date.

4 CONCLUSIONS

Examination of the spatial and temporal distributions of river herring early life stages demonstrates that they are typically found far upstream of IPEC and are not appreciably vulnerable to entrainment, except when relatively extreme flow events occur. When these events occur, larvae are transported downstream out of their typical habitat and may be subject to entrainment at IPEC, with entrainment mortality rates of up 3% to 5% (Figure 9). The estimate of entrainment effect, known as Conditional Mortality Rate (CMR), is the fractional reduction in year class strength, and was developed jointly by utility and federal agency scientists in the 1970s as a method for quantifying entrainment impacts on fish populations using empirical data obtained from riverwide monitoring (Barnthouse et al. 1984).

The larval cohorts that are transported downstream and become vulnerable to entrainment have extremely high natural mortality rates, and make essentially no contribution to the resulting year class. The apparent high entrainment mortality rates in high flow years therefore have no actual effect on the population. Additional spawning that occurs after the flow has returned to normal levels is the source of individuals that comprise the surviving cohort.

Early life stages of fishes need to coincide temporally and spatially with suitable conditions for development, feeding, and growth. If these conditions are not found, effectively complete mortality can result (Hassler 1970, Lasker 1981, Leggett et al. 1984, Govoni 2005). The loss of large portions of the annual cohort of early life stages due to extreme weather-related events is not restricted to blueback herring or to the Hudson River estuary. Very similar phenomena were observed in the Hudson for American shad during the 1984 spawning season (Figure 12). Larvae present at the end of May when the flow event occurred were moved far downstream from their typical locations, and did not contribute to the juveniles observed later in the summer. Similar patterns of highly variable within-year survival, have also been observed in the Potomac River for striped bass (Polgar et al. 1976), in the Connecticut River for American shad (Crecco and Savoy 1987), and in the Sandusky River for walleye (Mion et al. 1998).

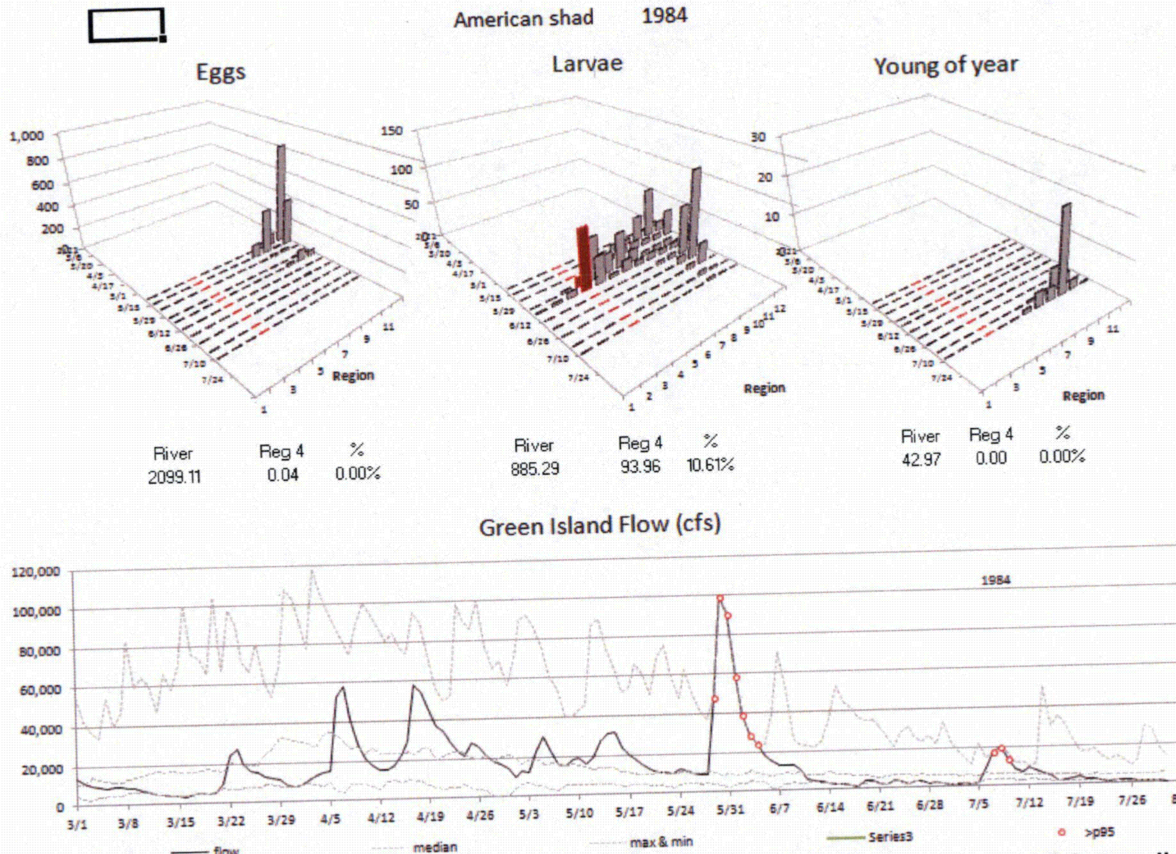

Figure 12 Spatial-temporal distribution of eggs, larvae, and YOY American shad from LRS sampling in 1984, with total river population and region 4 population summed across all sampling weeks. Red bars indicate region 4. Freshwater inflows for March-July, with actual flow for each date, and maximum, minimum and median for each calendar date for 1946-2005. Red circles indicate actual flow exceeding 95th percentile for the date.

The conclusion in the FSEIS that the SOC for blueback herring is "High" and that IPEC entrainment impact could destabilize the blueback herring population, i.e. "Large" impact, is inconsistent both with peer-reviewed scientific literature and with the evidence accumulated over four decades of monitoring.

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Appendix 2D:

Assessment of Potential Bias in NRC Staff's Estimate of Entrainment Mortality Rate (EMR) at IPEC for Rainbow Smelt

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March 2016

Background

1. Entrainment sampling began in early-May in all years (1981, 1982-1987) except 1986. Entrainment sampling began in January in 1986. Entrainment sampling ended in August in all years.
2. 1986 is the only year (1981, 1983-1987) in which Rainbow Smelt eggs were recorded in entrainment sampling. They were collected in March 1986.
3. Rainbow Smelt eggs are demersal and adhesive.
4. No Rainbow Smelt eggs were reported in any year (1981, 1983-1987) of LRS sampling.
5. LRS sampling began in early-May to late-April and ended in July in all years (1981, 1983-1987).
6. To calculate EMR for Rainbow Smelt, NRC Staff assumed the number of Rainbow Smelt eggs entrained in 1981, 1983, 1984, 1985 and 1987 was the same as the number entrained in 1986 (Figure 5).
7. The NRC Staff EMR estimate for Rainbow Smelt only used entrainment and abundance estimates from 1984 and 1987 (two years selected – as the 75th percentile - after ranking the 6 years based on relative magnitude of estimates).

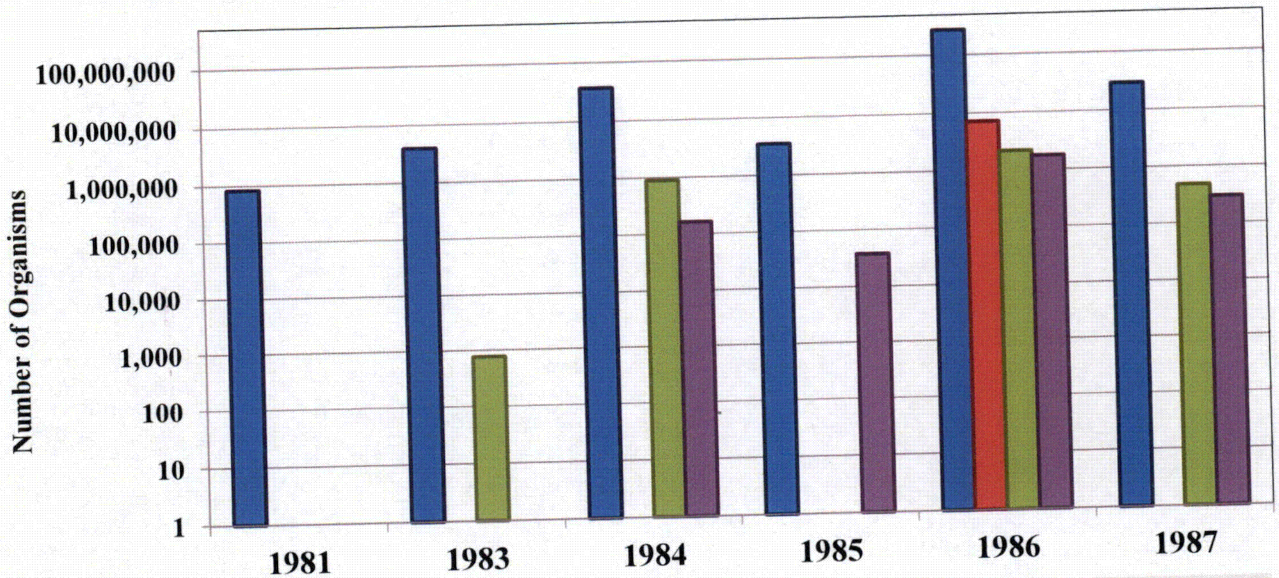
Approach to Ascertain Magnitude of Bias

1. A minimum estimate of annual egg abundance is the maximum number of larvae observed in any week.
2. Riverwide egg abundance (minimum estimate based on LRS larval data) of Rainbow Smelt in 1986 was 275 million, whereas the average egg abundance estimate over all other years (1981, 1983, 1984, 1985 and 1987) was only 14 million (Figure 1).
3. Annual numbers of Rainbow Smelt larvae entrained and Rainbow Smelt juveniles entrained are well predicted by the annual estimates of minimum riverwide egg abundance (Figures 2 and 3).
4. Predict annual egg entrainment (for 1981, 1983, 1984, 1985 and 1987) based on: (a) annual estimates of minimum riverwide egg abundance, and (b) the ratio of numbers of eggs entrained in 1986 to the estimate of minimum riverwide egg abundance in 1986 (Figure 4).
5. Recalculate EMR estimate based on year-specific predictions of egg entrainment.

Results

1. The NRC Staff estimate of EMR for Rainbow Smelt is 25.8% (Table 1).
2. The corresponding EMR estimate (still calculated using NRC Staff's method) based on year-specific predicted egg entrainment is 8.4% (Table 1).

Figure 1: Rainbow Smelt - Abundance and Entrainment Data (Note: entrainment of eggs was only recorded in 1986 when entrainment sampling was conducted in March.



Estimated Annual Total Number Entrained					
0	771	1,056,821	36,904	10,952,471	767,691

Figure 2: Rainbow Smelt Riverwide Egg Abundance as Predictor of Larval Entrainment.

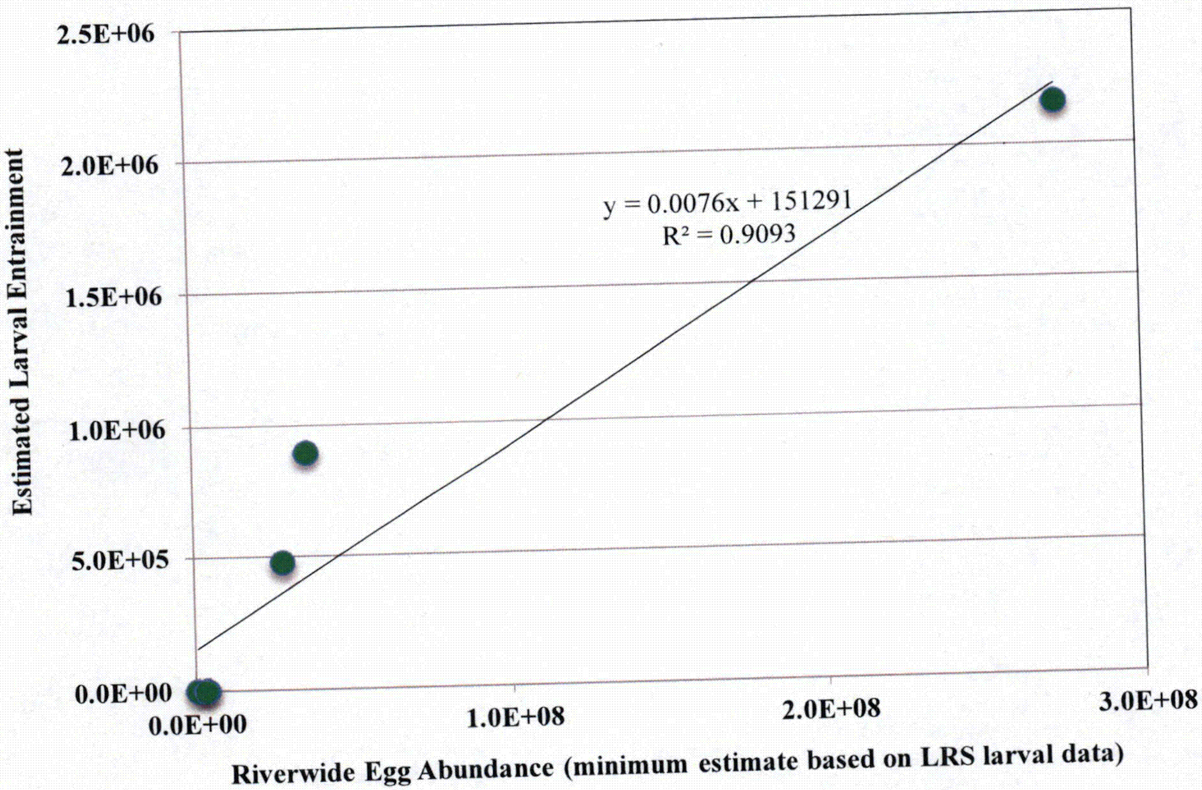


Figure 3: Rainbow Smelt Riverwide Egg Abundance as Predictor of Juvenile Entrainment.

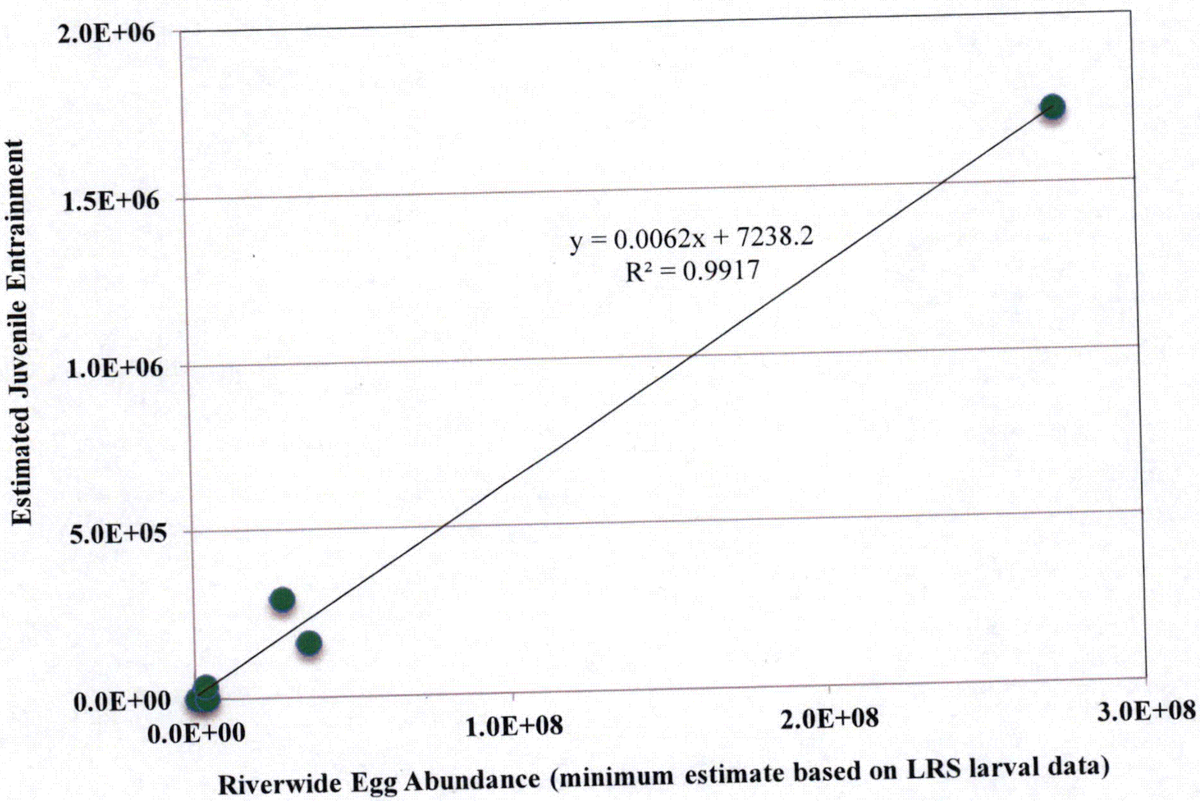
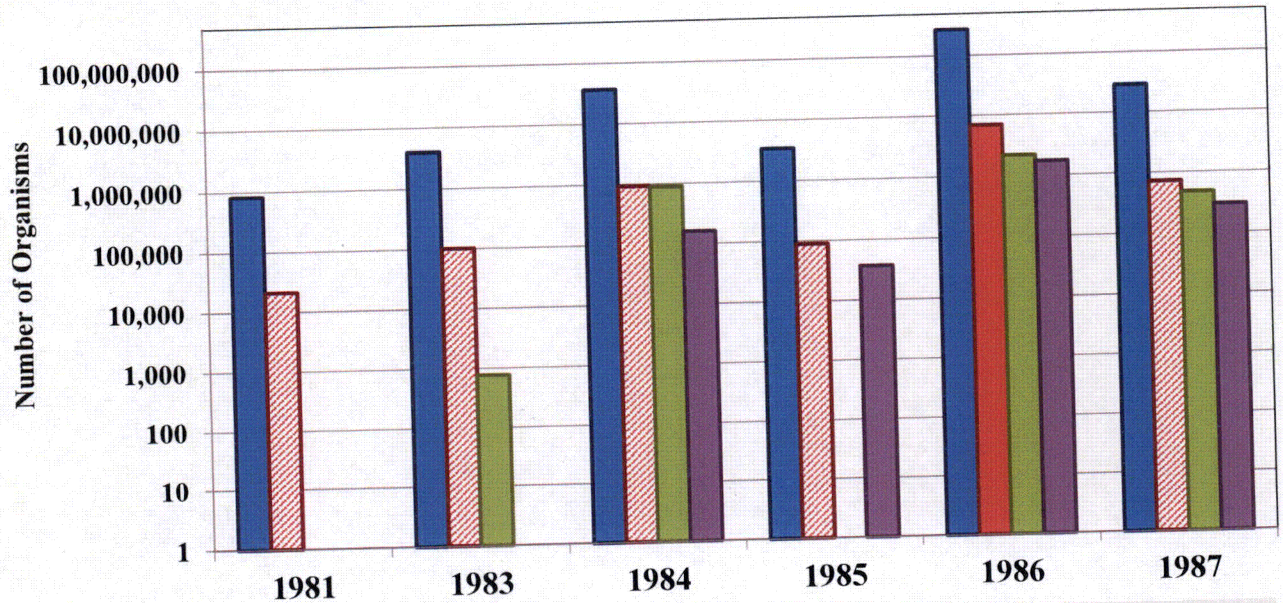


Figure 4: Rainbow Smelt – Predicted Egg Entrainment Based on Riverwide Egg Abundance (Note: entrainment of eggs were only recorded in 1986 when entrainment sampling was conducted in March).



Estimated Annual Total Number Entrained					
21,142	102,121	1,989,940	124,683	10,952,471	1,490,096

Figure 5: Rainbow Smelt – NRC Staff's Predicted Egg Entrainment (Note: entrainment of eggs was only recorded in 1986 when entrainment sampling was conducted in March

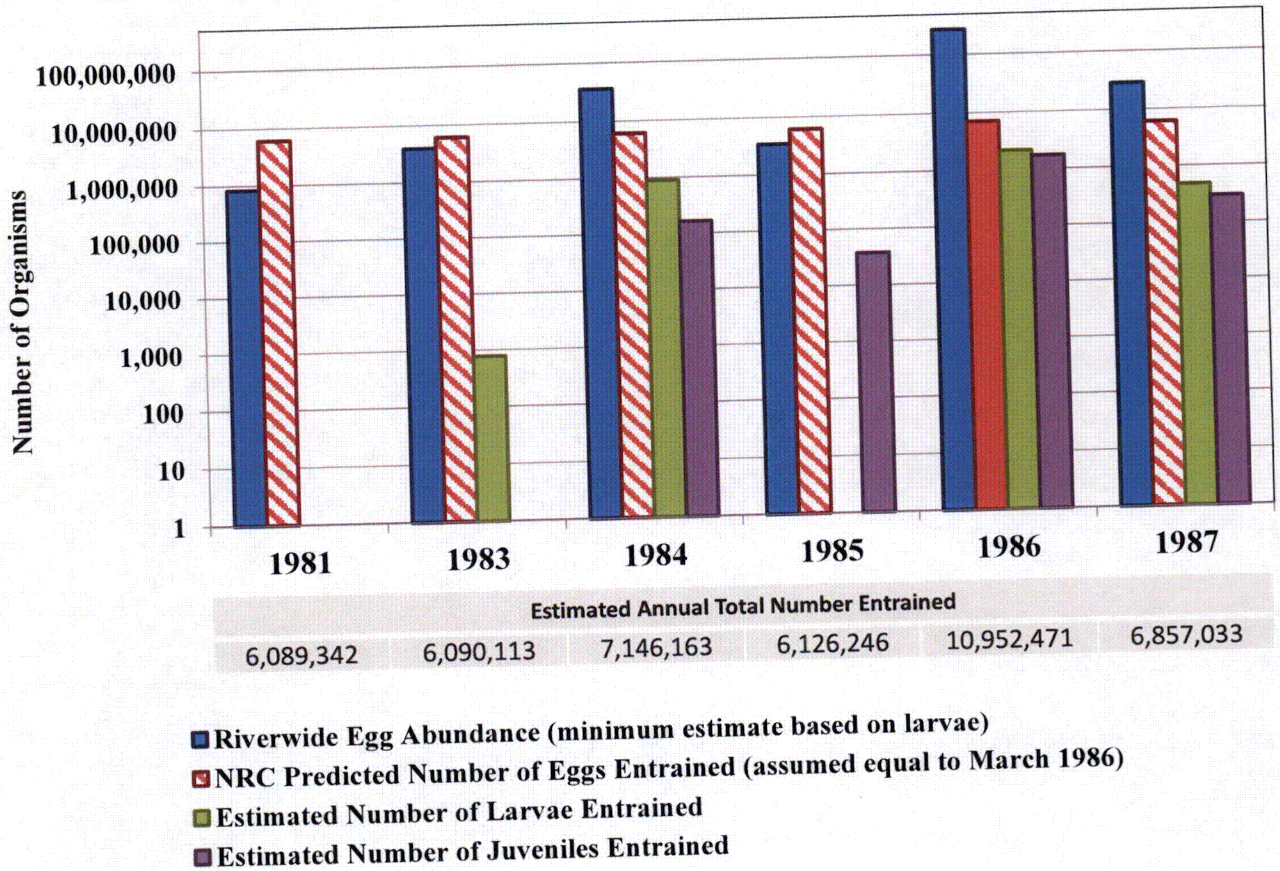


Table 1: NRC Staff's Method for Estimating Rainbow Smelt EMR Based on 75th Percentiles (i.e., shaded cells only)

NRC Staff assumed 1986 egg entrainment in all years (from 2010 FSEIS)

Year	Region 4 Abundance* (Table I-41)	Number Entrained* (Table I-42)	Number At Risk*	EMR
1981	1,341	6,089	7,430	
1983	841	6,090	6,931	
1984	16,111	7,146	23,257	
1985	992	6,126	7,118	
1986	46,771	10,952	57,723	
1987	21,926	6,857	28,783	
Wt. Ave.		**7,074**	**27,402**	**0.258**

* In thousands.

Predicted egg entrainment based on annual minimum egg abundance estimates

Year	Region 4 Abundance*	Number Entrained*	Number At Risk*	EMR
1981	1,341	21	1,362	
1983	841	102	943	
1984	16,111	1,990	18,101	
1985	992	125	1,117	
1986	46,771	10,952	57,723	
1987	21,926	1,490	23,416	
Wt. Ave.		**1,865**	**22,087**	**0.084**

* In thousands.

APPENDIX 2E

REVIEW OF NRC'S STRENGTH OF CONNECTION CALCULATIONS

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March 2016

REVIEW OF NRC'S STRENGTH OF CONNECTION CALCULATIONS

In the December 2015 Final Supplemental Environmental Impact Statement ("FSEIS") to the Generic Environmental Impact Statement for License Renewal of Nuclear Plants Supplement 38 Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3 Draft Report for Comment (USNRC 2015) NRC Staff reached results for blueback herring and rainbow smelt (Large Impacts) which are inconsistent with the ecology and life history of the species. To arrive at the "Large" impact result, NRC Staff's analysis determined there was a "High" Strength of Connection (SOC) between entrainment and impingement impacts and the population trends. To assess the validity of this SOC result, the NRC's simulation to establish SOC was evaluated by attempting to replicate the analysis using methods described on pages A-11 through A-19 of the SFSEIS, particularly equations (1) and (2) on page A-11.

An appropriate methodology to assess SOC would have low type 1 and type 2 error rates, i.e. it would have a low probability of reaching a conclusion of high SOC when SOC is actually low, and a low probability of reaching a conclusion of low SOC when it is actually high. Neither of these probabilities appear to have been assessed by NRC Staff.

The initial step in our analysis of SOC methodology was to attempt to match the NRC's results in Table A-16. Using equations (1) and (2), and the input data in Table A-15, we were initially not able to approximate NRC Staff's results.[1] However, since many of the simulated annual population sizes for many of the cases were negative, which is a physical impossibility, we set the negative values to 0, which then produced a satisfactory match to Table A-16 (Table 1).

Next, to address the risk of type 1 error (probability of false conclusions of High SOC) of NRC staff's methodology, the simulation was repeated after setting both EMR and IMR to 0. This analysis, with no entrainment or impingement mortality, should result in Low SOC for all species. However, for this simulation, three species (blueback herring, hogchoker, and rainbow smelt) out of 13 still were labeled as High SOC (Table 2). This is a probability of false positive (High) result of 0.231, which is about 4.5 times as high as the commonly used value of 0.05 in statistical analyses. These false positive results demonstrate that the methodology is not reliable for these species.

[1] Because the SOC analysis is a Monte Carlo simulation, NRC Staff's results cannot be exactly duplicated. However, if the same methodology is used, the median, Q1, and Q3 values should approximate those of Table A-16.

Table 1. Results of SOC simulation using methods described by NRC equations in Appendix A. Medians, Q1, and Q3 values approximate those in Table A-16. SOC conclusions match exactly.

			N_0 = 1000			N_0 = 100000000		
RIS	SOC	years	median	Q1	Q3	median	Q1	Q3
Alewife	Low	20	0.16	-0.35	0.61	0.17	-0.31	0.58
		27	0.05	-0.42	0.57	0.09	-0.44	0.57
American shad	Low	20	0.06	-0.02	0.15	0.06	-0.03	0.16
		27	0.06	-0.00	0.13	0.06	-0.00	0.13
Atlantic tomcod	Low	20	0.18	-0.02	0.40	0.18	-0.05	0.39
		27	0.24	0.07	0.41	0.24	0.05	0.43
Bay anchovy	High	20	0.25	0.12	0.37	0.24	0.12	0.37
		27	0.25	0.16	0.35	0.25	0.15	0.36
Blueback herring	High	20	0.35	0.11	0.57	0.33	0.08	0.58
		27	0.37	0.17	0.56	0.38	0.19	0.56
Bluefish	Low	20	0.17	-0.02	0.36	0.16	-0.00	0.33
		27	0.19	0.03	0.35	0.20	0.07	0.35
Hogchoker	High	20	0.70	0.43	0.99	0.70	0.44	0.99
		27	0.70	0.48	0.97	0.70	0.51	0.92
Rainbow smelt	High	20	0.67	0.38	0.97	0.69	0.39	0.99
		27	0.66	0.46	0.91	0.67	0.44	0.92
Spottail shiner	Low	20	0.19	-0.04	0.44	0.20	-0.05	0.44
		27	0.27	0.07	0.47	0.27	0.05	0.48
Striped bass	High	20	0.33	0.14	0.52	0.33	0.13	0.55
		27	0.43	0.25	0.62	0.43	0.26	0.62
Weakfish	High	20	0.69	0.44	0.91	0.70	0.45	0.91
		27	0.70	0.50	0.91	0.70	0.50	0.88
White catfish	Low	20	0.12	-0.45	0.73	0.17	-0.47	0.70
		27	0.09	-0.41	0.58	0.14	-0.39	0.61
White perch	High	20	0.30	0.05	0.53	0.32	0.07	0.56
		27	0.37	0.15	0.60	0.35	0.15	0.56

Note: Although not discussed in SFEIS, results did not match NRC result unless negative population values are set to 0.

Table 2. Results of SOC simulation using methods described by NRC equations in Appendix A, except that EMR and IMR are both set to 0.

RIS	SOC	years	N_0 = 1000 median	N_0 = 1000 Q1	N_0 = 1000 Q3	N_0 = 100000000 median	N_0 = 100000000 Q1	N_0 = 100000000 Q3
Alewife	Low	20	-0.03	-0.51	0.35	-0.05	-0.51	0.38
		27	-0.16	-0.62	0.29	-0.14	-0.63	0.30
American shad	Low	20	0.04	-0.05	0.13	0.04	-0.05	0.12
		27	0.04	-0.02	0.11	0.04	-0.02	0.12
Atlantic tomcod	Low	20	0.15	-0.06	0.36	0.14	-0.08	0.35
		27	0.17	0.01	0.35	0.19	0.01	0.37
Bay anchovy	Low	20	0.10	-0.02	0.23	0.11	-0.00	0.23
		27	0.10	0.01	0.19	0.11	0.02	0.21
Blueback herring	High	20	0.23	0.01	0.45	0.25	0.03	0.47
		27	0.26	0.08	0.45	0.27	0.09	0.45
Bluefish	Low	20	0.15	-0.02	0.33	0.16	-0.01	0.33
		27	0.20	0.05	0.35	0.20	0.05	0.36
Hogchoker	High	20	0.32	0.10	0.53	0.31	0.09	0.53
		27	0.34	0.17	0.53	0.33	0.15	0.51
Rainbow smelt	High	20	0.36	0.13	0.60	0.36	0.14	0.60
		27	0.40	0.19	0.61	0.41	0.22	0.61
Spottail shiner	Low	20	0.18	-0.04	0.45	0.21	-0.04	0.44
		27	0.25	0.04	0.46	0.22	0.02	0.42
Striped bass	Low	20	0.18	-0.00	0.38	0.20	0.00	0.40
		27	0.27	0.10	0.45	0.26	0.08	0.46
Weakfish	Low	20	0.14	-0.02	0.32	0.15	-0.03	0.33
		27	0.19	0.04	0.33	0.19	0.04	0.32
White catfish	Low	20	-0.07	-0.59	0.43	-0.05	-0.63	0.49
		27	-0.11	-0.61	0.34	-0.16	-0.61	0.32
White perch	Low	20	0.22	-0.03	0.44	0.19	-0.05	0.46
		27	0.28	0.07	0.48	0.27	0.07	0.46

Note: Although not discussed in SFEIS, results did not match NRC result unless negative population values are set to 0.

Appendix 2F:

Application of NRC Staff's Aquatic Impact Analysis Methodology to Atlantic Menhaden and Gizzard Shad Data for IPEC

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March 2016

Table of Contents

I. Introduction

A. NRC Staff's Methodology Change to Include Finding of "Unresolved"

In the December 2015 Final Supplemental Environmental Impact Statement ("FSEIS") to the Generic Environmental Impact Statement for License Renewal of Nuclear Plants Supplement 38 Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3 Draft Report for Comment (USNRC 2015), NRC Staff reached intermediate, species-specific potential impact findings of "Unresolved" for Atlantic menhaden and gizzard shad (USNRC 2015, page 36):

> "In the present analysis, the NRC staff also included a category, "Unresolved" for those RIS for which a Population Trend line of evidence (LOE) could not be established and too little data were available to model the SOC. Previously, the FSEIS and AKRF's analyses assumed the impact level to be Small where this occurred."

In connection with the FSEIS, NRC Staff indicate that "SOC" refers to strength of connection, "RIS" refers to representative important species, "WOE" refers to weight of evidence, and "FSEIS" refers to final supplemental environmental impact statement.

NRC Staff provided the following explanation for changing the species-specific findings category from "Small" to "Unresolved" for several taxa (USNRC 2015, page 37):

> "Because of undetected declines in population trend, combined with unresolved strength of connection, impacts could not be resolved for Atlantic menhaden, gizzard shad, blue crab, Atlantic sturgeon, and shortnose sturgeon. In the FSEIS, the NRC staff assigned species with unresolved SOC assessments a value of "Low" rather than "Unresolved," the same description that is used for an unresolved population trend LOE, because these species generally occurred in low numbers in entrainment and impingement samples. Assigning an impact level of "Low" to unresolved SOC assessment for these species in the FSEIS resulted in a final WOE impact of "Low." Here, the lack of resolution in both LOEs is assigned a WOE impact value of "Unresolved" to make the decision rules for both LOEs the same, to remove an assumption in the SOC analysis, and to more clearly communicate a lack of resolution in the SOC analysis where it occurred."

A review of the available data indicated that sufficient data are available to apply NRC Staff's aquatic impact methodology to Atlantic menhaden and gizzard shad. This report documents the application of NRC Staff's aquatic impact assessment methodology (USNRC 2015) to the available data for Atlantic menhaden and gizzard shad in connection with the Indian Point Energy Center ("IPEC") FSEIS.

B. Biological Backgound

It should be noted that the life history characteristics of Atlantic menhaden and gizzard shad are such that neither species would be expected to be susceptible to IPEC entrainment in a significant manner. Atlantic menhaden spawn well downriver of IPEC in marine waters (Rogers and Van Den Avyle 1989). Gizzard shad spawn well upriver of IPEC in freshwater (Miller 1960). Low catch rates of these species in the vicinity of IPEC, which NRC Staff refers to as "River Segment 4", are indicative of their scarcity near IPEC and their low level of entrainment by IPEC.

1. Gizzard Shad Data and Assessment Overview

Entrainment data submitted to NRC by Entergy in 2007 documented that no gizzard shad were collected by entrainment sampling performed in 1981 or 1983-1987. River density data submitted at the same time documented that no gizzard shad eggs or larvae were collected in River Segment 4 during those years as well. Those data clearly demonstrate that the SOC between IPEC entrainment of gizzard shad present in other river regions is "Low".

River density data submitted to NRC by Entergy in 2015 demonstrated that gizzard shad juveniles have exhibited positive trends in abundance for the period 1985-2011. Analysis of data from both the Fall Shoals Survey ("FSS") and Beach Seine Survey ("BSS") showed positive trends in riverwide CPUE, with the regression based on BSS data being statistically significant. Due to the life history of gizzard shad, an insufficient number of juveniles were collected by the FSS in River Segment 4 to support a trends analysis. However, the gizzard shad trend analysis for River Segment 4 based on BSS data showed at statistically significant positive trend. Based on NRC Staff's methodology, which includes consideration of riverwide as well as River Segment 4 data, these results would lead to a conclusion of "Undetected Decline".

The combination of these results, and an understanding of the life history of gizzard shad in the Hudson River, support an intermediate, species-specific impact finding of "small", rather than "unresolved".

These findings are contrary to NRC Staff's intermediate conclusions regarding gizzard shad (USNRC 2015, page A-40):

> "Too few gizzard shad were caught to assess trends in River Segment 4, and two trends, not statistically significant, could be assessed Riverwide. The SOC could not be modeled, and the impact was unresolved (Table A–18)".

2. Atlantic Menhaden Data

NRC's initial request for in-river data was for "Year Class Report Table E Series Density Data" which did not include data on Atlantic Menhaden. Accordingly, in-river density data for Atlantic Menhaden were not provided with the initial response to NRC's data request in 2007. In-river data for Atlantic Menhaden data were inadvertently omitted from subsequent data submittals as well. Therefore, no assessment for Atlantic menhaden was conducted by NRC Staff.

The analyses for Atlantic menhaden presented in this report are based on data that are being submitted to NRC in 2016.

II. Methods and Data

A. EMR Estimates

1. Methods

Entrainment mortality rates were estimated using the methods described in USNRC 2015 (Appendix A pages A-13 and A-14):

> "The NRC staff estimated EMR as the ratio of the number entrained to the sum of the standing crop of eggs, larvae, and juveniles in River Segment 4 (Indian Point) obtained from the Longitudinal River Survey ("LRS"), FSS, and BSS 1981 and 1983 through 1987 data. The NRC staff used all three surveys, because entrainment of juveniles was proportionally greater during July and August than during May and June, which was when the majority of the sampling for the LRS took place (Table A–4). Estimation of the number entrained and the river segment standing crop is based on the calculations presented in Table A–5."
>
> "The number of RIS by life stage (i = eggs, yolk sac larvae, post-yolk sac larvae, juvenile, and undetermined) entrained (E_{ijk}) was calculated weekly (k = 2 through 35) for each year (j = 1981, 1983 through1987) as
>
> $$E_{ijk} = \bar{d}_{ijk}(V_{IP2} + V_{IP3})(60 \times 24 \times 7 \times 1000)$$
>
> where $\bar{d}_{ijk}$ is the input mean weekly density entrained (number/1000 m3) for a given RIS (Table A–5) along with the associated volume of water withdrawn (1000 m3 /min) at IP2 and IP3 (VIP2 and VIP3, respectively)." The NRC staff calculated seasonal numbers of RIS entrained by summing over life stages and weeks. Season 1 (January–March) was only sampled in

1986, so that the number of fish entrained during that season was added to the totals for all other years."

"The NRC staff based the estimate of the River Segment 4 standing crop of each life stage on the combined standing crop estimates from the LRS, FSS, and BSS (Table A–5). The LRS and FSS weekly standing crops are estimated as the weekly density of fish caught times the River Segment 4 volume (208,336,266 m3 ; 168,901 acre-ft). The BSS weekly standing crop was estimated as the weekly density of fish caught times the River Segment 4 surface area of the shore stratum (4,147,000 m2 ; 1,025 acres) divided by the area of a seine sample (450 m2 ; 4,844 ft2). The total number of RIS at risk from I&E was calculated as the sum of those RIS entrained (or impinged) and the RIS caught in the river."

As described in Table A-5 of USNRC (2015), *EMR* was calculated as the ratio of:

- The 75th percentile annual number entrained, divided by
- The 75th percentile (annual number entrained + annual standing crop)

where:

- The annual number entrained for each year was calculated as the "Sum of Season1, 1986, with each year's totals from Season 2 and Season 3";
- The annual River Segment 4 standing crop for each year was calculated as the "Sum of seasonal standing crop estimates for River Segment 4";
- The seasonal number entrained for each season (1, 2 and 3) and year was calculated as the "Sum of weekly estimates of number of organisms entrained by IP2 and IP3"; and
- The seasonal River Segment 4 standing crop for each season and year was calculated as the "Sum of weekly standing crop estimates".

2. Data and Other Inputs

Reported weekly mean entrainment densities of Atlantic menhaden and gizzard shad ($\bar{d}_{ijk}$) were taken from the entrainment data file, "EntDensity.csv", Entergy provided to NRC in 2007. Reported cooling water withdrawal volumes for IP2 and IP3 (V_{IP2} and V_{IP3}) were also taken from the entrainment data file, "EntDensity.csv".

The corresponding data files containing River Segment 4 density estimates, provided to NRC in 2007: Year Class Report Appendix Table E files ("LRSdensity*year1year2*.csv", "FSSdensity*year1year2*.csv", and "BSSdensity*year1year2*.csv"), did not include estimates for Atlantic menhaden. Therefore for this analysis, estimates of weekly River Segment 4

densities of eggs, larvae and juveniles were computed using the raw data files from the LRS, FSS and BSS programs. The density estimates were computed using methods consistent with the methods used to generate the Year Class Report Appendix Table E files submitted to NRC in 2007.

No Atlantic menhaden were reported entrained during season 1 in 1986; therefore, the estimated number entrained in each year was calculated simply as the sum of the estimated number entrained in season 2 and season 3 of each year. No gizzard shad were reported entrained in the entrainment sampling performed in 1981 and 1983-1987. Accordingly, the *EMR* for gizzard shad was set to zero.

B. Linear Trends

1. Methods

As described in USNRC (2015), Ordinary least-squares regression was used to estimate linear slopes and associated statistics to assess trends in young of year ("YOY") abundance. For the trends assessments, NRC Staff computed measures of annual abundance based on data from the LRS, FSS and BSS and used indices of abundance from the Year Class Reports. For all species except Atlantic tomcod and rainbow smelt, which spawn early in the year, USNRC (2015) reported conducting trends assessments using three measures of annual River Segment 4 abundance and two measures of river-wide abundance based on annual abundance measures NRC Staff computed using data from the FSS and BSS. Accordingly, the trends assessments for Atlantic menhaden and gizzard shad were based on these three River Segment 4 measures of abundance and two river-wide measures of abundance. The Year Class Reports did not report indices of abundance for Atlantic menhaden or gizzard shad.

For River Segment 4, abundance trends analyses were conducted using the following measures of abundance (from USNRC 2015, page A-47):

- 3-year running average of the standardized (by subtracting the mean and dividing by the standard deviation) annual 75th percentile (over weeks within year) of the weekly density from the FSS,
- 3-year running average of the standardized (by subtracting the mean and dividing by the standard deviation) annual 75th percentile (over weeks within year) weekly density from the FSS, and
- standardized (by subtracting the mean and dividing by the standard deviation) annual 75th percentile (over weeks within year) of the weekly CPUE from the FSS.

For river-wide abundance trends analyses were conducted using the following measures of abundance (from USNRC 2015, page A-47):

- standardized (by subtracting the mean and dividing by the standard deviation) annual CPUE from the FSS,
- standardized (by subtracting the mean and dividing by the standard deviation) annual CPUE from the BSS, and

2. Data and Other Inputs

Trends analyses for gizzard shad were conducted using copies of the Format 2 data files Entergy submitted to NRC Staff in March 2015. Trends analyses for Atlantic menhaden were conducted using copies of the Format 2 data files submitted to NRC Staff in March 2016.

C. SOC

1. Methods

a. As Documented by NRC Staff

The SOC analyses for Atlantic menhaden and gizzard shad were based on the methods described in USNRC (2015), pages A-10 and A-11:

> "The NRC staff determined the SOC from the uncertainty in estimating the difference in the RIS YOY population abundance with and without losses from I&E. A series of Monte Carlo simulations (n = 1000 for each series) was used to estimate the first and third quartiles of the modeled relative cumulative difference in the population abundance achieved over a specified number of years (i.e., $t = 1$ to 27) with and without removal of eggs, larvae, and juveniles by I&E. The NRC staff used a simple exponential model to estimate the annual juvenile population abundance (N_t) as follows:
>
> $$N_t = N_0 e_{rt} + \left(\delta N_0 e^{rt}\right)\varepsilon_t \qquad (1)$$
>
> where
>
> $t = 1$ to 20 (number of years associated with relicensing) or 27 years (number of years for trend analysis: 1985 through 2011);
>
> N_0 = the initial juvenile population abundance at the beginning of the YOY life stage set to either 1000 or 1×10^8 ;
>
> r = the population growth rate estimated from the slope from the linear model of standardized YOY River Segment 4 (Indian Point) LRS, FSS, or BSS density data (1985 through 2011), whichever had the greatest riverwide median CPUE for a given RIS (Table A–3);

δ = the level of variability in the density data which was estimated as the sum of the CV of the annual 75th percentiles from the weekly catch density and the error mean square from the linear regression; and

ε_t = an independent Normal (0,1) random variable.

Two different values for the starting population parameter N_0 and the extent of the number of years simulated (20 or 27) were used to assess their impact on the simulation results. The number of simulation runs (1,000) should be large enough such that these two parameters will not affect the results. Equation (1) models annual abundance of YOY RIS with the removal of eggs, larvae, and juveniles from entrainment and impingement implicit in the parameters N0 and r. Annual abundance of YOY RIS without losses of eggs, larvae, and juveniles from entrainment and impingement was estimated using the same model form but with an independent ε_t ,and N_0 and r replaced with

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

where

EMR [entrainment mortality rate] and *IMR* [impingement mortality rate] are conditional mortality rates (CMRs) for entrainment and impingement;

r_{UL} is the upper limit of the linear slope defined as the estimated slope plus one standard error of the estimated slope; and

CV is the coefficient of variation of the annual 75th percentiles from the weekly catch density.

The growth rate divided by the CV in the density data provides an alternative growth rate closer to zero for negative values of r and a slightly larger growth rate for positive values of r with the amount of increase dependent on the magnitude of the variability. The divisor is set to 1 (allowing a maximum increase in growth rate) when the CV is greater than 1."

b. Method Adjustments

Based on the method documentation in USNRC (2015) the modeled rate of increase in the absence of impingement mortality, r^*, gets closer to zero as *IMR* increases. For populations with a negative slope, this property is consistent with the premise of NRC Staff's method and the difference between the modeled slopes, with and without impingement, increases as *IMR* increases. However, if the observed trend is positive, the difference

between the modeled slopes, with and without impingement, decreases as *IMR* increases and r^* gets closer to zero. Furthermore, r^* becomes smaller than r when the following condition is met:

$$\frac{se(r)}{r} < \frac{(\max(1,CV)-1)+IMR}{(1-IMR)}$$

This structural flaw in NRC Staff's SOC formulation when the observed rate of increase, r, is positive, suggested that NRC Staff's SOC model was not intended to be applied to RIS with observed positive trends in abundance. However, NRC Staff did in fact apply its methodology to three RIS (alewife, striped bass and white catfish) with positive trends in abundance (USNRC 2015, Table A-15, page A-30).

As noted below, the observed trends, r, for Atlantic menhaden and for gizzard shad are positive. To avoid the contradictory results, NRC Staff's equation (2) produces under these circumstances, NRC Staff's equation (2) was modified for these analyses as follows:

$$r^* = r_{UL}(1+IMR)/\max(1,CV)$$

With this formulation, the difference between an observed positive slope and a modeled slope, without impingement, increases as *IMR* increases.

However, even with this revised formulation for positive trends, r^* can become smaller than r if CV is large. Therefore, for the current analyses, NRC Staff's equation (2) was further revised to be:

$$r^* = r_{UL}(1+IMR)/\min(1,CV)$$

In addition, an adjustment to NRC Staff's equation (1) was implemented for these analyses. Based on the method documentation in USNRC (2015) it would be possible for NRC Staff's equation (1) to predict negative population abundance values. To avoid this unrealistic outcome, the analyses for Atlantic menhaden and gizzard shad were conducted with simulated negative values for N_t in NRC Staff's equation (1) set to zero.

2. Data and Other Inputs

a. IMR Estimates

USNRC (2015) used estimates of *IMR* from the 1999 Draft Environmental Impact Statement ("DEIS") for Hudson River Power Plants (CHG&E et al 1999). In the DEIS, *IMR* was referred to as CIMR. Estimates of *CIMR* for each species was based on a comparison of the number of fish impinged to the corresponding river-wide abundance of the fish (CHG&E et al 1999, Appendix VI-2-B). The DEIS did not report *IMR* estimates for Atlantic menhaden or gizzard shad. Therefore, *IMR*s for Atlantic menhaden and gizzard shad were

estimated using available impingement and river abundance data based on NRC Staff's method for estimating *EMR*.

Estimates of numbers of Atlantic menhaden and gizzard shad impinged at IPEC Units 2 and 3 were taken from the impingement data file submitted to NRC by Entergy in 2007 ("Imp19811990.csv"). Estimates in the data file were listed quarterly for the 10-year period 1981-1990. Estimates of the river wide abundance of young of year ("YOY") and older Atlantic menhaden were derived from density estimates computed from the raw data files from the LRS, FSS and BSS programs. The density estimates were computed as described above for *EMR* estimates.

Although impingement estimates were reported for all four quarters of each year, the LRS, FSS and BSS did not collect samples during the first or fourth quarters of most years. For the impingement estimates to be comparable to in-river abundance estimates, both the impingement and in-river sampling data were subset to the common period of April through September.

The *IMR* estimate for each species was computed as the ratio of the total number impinged (April through September) divided by the number at risk during that period. Consistent with the *CIMR* estimates used by NRC Staff for *IMR* of the other RIS, the number of Atlantic menhaden and gizzard shad at risk was defined in terms of river-wide abundance. The number at risk was estimated as the maximum river-wide abundance in any week during the period, April through September. River-wide abundance estimates were computed by summing all river region-specific estimates of abundance where each region-specific estimate of abundance was calculated as the product of the reported region-specific density times the corresponding region volume (ASAAC 2016). Following the *EMR* method in USNRC (2015), the *IMR* estimate was calculated as the 75% of annual estimates of number impinged divided by the 75% of annual estimates of number at risk.

b. r Estimates

For Atlantic menhaden and gizzard shad, the BSS had the largest median river-wide CPUE among the three river-wide sampling programs (Table 1). Accordingly for each of these species, the slope parameter, *r*, was computed as the slope from the trends analysis based on River Segment 4 BSS density data.

III. Analysis Results

A. Atlantic Menhaden

1. Population Trend LOE

River Segment 4 trends analyses for Atlantic menhaden YOY, based on the 3-year moving average of standardized annual 75th percentile of weekly densities from the FSS and BSS, produced positive slopes that were not significantly different from zero at $\alpha = 0.05$

(Tables 2 and 3). The River Segment 4 trend analysis for Atlantic menhaden YOY based on the standardized annual 75th percentile of weekly CPUEs also produced a positive slope that was not statistically significant (Table 4). Based on the NRC Staff methodology and these regression results, Atlantic menhaden received a River Segment 4 Assessment score of 1.0 (Table 5).

Riverwide trends analyses for Atlantic menhaden YOY based on standardized annual CPUE from the FSS and BSS produced positive slopes that were not significantly different from zero at α =0.05 (Tables 6 and 7). Based on the NRC Staff methodology and these regression results, Atlantic menhaden received a Riverwide Assessment score of 1.0 (Table 8).

Combining the results from the River Segment 4 and Riverwide trends analyses as prescribed by NRC Staff's methodology produces a Population Trend LOE impact conclusion of "Undetected Decline" for Atlantic menhaden YOY (Table 9).

2. SOC LOE

a. EMR

The 75th percentile of annual estimates of the number of Atlantic menhaden entrained was 113,738, and the 75th percentile of annual estimates of number of Atlantic menhaden at risk was 674,519 (Table 10). Based on NRC Staff's *EMR* methodology and these results, the *EMR* for Atlantic menhaden was estimated to be 0.169.

b. IMR

The 75th percentile of annual estimates of the number of Atlantic menhaden impinged (April through September) was 2,800 and the 75th percentile of annual estimates of number of Atlantic menhaden at risk (April through September) was 184,880 (Table 11). Based on NRC Staff's methodology for *EMR* and these results, the *IMR* for Atlantic menhaden was estimated to be 0.015.

c. SOC

The parameter estimates for Atlantic menhaden that were used as inputs to NRC Staff's SOC model are listed in Table 13.

As noted in Section II.C.1.b above, NRC Staff's SOC formulation, as documented by NRC Staff, can lead to results that are contrary to the premise underlying NRC Staff's method. Accordingly, the SOC analyses were conducted under two scenarios based on the modeled definition of the rate of population increase in the absence of impingement:

1. $r^* = r_{UL}(1 - IMR)/\max(1, CV)$, as documented in USNRC (2015), and
2. $r^* = r_{UL}(1 + IMR)/\min(1, CV)$, adjusted to prevent irrational results when the observed population trend is positive

Under Scenario 1, the modeled rate of Atlantic menhaden population increase in the absence of impingement was $r^* = 0.009$, lower than the observed rate of population increase of $r = 0.015$ (Table 14), which is not consistent with the premise of NRC Staff's model. For Scenario 1, the first and third quartiles of the simulated cumulative relative difference between population projections with and without entrainment and impingement bracketed zero for Atlantic menhaden (Table 14). Therefore, according to NRC Staff's methodology, the SOC conclusion for Atlantic menhaden under Scenario 1 was "Low" (Table 14).

Under Scenario 2, the modeled rate of Atlantic menhaden population increase in the absence of impingement was $r^* = 0.044$, higher than the observed rate of population increase of $r = 0.015$ (Table 15), which is consistent with the premise of NRC Staff's model. For Scenario 2, the first and third quartiles of the simulated cumulative relative difference between population projections with and without entrainment and impingement did not bracket zero for Atlantic menhaden (Table 15). Therefore, according to NRC Staff's methodology, the SOC conclusion for Atlantic menhaden under Scenario 2 was "High" (Table 15).

To better understand the performance of NRC Staff's SOC methodology as documented (Scenario 1), and as adjusted (Scenario 2), the SOC analysis for Atlantic menhaden was rerun with the assumption that *EMR*=0 and *IMR*=0. Under Scenario 1 with *EMR*=0 and *IMR*=0, the first quartiles of simulated cumulative relative differences were all negative, and the fourth quartiles were all positive leading to a "Low" SOC conclusion (Table 16). Under Scenario 2, the first and third quartiles of the cumulative relative differences were all positive which lead to a "High" SOC conclusion for Atlantic menhaden, even though *EMR* and *IMR* were set to zero (Table 17).

3. Impact Finding

Using NRC Staff's methodology, combining the Population Trend LOE results with the SOC LOE results produces an overall impact conclusion (USNRC 2015, page A-32):

> "If the SOC is low, the impact level will not be greater than Small because of little evidence that an observable relationship exists between the cooling system and RIS trend. Conversely, if an RIS exhibits a high SOC to the IP2 and IP3 cooling system operation but no statistically significant population decline, the final determination will be Small. If, for any RIS, the population trend is unresolved and the SOC could not be modeled, the WOE conclusion is "unresolved." "

Accordingly, Atlantic menhaden with no statistically significant population decline, even with a "High" SOC score, should be assigned an impact level of "Small" (Table 18).

B. Gizzard Shad

1. Population Trend LOE

River Segment 4 trends analysis for gizzard shad YOY, based on the 3-year moving average of standardized annual 75th percentile of weekly densities from the BSS, produced a positive slope that was statistically significantly different from zero at α =0.05 (Table 3). A River Segment 4 trend analysis for gizzard shad YOY based on the 3-year moving average of standardized annual 75th percentile of weekly densities from the FSS could not be conducted because the 75th percentile in all years was zero (Table 2). Similarly, a River Segment 4 trend analysis for gizzard shad YOY based on the standardized annual 75th percentile of weekly CPUEs from the FSS could not be conducted because the 75th percentile in all years was zero (Table 4). Based on the NRC Staff methodology and these regression results, gizzard shad received a River Segment 4 Assessment score of 1.0 (Table 5).

It should be noted that NRC Staff assigned a River Segment 4 Assessment score of 1.0 to spottail shiner (USNRC 2015, Table A-12 page A-28) which, like gizzard shad, only had an abundance index-specific score assigned for one index, i.e., BSS density. Furthermore, for spottail shiner, the slope was negative but not statistically significant (USNRC 2015, Table C page A-59).

Riverwide trend analysis for gizzard shad YOY based on standardized annual CPUE from the FSS produced a positive slope that was not significantly different from zero at =0.05 (Table 6). However, the Riverwide trend analysis based on standardized annual CPUE from the BSS produced a positive slope that was statistically significant (Table 7). Based on the NRC Staff methodology and these regression results, gizzard shad should have received a Riverwide Assessment score of 1.0 (Table 8).

Combining the results from the River Segment 4 and Riverwide trends analyses as prescribed by NRC Staff's methodology produces a Population Trend LOE impact conclusion of "Undetected Decline" for gizzard shad YOY (Table 9).

2. SOC LOE

a. EMR

As noted in Section I.B.1 above, no gizzard shad were collected in entrainment sampling in 1981 and 1983-1987, and no gizzard shad eggs, larvae or YOY were collected in LRS, FSS, or BSS sampling in River Segment 4 during the years of entrainment sampling. These results are consistent with the life history characteristics of gizzard shad and reflect the lack of susceptibility of entrainable life stages of gizzard shad to entrainment at IPEC. Based

on these results from entrainment and in-river sampling, the *EMR* for gizzard shad should be set to zero.

b. IMR

The 75th percentile of annual estimates of the number of gizzard shad impinged (April through September) was 156, and the 75th percentile of annual estimates of number of gizzard shad at risk (April through September) was 1,407 (Table 12). Based on NRC Staff's methodology for *EMR* and these results, *IMR* for gizzard shad was estimated to be 0.111.

c. SOC

The parameter estimates for gizzard shad that were used as inputs to NRC Staff's SOC model are listed in Table 13.

As was done for Atlantic menhaden, the SOC analysis for gizzard shad was conducted under two scenarios:

1. $r^* = r_{UL}(1 - IMR)/\max(1, CV)$, as documented in USNRC (2015), and
2. $r^* = r_{UL}(1 + IMR)/\min(1, CV)$, adjusted to prevent irrational results when the observed population trend is positive

Under Scenario 1, the modeled rate of gizzard shad population increase in the absence of impingement was $r^* = 0.027$, lower than the observed rate of population increase of $r = 0.071$ (Table 14), which is not consistent with the premise of NRC Staff's model. For Scenario 1, the first and third quartiles of the simulated cumulative relative difference between population projections with and without entrainment and impingement did not bracket zero for gizzard shad (Table 14). However, the median and quartiles were all negative indicating the simulated population without entrainment and impingement was smaller than the simulated population with entrainment and impingement.

NRC Staff's methodology for scoring SOC analysis results did not address the possibility that the first and third quartiles would be negative (USNRC 2015, page A-29):

> "The SOC was low if the range of the first and third quartiles of the distribution of the relative cumulative difference in YOY population abundance included zero for any of the simulation series. The SOC was high if both quartiles were positive for all parameter *t* and N_0 pairs."

(Parameter *t* refers to the number of year in the population simulation (*t*=20 or 27), and parameter N_0 refers to the initial population abundance.) Accordingly, no SOC conclusion for gizzard shad under Scenario 1 was drawn (Table 14).

Under Scenario 2, the modeled rate of gizzard shad population increase in the absence of impingement was $r^* = 0.105$, higher than the observed rate of population increase of $r = 0.017$ (Table 15), which is consistent with the premise of NRC Staff's model. For Scenario 2, the first and third quartiles of the simulated cumulative relative difference between population projections with and without entrainment and impingement did not bracket zero for gizzard shad (Table 15). Therefore, according to NRC Staff's methodology, the SOC conclusion for gizzard shad under Scenario 2 was "High" (Table 15).

As was done for Atlantic menhaden, the SOC analysis for gizzard shad was rerun with the assumption that *EMR*=0 and *IMR*=0. Under Scenario 1 with *EMR*=0 and *IMR*=0, the first and third quartiles of simulated cumulative relative differences were all negative which again lead to no SOC conclusion (Table 16). Under Scenario 2, the first and third quartiles of the cumulative relative differences were all positive which lead to a "High" SOC conclusion for gizzard shad, even though *EMR* and *IMR* were set to zero (Table 17).

3. Impact Finding

As was the case for Atlantic menhaden, gizzard shad received a "High" SOC score (under the Scenario 2 analysis), but had no statistically significant population decline. Therefore, according to NRC Staff's methodology, gizzard shad should be assigned an impact level of "Small" (Table 18).

Even if the SOC results under the structurally flawed Scenario 1 analysis were considered, and it was concluded that the SOC could not be modeled, the results from the trends analyses would preclude gizzard shad from receiving an "Unresolved" conclusion according to the NRC Staff methodology (USNRC 2015, page A-32):

> "If, for any RIS, the population trend is unresolved ***and*** the SOC could not be modeled, the WOE conclusion is "unresolved." " (emphasis added)

Since the NRC Staff's methodology assigns a "Small" level of impact to an RIS if there is no statistically significant population decline, even if the SOC is "High" (USNRC 2015, page A-32):

> "Conversely, if an RIS exhibits a high SOC to the IP2 and IP3 cooling system operation but no statistically significant population decline, the final determination will be Small."

Based on these results, a finding of "Small" potential impact should be reached for gizzard shad.

IV. Literature Cited

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V. Tables

Table 1. YOY catch rates (riverwide annual CPUE) of Atlantic menhaden and gizzard shad from three sampling programs, 1985-2011.

Species	Sampling Program	Median CPUE (#/1000m^3)	Total Number Collected
Atlantic menhaden	BSS	1.1922	81,088
	FSS	0.0472	14,981
	LRS	0.0608	3,499
Gizzard shad	BSS	0.0762	1,462
	FSS	0.0006	72
	LRS	0.0000	2

Table 2. Standardized River Segment 4 FSS Population Trends of YOY Fish Density Using a 3-Year Moving Average of 75th Percentile of Weekly Densities (see USNRC 2015 Table B, page A-58).

Species	Linear Regression				
	Mean Squared Error	Slope	Std Err of Slope Estimate	t-value	p-value
Atlantic Menhaden	0.949	0.041	0.027	1.510	0.1439
Gizzard Shad*	.	.	.	.	

(* 75th Percentile was zero in all years)

Table 3. Standardized River Segment 4 BSS Population Trends of YOY Fish Density Using a 3-Year Moving Average of 75th Percentile of Weekly Densities (see USNRC 2015 Table C, page A-59).

Species	Linear Regression				
	Mean Squared Error	Slope	Std Err of Slope Estimate	t-value	p-value
Atlantic Menhaden	1.031	0.015	0.028	0.530	0.6028
Gizzard Shad	0.762	0.071	0.024	2.910	0.0078

Table 4. Standardized River Segment 4, FSS Population Trends of YOY Fish 75th Percentile of Weekly CPUEs (see USNRC 2015 Table E, page A-60).

Species	**Linear Regression**				
	Mean Squared Error	**Slope**	**Std Err of Slope Estimate**	**t-value**	**p-value**
Atlantic Menhaden	1.030	0.012	0.025	0.490	0.6299
Gizzard Shad*	.	.	.	.	

(* 75th Percentile was zero in all years)

Table 5. Assessment of Population Impacts for IP2 and IP3 River Segment 4 (see USNRC 2015 Table A-12, page A-27).

Species	**Density**			**CPUE**		**River Segment 4 Assessment**
	FSS	**BSS**	**LRS**	**FSS**	**LRS**	
Atlantic Menhaden	1	1	N/A	1	N/A	1.0
Gizzard Shad	N/A	1	N/A	N/A	N/A	1.0

Table 6. Standardized Riverwide FSS Population Trends of YOY Fish CPUE (see USNRC 2015 Table G, page A-62).

Species	Linear Regression				
	Mean Squared Error	Slope	Std Err of Slope Estimate	t-value	p-value
Atlantic Menhaden	1.029	0.013	0.025	0.510	0.6129
Gizzard Shad	1.038	0.006	0.025	0.220	0.8282

Table 7. Standardized Riverwide BSS Population Trends of YOY Fish CPUE (see USNRC 2015 Table H, page A-63).

Species	Linear Regression				
	Mean Squared Error	Slope	Std Err of Slope Estimate	t-value	p-value
Atlantic Menhaden	1.013	0.020	0.025	0.820	0.4192
Gizzard Shad	0.811	0.059	0.022	2.660	0.0136

Table 8. Assessment of Riverwide Population Impacts (see USNRC 2015 Table A-13, page A-28).

Species	CPUE			Riverwide Assessment
	FSS	BSS	LRS	
Atlantic Menhaden	1	1	N/A	1.0
Gizzard Shad	1	1	N/A	1.0

Table 9. Weight of Evidence Results for the Population Trend Line of Evidence (see USNRC 2015 Table A-14, page A-29).

Species	River Segment 4 Assessment Score	Riverwide Assessment Score	WOE Score	Impact Conclusion
Atlantic Menhaden	1.0	1.0	1.0	Undetected Decline
Gizzard Shad	1.0	1.0	1.0	Undetected Decline

Table 10. NRC Staff's *EMR* method applied to Atlantic Menhaden data. Shaded cells indicate years of data used to estimate NRC Staff's *EMR*. NRC Staff's *EMR* is a ratio of a weighted average number entrained to a weighted average number at risk (the sum of Region 4 abundance and the number entrained). Each weighted average was based on data from two year (shaded cells) and represents the 75th percentile.

Year	Region 4 Abundance	Number Entrained	Number At Risk	Year-Specific *EMR*
1981	12,902	0	12,902	0.000
1983	7,882	0	7,882	0.000
1984	539,376	0	539,376	0.000
1985	567,915	151,651	719,566	0.211
1986	7,232,596	391,619	7,624,214	0.051
1987	0	0	0	0.000
			Average:	0.044
		NRC Staff's *EMR*		
Wt. Ave.		113,738	674,519	**0.169**

Table 11. NRC Staff's *EMR* method applied to Atlantic Menhaden impingement data to estimate *IMR*. Shaded cells indicate years of data used to estimate *IMR*. *IMR* was calculated as the ratio of a weighted average number entrained to a weighted average number at risk (the sum of Region 4 abundance and the number entrained). Each weighted average was based on data from two year (shaded cells) and represents the 75th percentile.

Year	Number Impinged*	In-River Abundance**	Number At Risk	Year-Specific *IMR*
1981	8,508	125,040	133,548	0.064
1982	296	88,623	88,919	0.003
1983	837	188,741	189,578	0.004
1984	238	12,374	12,612	0.019
1985	1,085	179,096	180,181	0.006
1986	18,608	791,738	810,346	0.023
1987	3,592	90,015	93,607	0.038
1988	1,788	21,901	23,688	0.075
1989	1,785	62,942	64,727	0.028
1990	2,009	1,060,989	1,062,998	0.002
			Average:	0.026
		IMR		
Wt. Ave.	2,800		184,880	**0.015**

[* April through September]

[** Maximum weekly in-river abundance, April through September]

Table 12. NRC Staff's *EMR* method applied to gizzard shad impingement data to estimate *IMR*. Shaded cells indicate years of data used to estimate *IMR*. *IMR* was calculated as the ratio of a weighted average number entrained to a weighted average number at risk (the sum of Region 4 abundance and the number entrained). Each weighted average was based on data from two year (shaded cells) and represents the 75th percentile.

Year	Number Impinged*	In-River Abundance**	Number At Risk	Year-Specific *IMR*
1981	0	1,108	1,108	0.000
1982	0	0	0	0.000
1983	0	1,705	1,705	0.000
1984	139	92	231	0.600
1985	0	0	0	0.000
1986	0	0	0	0.000
1987	557	3,093	3,650	0.153
1988	0	138	138	0.000
1989	173	862	1,035	0.168
1990	458	6,162	6,620	0.069
			Average:	0.099
		IMR		
Wt. Ave.	156		1,407	**0.111**

[* April through September]

[** Maximum weekly in-river abundance, April through September]

Table 13. Parameter Values Used in the Monte Carlo Simulation (see USNRC 2015 Table A-15, page A-30).

RIS	Survey Used	Linear Slope (r)	Slope plus Standard Error of the Slope Estimate r_{UL}	Error Mean Square from Regression	CV of Density Data (1985-2011)	*EMR*	*IMR**
Atlantic Menhaden	BSS	0.015	0.043	1.031	4.467	0.169	0.015
Gizzard Shad	BSS	0.071	0.095	0.762	3.169	0.000	0.111

Table 14. Quartiles of the Relative Difference in Cumulative Abundance and Conclusions for the Strength-of-Connection From the Monte Carlo Simulation (see USNRC 2015 Table A-16, page A-31). Scenario 1: $r^* = (1\text{-}IMR)/\max(1,CV)$

	Observed Rate of Increase ***r***	**Modeled Rate of Increase Without Impingement** ***r****
Atlantic Menhaden	0.015	0.009
Gizzard Shad	0.071	0.027

Taxa	**Number of Years**	**$N_0 = 1000$**			**$N_0 = 1 \times 10^8$**			**Strength of Connection Conclusion**
		Median	**Q1**	**Q3**	**Median**	**Q1**	**Q3**	
Atlantic Menhaden	20	0.295	-0.597	1.285	0.351	-0.571	1.237	Low
	27	0.287	-0.497	1.111	0.197	-0.611	1.065	
Gizzard Shad	20	-1.936	-3.051	-0.860	-1.849	-3.016	-0.852	.
	27	-3.434	-4.683	-2.043	-3.355	-4.661	-2.181	

Table 15. Quartiles of the Relative Difference in Cumulative Abundance and Conclusions for the Strength-of-Connection From the Monte Carlo Simulation (see USNRC 2015 Table A-16, page A-31). Scenario 2: $r^* = (1+IMR)/\min(1,CV)$.

	Observed Rate of Increase ***r***	**Modeled Rate of Increase Without Impingement** ***r****
Atlantic Menhaden	0.015	0.044
Gizzard Shad	0.071	0.105

Taxa	**Number of Years**	**$N_0 = 1000$**			**$N_0 = 1 \times 10^8$**			**Strength of Connection Conclusion**
		Median	**Q1**	**Q3**	**Median**	**Q1**	**Q3**	
Atlantic Menhaden	20	1.939	0.791	3.256	2.017	0.858	3.200	High
	27	2.761	1.720	3.973	2.768	1.514	4.015	
Gizzard Shad	20	2.761	0.833	4.737	2.712	1.033	4.740	High
	27	5.841	2.949	8.696	5.832	3.296	8.512	

Table 16. Quartiles of the Relative Difference in Cumulative Abundance and Conclusions for the Strength-of-Connection From the Monte Carlo Simulation. Scenario 1: $r^* = (1-IMR)/\max(1,CV)$. Assuming EMR=0 and IMR=0

	Observed Rate of Increase r	**Modeled Rate of Increase Without Impingement** r^*
Atlantic Menhaden	0.015	0.010
Gizzard Shad	0.071	0.030

Taxa	**Number of Years**	**N_0 = 1000**			**$N_0 = 1 \times 10^8$**			**Strength of Connection Conclusion**
		Median	**Q1**	**Q3**	**Median**	**Q1**	**Q3**	
Atlantic Menhaden	20	-0.188	-1.025	0.723	-0.165	-1.019	0.667	Low
	27	-0.217	-0.947	0.544	-0.310	-1.065	0.500	
Gizzard Shad	20	-1.846	-2.952	-0.732	-1.724	-2.912	-0.727	.
	27	-3.261	-4.542	-1.854	-3.182	-4.487	-2.027	

Table 17. Quartiles of the Relative Difference in Cumulative Abundance and Conclusions for the Strength-of-Connection From the Monte Carlo Simulation. Scenario 2: $r^* = (1+IMR)/\min(1,CV)$. Assuming EMR=0 and IMR=0

	Observed Rate of Increase r	**Modeled Rate of Increase Without Impingement** r^*
Atlantic Menhaden	0.015	0.043
Gizzard Shad	0.071	0.095

Taxa	**Number of Years**	**N_0 = 1000**			**$N_0 = 1 \times 10^8$**			**Strength of Connection Conclusion**
		Median	**Q1**	**Q3**	**Median**	**Q1**	**Q3**	
Atlantic Menhaden	20	1.155	0.116	2.389	1.246	0.215	2.306	High
	27	1.816	0.912	2.944	1.828	0.742	2.915	
Gizzard Shad	20	1.768	0.021	3.568	1.725	0.266	3.519	High
	27	3.587	1.229	5.929	3.615	1.482	5.903	

Table 18. Impingement and Entrainment Impact Summary for Hudson River YOY RIS (see USNRC 2015 Table A-18, page A-33).

Species	Population Trend Line of Evidence	Strength of Connection Line of Evidence	Impacts of IP2 and IP3 Cooling Systems on YOY RIS
Atlantic Menhaden	Undetected Decline	High	Small
Gizzard Shad	Undetected Decline	High	Small