Technical Review of
FSEIS for Indian Point Nuclear Generating Unit Nos. 2 and 3
Sections 4.1.1-4.1.3 and Appendices H and I

Prepared for

Entergy Nuclear Operations, Inc.
Entergy Nuclear Indian Point 2, LLC, and
Entergy Nuclear Indian Point 3, LLC
Indian Point Energy Center
450 Broadway, Suite 1
Buchanan, NY 10511

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

March 28, 2011

TABLE OF CONTENTS

A. Introduction 1

B. Appropriateness of Approach USNRC Used to Conclude Impingement and Entrainment Impacts are LARGE 1
  1. Overview 1
  2. Limitations of USNRC's LOE Results 3

C. Implementation of the SOC Method 4
  1. Operating Characteristics of the SOC Method 4
    a. Number of Years in the Projection 5
    b. Precision of Abundance Estimates 6
    c. Width of Confidence Limits on Slope Estimate 6
    d. Rule for Assigning High vs. Low SOC Rating 7
  2. EMR Estimates 8
    a. Background 8
    b. FSEIS Method 9
      1) Formulation 9
      2) Input Errors 11
    c. Species-Specific Details 11
      1. Blueback Herring 12
      2. Hogchoker 13
      3. Rainbow Smelt 15
      4. Spottail Shiner 17
      5. White Perch 19
    d. Comparison of EMRs to Natural Mortality Rates 20

D. Conclusions 21

E. References 22

A. Introduction

This report documents a technical review of the United States Nuclear Regulatory Commission's ("USNRC") evaluation of potential environmental impacts of entrainment and impingement at Entergy Nuclear Operations, Inc., Entergy Nuclear Indian Point 2, LLC, and Entergy Nuclear Indian Point 3, LLC's (collectively, "Entergy") Indian Point Energy Center ("IPEC"), during the proposed twenty-year extended period of operation as defined in the IPEC License Renewal Application. The evaluation that is the subject of this review is presented in USNRC's *Generic Environmental Impact Statement for License Renewal of Nuclear Plants Supplement 38 Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3. Final Report. December 2010. Office of Nuclear Reactor Regulation NUREG-1437, Supplement 38.* ("FSEIS"). This review focuses on material presented in Appendices H (*U.S. Nuclear Regulatory Commission Staff Evaluation of Environmental Impacts of Cooling System*) and I (*Statistical Analyses Conducted for Chapter 4 Aquatic Resources and Appendix H*) of the FSEIS which describe the analyses that support the summaries and conclusions presented in Sections 4.1.1-4.1.3 of the FSEIS (collectively, the "Appendices").

Specifically, this review addresses USNRC's conclusion that environmental impacts of entrainment and impingement at IPEC were LARGE for five out of the eighteen identified fish species. By USNRC's definition of LARGE impacts, the effects of entrainment and impingement would have to be sufficient to destabilize those five fish populations. As documented in the following sections, USNRC did not demonstrate that entrainment and impingement are the cause of any destabilization of those five fish populations. Rather than providing evidence to support their claim, USNRC assumed entrainment and impingement was the cause of observed trends in abundance of those fish populations. Furthermore, USNRC's analysis of historical data on those five fish populations contains discrepancies that bias the results of the analysis in favor of the conclusion that impacts are LARGE.

This technical review examines the approach and detailed methods USNRC used to reach its conclusion that IPEC's license renewal will result in LARGE impacts to five fish species. The review consists of two parts. The first addresses the appropriateness of the overall approach USNRC used to conclude that impingement and entrainment impacts are LARGE. The second addresses detailed data analysis discrepancies and their likely effects on the outcomes of the USNRC's analysis. This review addresses significant identified discrepancies relating to the LARGE impact determinations, but is not intended to be exhaustive.

B. Appropriateness of Approach USNRC Used to Conclude Impingement and Entrainment Impacts are LARGE

1. Overview

In Section 4.1.3 of the FSEIS, USNRC concludes that potential environmental impacts of entrainment and impingement associated with IPEC license renewal are LARGE for five out of eighteen fish species (USNRC 2010 at page 2-52). Specifically, USNRC concluded that such impacts are LARGE for blueback herring, hogchoker, rainbow smelt, spottail shiner and white perch (USNRC 2010 at pages 4-21 to 4-22). In Chapter 1 of the FSEIS, USNRC defines three levels of potential impact:

"the [US]NRC established three significance levels—SMALL, MODERATE, or LARGE. The definitions of the three significance levels are ... as follows:

SMALL—Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.

MODERATE—Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.

LARGE—Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource." (USNRC 2010 at page 1-3)

To determine whether impacts are LARGE for a species, USNRC relied on two types of analyses (referred to as two lines of evidence ("LOE")): 1) a population trends analysis to determine whether a population had declined in abundance, and 2) what USNRC refers to as a strength of connection ("SOC") analysis. USNRC concludes impacts are LARGE if a declining trend in abundance was detected and if its measure of SOC was HIGH:

"The staff defined the cooling system impact as LARGE for a given RIS if the first LOE concluded that there was a detectable population decline and the second LOE concluded that there was a high strength of connection." (USNRC 2010 at page 4-19).

Because a population decline can occur that is unrelated to IPEC, the burden of establishing causation falls on USNRC's SOC analysis. If it does not establish causation, then USNRC's conclusions regarding LARGE would not be supported. That is what occurred here: USNRC's assessment of trends and SOC analyses, collectively, do not provide credible evidence of LARGE impacts, as defined by USNRC. As noted above, USNRC's definition of LARGE impacts has two elements:

1) that the effects of entrainment and impingement are clearly noticeable, and
2) that the effects of entrainment and impingement are sufficient to destabilize important attributes of the resource (USNRC 2010 at page 1-3).

As explained in Section 4.1.3 of the FSEIS, it appears the SOC analysis is intended to address the question of whether effects of entrainment and impingement would be detectable. USNRC defines its SOC model results as follows:

"A high strength of connection occurred when model simulations showed that the difference in population abundance with and without losses from impingement and entrainment was *detectable* with respect to annual population variability. In this case, the effects of impingement and entrainment were greater than the variability in the RIS population trends" (USNRC 2010 at page 4-18) (emphasis supplied).

Just as the SOC method is an essential element of USNRC's method for establishing a LARGE impact, USNRC also relies on a second LOE that addresses historical trends in fish populations. As explained in Section 4.1.3, the population trend analysis apparently is intended to address the question of whether a declining trend in abundance was detectable.

> "RIS populations were declining if their population trends had slopes that were significantly less than zero (i.e., *detectable* population decline)." (USNRC 2010 at page 4-18) (emphasis supplied).

Notably, both LOEs (i.e., trends and SOC) addressed questions of *detectable* changes. This approach appears consistent with the objective of addressing differences between SMALL (i.e., not detectable) and MODERATE (i.e., noticeable) effects.

However, the FSEIS did not explain how either LOE provided any evidence that entrainment and impingement were sufficient to cause *destabilization* of important attributes of fish populations as required by the definition of LARGE impacts. The scientific connection between *detectable* changes and *destabilization* is not evident in the FSEIS. Rather, as noted below, it appears USNRC assumes that a high SOC result indicates that any observed decline in abundance was due to entrainment and impingement – that is, assumes causation without demonstrating it.

2. Limitations of USNRC's LOE Results

Inherent characteristics of the SOC method limit its usefulness for determining LARGE impacts. As noted in the Appendices, USNRC used a "simple exponential" modeling approach for its SOC assessment:

> "For this analysis, the strength of connection was determined from the uncertainty associated with estimating the difference in the RIS [young of year] YOY population abundance with and without losses from impingement and entrainment associated with IP2 and IP3 cooling systems. A simple exponential model was used to estimate the annual juvenile population abundance..." (USNRC 2010, Appendix I at pages I-50 and I-51).

For the SOC analysis, actual effects of entrainment and impingement on fish populations were not observed or examined. Accordingly, the SOC analysis does not address the question of whether the effects of entrainment and impingement are "clearly noticeable," as required by USNRC's definition of LARGE impacts. Rather, the SOC analysis addresses a hypothetical question of whether effects would be detectable if fish populations behaved according to the rules of a simple exponential model. With a simple exponential model, only two long-term outcomes are possible - either a fish population would increase in abundance without limit or it would decline to extinction. Neither outcome is realistic, with the result that the SOC analysis does not establish destabilization (and therefore LARGE impacts) in a credible manner.

By way of analogy, if this simple exponential model were used to evaluate the effects of fishing (as opposed to impingement and entrainment) then it is unlikely any fishing would ever be allowed. This is because the effect, according to the simple exponential model, of adding any level of fishing mortality to a stable fish stock would be to drive the stock to extinction. In fact, many fish populations are fished without becoming extinct. Fisheries managers routinely allow fishing mortality while protecting the long-term well-being of fish stocks. For example, the Atlantic States

Marine Fisheries Commission ("ASMFC"), in Amendment 6 to the Striped Bass Management Plan, established a target exploitation (harvest) rate of 24% for the Atlantic striped bass stock in order to provide for sustainable harvests and to protect the striped bass spawning population:

> "Amendment 6 also establishes a fishing mortality target of F=0.30, which equates to an exploitation rate of 24%. This target (F=0.30) provides a higher long–term yield from the fishery and adequate protection to ensure that the striped bass population is not reduced to a level where the spawning potential is adversely affected." (ASMFC, 2003).

In contrast, USNRC's simple exponential model would predict that an annual exploitation rate of 24% would cause a stock to decline to less than 1% of its initial abundance in 17 years. This contrary result indicates that the simple exponential model does not accurately reflect and, in this instance, substantially overstates the effect of mortality on future population abundance. Consequently, its use in USNRC's SOC method is inappropriate, particularly when applied to determine conditions under which LARGE potential impacts are likely to occur.

Likewise, for the trends LOE, the FSEIS provides no direct evidence that any detectable declines in population abundance are due to entrainment and impingement at IPEC. Furthermore, except for an analysis of possible effects of zebra mussels, and qualitative discussions of possible effects of changes in water quality and climate, the FSEIS does not present analyses of potential effects of alternative stressors (e.g., as was done in Barnthouse et al 2008) on the fish populations that exhibited declines in abundance.

For example, the FSEIS does not include an assessment of the potential effects of increases in striped bass predation on other fish stocks of the Hudson River. Barnthouse et al (2008) showed that increases in striped bass predation since 1990 were highly correlated with declines in juvenile abundance of Atlantic tomcod, blueback herring, bay anchovy and white perch; and Heimbuch (2008) showed that the increase in predatory demand by striped bass since 1990 was large enough to account for declines in juvenile abundance of four species (Atlantic tomcod, alewife, blueback herring and white perch) in the Hudson River.

Rather, USNRC expressly assumes entrainment and impingement are responsible for any observed population declines where the SOC score for a species is high, as noted in Table H-12, which lists the SOC conclusion associated with a high SOC rating:

> "High strength of connection suggesting the RIS population trend is highly likely to be associated with the effects of the cooling system." (USNRC 2010 Appendix H at page H-40).

As noted in the previous section, the SOC method addresses the *detectability* of *hypothetical* differences in population abundance; it does not address cause and effect. Therefore, the assumption, that results from the SOC analysis provide insight into cause and effect, lacks credibility.

C. Implementation of the SOC Method

1. Operating Characteristics of the SOC Method

The SOC method, as implemented in the FSEIS, has several characteristics that seem to make it unsuitable for its intended purpose. In particular, the results of the SOC analysis depend heavily on

three factors that are unrelated to the association between detected declines in population abundance and entrainment and impingement:

1) the number of years included in the projection of juvenile abundance,
2) the precision of annual estimates of juvenile abundance, and
3) the width of the confidence limits on the slope parameter from the trends assessment.

a. Number of Years in the Projection

Results from the SOC analysis were profoundly affected by the number of years included in the projection of juvenile abundance. For any given level of entrainment and impingement, the likelihood that the outcome would be a high SOC increases as the number of years included in the projection increases. This is because 1) with the simple exponential model, the difference between the projected abundance with and without entrainment and impingement increases without limit as the number of years in the projection increases, and 2) the precision of the estimate of that difference increases as the sample size (i.e., number of years) increases. Therefore, at any level of entrainment and impingement, a projected difference would be more detectable with more years in the projection.

Figure 1, below, depicts how the outcome (using hogchoker as an example) depends on the level of entrainment and impingement and on the number of years included in the projection of juvenile abundance. The SOC analysis presented in the FSEIS included juvenile abundance projections for 20 years and 27 years. The FSEIS did not clearly indicate why 20 and 27 years were selected for the SOC projections, but it appears it may be related to the number of years of historical data that were available. While we have been advised that 20 years coincides with the project license renewal term, USNRC offers no basis for extending the projection beyond the license renewal term to 27 years.

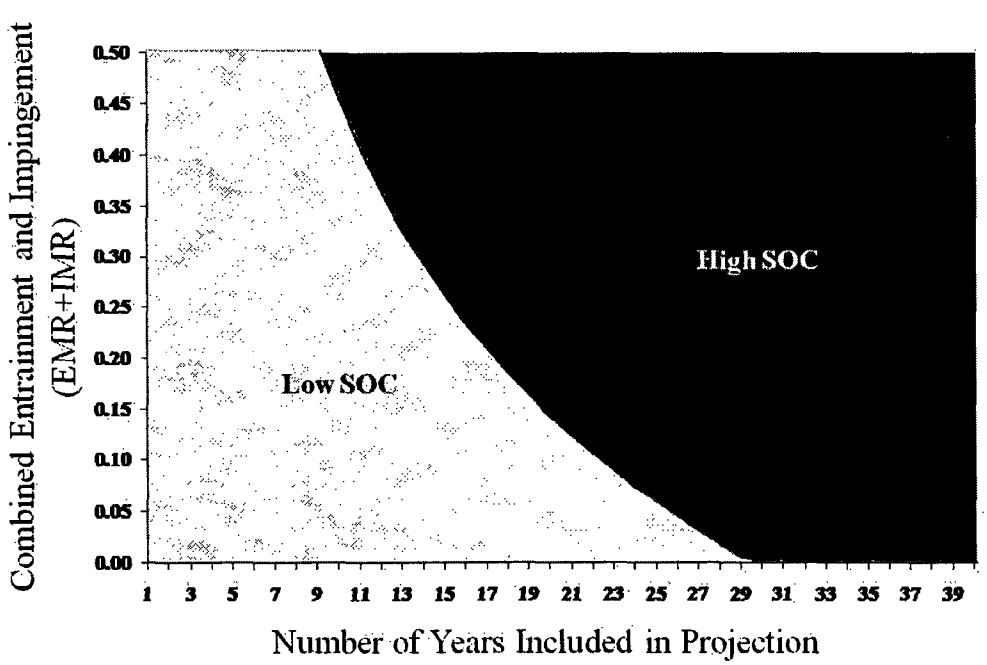

Figure 1. Expected outcome (i.e., LOW or HIGH SOC) from SOC analysis for hogchoker as a function of the number of years included in the population projection (X-axis) and the assumed conditional mortality rate for entrainment and impingement (Y-axis).

The credibility of the SOC analysis is undermined by the fact that the number of years in the population projection substantially affects the results of the SOC analysis. In particular this is the case absent a clear rationale for selecting 20 or 27 years for the population projection.

b. Precision of Abundance Estimates

For species with precise estimates of juvenile abundance, the outcome from the SOC method was more likely to be a high SOC. That is because a high SOC was assigned when projected differences in juvenile abundance (with and without entrainment and impingement) were statistically different. Precise estimates of abundance are more likely to lead to statistically significant differences than imprecise estimates. Species like striped bass, which are primary target species of the Hudson River biological monitoring program, have more precise abundance estimates than non-target species like hogchoker. Therefore, they would be more likely to be assigned a SOC rank of high (Figure 2, below). In that way, the SOC method is biased against facilities with high quality monitoring data for key species. As a result, it is more likely that facilities with high quality data are more likely to be assumed to have LARGE impacts, where there are declining population trends. This characteristic of the SOC method also undermines its credibility.

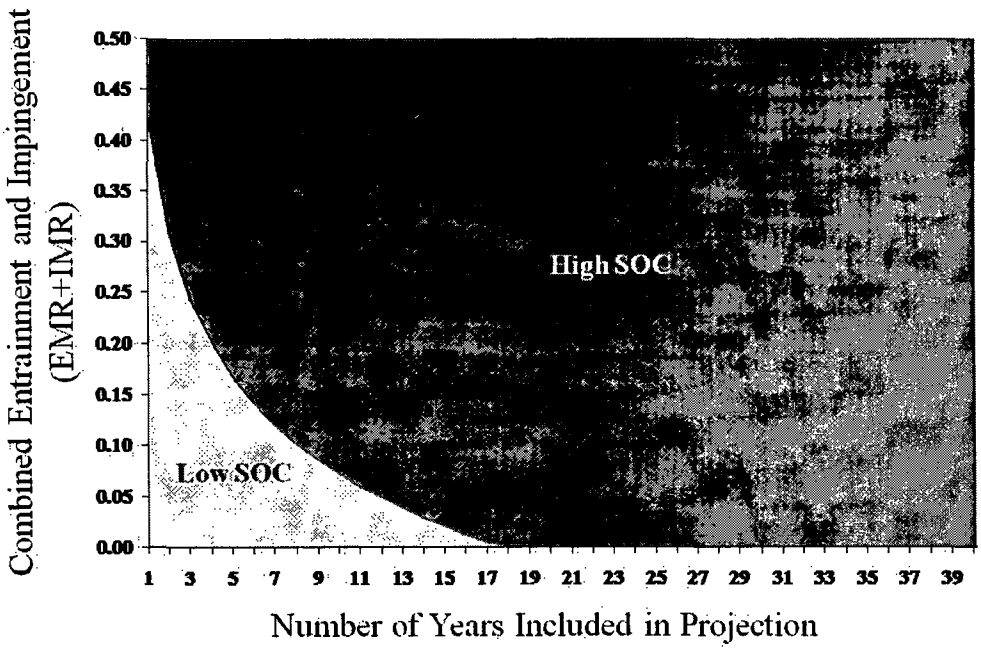

Figure 2. Expected outcome (i.e., LOW or HIGH SOC) from SOC analysis for striped bass as a function of the number of years included in the population projection (X-axis) and the assumed conditional mortality rate for entrainment and impingement (Y-axis).

c. Width of Confidence Limits on Slope Estimate

As indicated in Figure 2, with a sufficient number of years included in the projection of juvenile abundance, the outcome of USNRC's model will be a finding of high SOC – *even if there is no entrainment and impingement.* This remarkable result occurs because the juvenile projections for the scenario of no entrainment and impingement use the upper confidence limit of the slope parameter

(from the trend analysis). However, for the scenario including entrainment and impingement, the juvenile projections used the slope parameter itself. Therefore, even with no entrainment and impingement, there is always a difference between the two projections. This aspect of USNRC's implementation of the SOC method introduces a clear, and unwarranted, bias.

d. Rule for Assigning High vs. Low SOC Rating

For each species, a graph (like Figure 1 or 2) depicting the combinations of years included in the projection and levels of entrainment and impingement that would lead to a low SOC or high SOC could be constructed based on three inputs from Table I-46 in Appendix I of the FSEIS:

1) the slope parameter (and confidence limit) from the trends analysis,
2) the mean square error from the trends analysis, and
3) the coefficient of variation of density data.

Once the number of years in the projection is selected, the assignment of low versus high SOC for a species depends on the magnitude of the entrainment and impingement mortality rate estimates ("EMR" and "IMR" respectively). Although it is not clear from the documentation in Appendices H and I, it appears that the results are dominated by the EMRs, which are generally much larger than the IMRs (USNRC 2010, Appendix I Table I-46).

How the estimates EMR and IMR were used in the SOC analysis is depicted in Figure 3, below, for the hogchoker example applying a 20-year population projection. For that example, an EMR estimate less than about 0.14 would lead to an outcome of a low SOC. Otherwise, the outcome would be a high SOC. As can be seen from the hogchoker example, the magnitude of the EMR estimate for a species is a critical input to the SOC analysis.

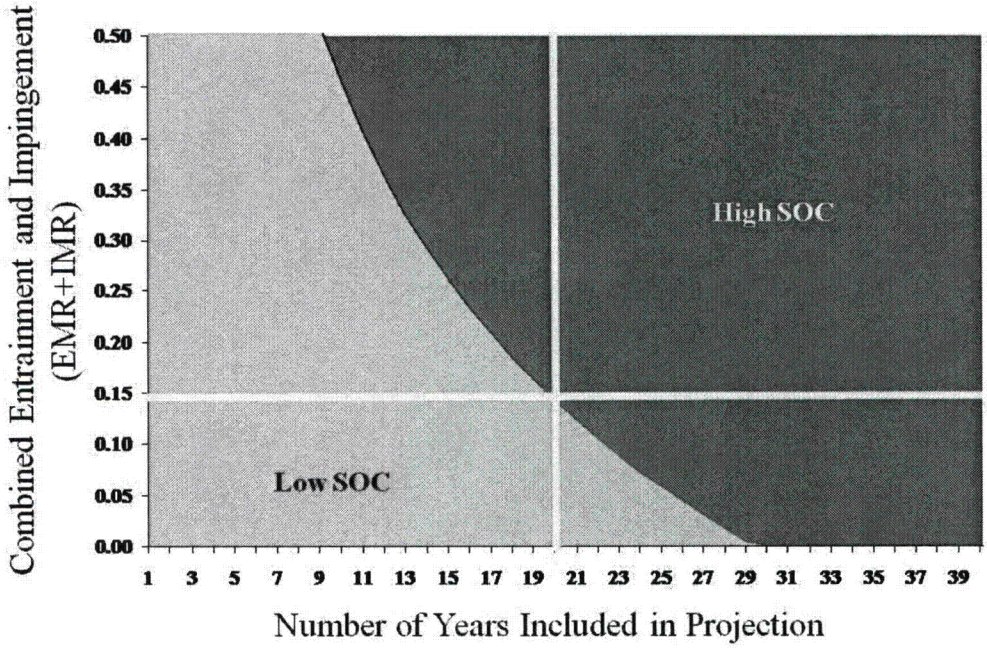

Figure 3. Expected outcome (i.e., LOW or HIGH SOC) from SOC analysis for hogchoker as a function of the number of years included in the population projection (X-axis) and the assumed conditional mortality rate for entrainment and impingement (Y-axis). With a 20-year population projection (yellow vertical line), a conditional mortality rate estimate of more than about 0.14 (yellow horizontal line) would result in a conclusion of HIGH SOC.

The following section discusses several data analysis discrepancies related to the EMR estimates and reviews the EMR estimates for the five fish species for which USNRC reached a conclusion of LARGE potential impacts.

2. EMR Estimates

a. Background

The FSEIS defines EMR as a conditional mortality rate due to entrainment (USNRC 2010, Appendix I at page I-51). A conditional mortality rate represents the fractional reduction in the abundance of a population over some defined time period due to a single cause (in this case, entrainment). Given the average population abundance over a time period and the entrainment losses over that same time period, the conditional mortality rate can be calculated (Ricker 1975) as:

$$EMR = 1 - e^{-\left(\frac{L}{\overline{N}}\right)} \qquad (1)$$

where $\overline{N}$ is the average population abundance during the period and L is the total number lost to entrainment during the period.

As indicated by the definition of a conditional mortality rate and by equation (1), EMR estimates based on entrainment losses and population abundance must be from the same time period.

For example, using loss estimates from April combined with population abundance estimates from November would not produce valid EMR estimates. Concurrent entrainment and in-river sampling occurred during the entrainment season of target species like striped bass (Figure 4, below). Accordingly, estimates of conditional entrainment mortality rate could be based on those data. However, compatible entrainment and in-river datasets are not available for some non-target species that spawn at times and in locations that were not adequately sampled (and were never targeted for sampling) by the in-river monitoring programs.

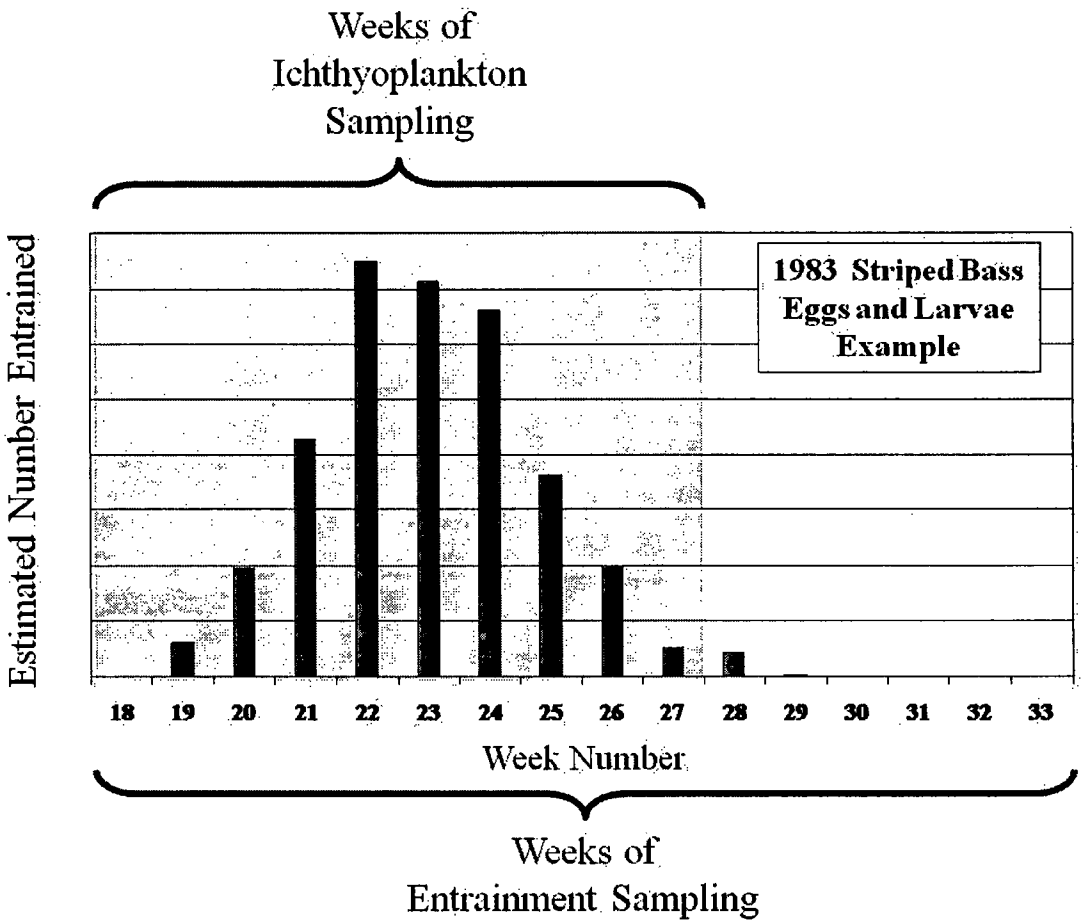

Figure 4. Graph depicting overlapping weeks of entrainment and ichthyoplankton sampling (grey shading) in 1983. Green bars indicate estimates of numbers of striped bass eggs and larvae entrained. Data from the overlapping weeks of sampling can be used to estimate a conditional mortality rate due to entrainment.

b. FSEIS Method

1) Formulation

Rather than using this standard formulation from fishery science (equation (1)), the FSEIS used the following formulation (USNRC 2010, Appendix I Table I-40 at page I-56) to estimate conditional mortality rates due to entrainment:

$$\hat{EMR} = \frac{L}{k\bar{N} - L} \tag{2}$$

where k is the number of weeks of standing crop data included in the calculation. The denominator of equation (2) was referred to as the number at risk.

In addition to using a non-standard formulation for estimating conditional mortality rates, the abundance estimates used for USNRC's EMR estimates were not consistent with their use in a population projection model (i.e., USNRC's simple exponential population projection model discussed above). Although the entrainment loss estimates used for the EMR estimates represented losses from the entire population, the abundance estimates were from Region 4 (referred to as the Indian Point region) only, which includes only 7 out of 152 miles of river (Figure5, below).

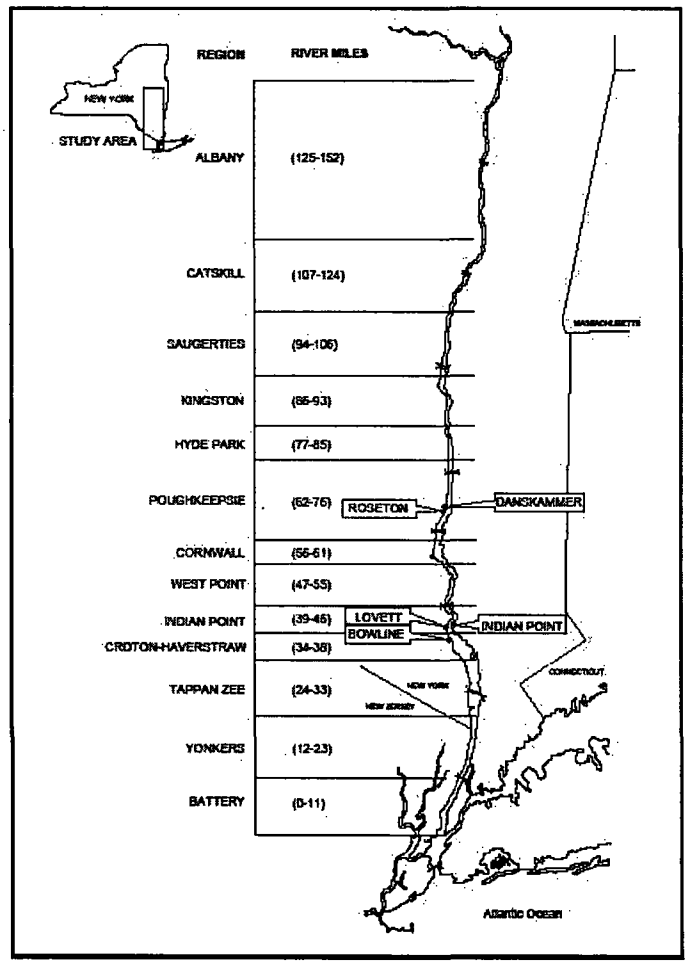

Figure 5. Map of Hudson River showing 13 sampling regions used for stratified random sampling of fish populations inhabiting the tidal Hudson River (from 2000 Year Class Report (ASA, 2001)).

Abundance estimates based on data collected from such a small portion of the full spatial extent of the population would not produce valid CMR estimates for a population projection model. The biology underlying this concern was acknowledged in the FSEIS:

> "The NRC staff acknowledges that River Segment 4 at Indian Point is not a closed biological system for which loses and gains to a population can be easily studied. Many of the RIS reproduce 100 river miles upriver, and the eggs and larvae then float downstream where some are entrained at IP2 or IP3." (USNRC 2010. Appendix H at page H-38).

The use of Region 4 in-river abundance, rather than riverwide in-river abundance, would cause the EMR estimates to be biased high. However, USNRC's formulation of EMRs (equation (2)) would cause EMR estimates to be biased low because the average in-river abundance term in the denominator is incorrectly multiplied by the number of weeks of standing crop data. Because one discrepancy would lead to underestimates and the other to overestimates, the biases of the two discrepancies may have offset one another to some extent.

2) Input Errors

Estimates of entrainment losses used as inputs to the EMR estimates (USNRC 2010, Appendix I Table I-42 at page I-58) were too large by a factor of 1000. Similarly, estimates of annual standing crops (also used as inputs to the EMR estimates) that were based on data from the long river ichthyoplankton survey ("LRS") and fall juvenile survey ("FJS") (USNRC 2010, Appendix I Table I-41at page I-57) were too large by a factor of 1000. However, estimates of annual standing crops that were based on data from the beach seine survey ("BSS") did not have that problem.

For species with standing crop estimates that were based largely on data from the LRS and FJS, the factor of 1000 canceled in equation (2) and did not bias the EMR estimates.

$$\hat{EMR} = \frac{1000L}{k1000\overline{N} - 1000L} = \frac{L}{k\overline{N} - L}$$

However, for species with standing crop estimates based largely on data from the BSS, EMR estimates were severely biased high.

$$\hat{EMR} = \frac{1000L}{k\overline{N} - 1000L} > \frac{L}{k\overline{N} - L}$$

c. Species-Specific Details

The following sections review the EMR estimates for the five species that are assigned a LARGE license renewal impact rating. For several of the species, data analysis discrepancies were identified and are discussed. For each species, the likely effects on EMR estimates of the two discrepancies discussed above (i.e., the non-standard algebraic formulation and the use of Region 4 abundance estimates only) together with any identified species-specific data analysis discrepancies are listed.

One data analysis discrepancy that affected several species was the use of different years of data for the entrainment loss estimates and the population abundance estimates. Different years of data were used because the FSEIS EMR estimates were computed using the 75th percentile of annual entrainment losses and the 75th percentile of numbers at risk – each was computed independently of the other. The 75th percentile was computed by first ranking the years based on the magnitude of the year-specific estimates (entrainment or numbers at risk). With six years of entrainment data available, the 75th percentile fell between the 4th and 5th ranked years. The FSEIS method was to compute the 75th percentile as a weighted average of the estimates from the 4th and 5th ranked years, where 75% of the weight was given to the 5th ranked year, and 25% of the weight was given to the 4th ranked year. Data from all other years were excluded from the EMR estimates. Because these steps were conducted independently for entrainment losses and for the numbers of organisms at risk, different years might be selected for the numbers entrained and in-river abundance. Estimates of numbers entrained and in-river abundance vary by two orders of magnitude among years for some species (see Tables 1-10, below). Therefore, mismatched years of entrainment and in-river data can lead to substantial errors in EMR estimates. For each species discussed below, the years of data included in the EMR estimates from the FSEIS are listed.

For the years with entrainment loss estimates (1981, 1983-1987), conditional entrainment mortality rate (referred to as entrainment CMRs) estimates were developed for river herring, spottail shiner and white perch by the Hudson River electric generators in consultation with NYSDEC. Those estimates were listed in the 1999 DEIS (CHG&E, et al 1999) and became part of the 2003 FEIS issued by the NYSDEC (NYSDEC, 2003). Those entrainment CMR estimates are listed below for comparison to FSEIS EMR estimates.

1. Blueback Herring

The FSEIS EMR estimate of 0.095 for blueback herring (USNRC 2010, Appendix I Table I-43, at page I-59) is based on entrainment loss data from 1981 and 1983, and on in-river abundance data from 1984 and 1986 (Table 1, below).

Table 1. Shaded cells indicate years of data used in the FSEIS to estimate EMR for **blueback herring**. The reported 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 is based on data from two year (shaded cells).

Year	Region 4 Abundance(1) (millions)	Number Entrained(2) (millions)	Number At Risk (millions)	EMR
1981	239,387	20,159	259,546	
1983	1,357,568	119,801	1,477,369	
1984	1,038,155	181,006	1,219,161	
1985	78,176	954	79,130	
1986	353,533	186	353,719	
1987	21,619	45	21,664	
Wt. Ave.(3)		94,891	1,002,801	**0.095**

(1) USNRC 2010. Table I-41, Appendix I
(2) USNRC 2010. Table I-42, Appendix I
(3) USNRC 2010. Table I-43, Appendix I

Corrected EMR estimates computed using equation (1), riverwide population abundances (rather than Region 4 abundance alone) and consistent, within-year data are listed in Table 2, below. Also listed in Table 2 are year-specific entrainment CMR estimates for river herring (blueback herring and alewife, which were not reliably distinguished as larvae) from the 1999 DEIS. The average of corrected EMR estimates for the six years is 0.013 (or 13.7% of the FSEIS EMR). The average of entrainment CMR estimates for river herring from the DEIS is 0.017 (or 17.9% of the FSEIS EMR).

Table 2. Year-specific entrainment conditional mortality rate estimates for **blueback herring**. Corrected EMR estimates based on consistent weeks of entrainment and river-wide abundance sampling.

Year	Average Population Abundance (millions)	Number Entrained (millions)	Corrected EMR Estimate	DEIS Entrainment CMR Estimate(1)
1981	6,878.44	19.911	0.003	0.006
1983	5,805.08	119.351	0.027	0.031
1984	4,393.44	180.691	0.049	0.053
1985	1,850.81	0.914	0.001	0.000
1986	2,663.20	0.097	0.000	0.009
1987	719.19	0.005	0.000	0.000
Average			**0.013**	**0.017**

(1) From CHG&E et al (1999).

2. Hogchoker

The FSEIS EMR estimate of 0.386 for hogchoker (USNRC 2010, Appendix I Table I-43 at page I-59) is based on entrainment loss data from 1983 and 1984, and on in-river abundance data from 1981 and 1986 (Table 3, below).

Table 3. Shaded cells indicate years of data used in the FSEIS to estimate EMR for **hogchoker**. The reported 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 is based on data from two year (shaded cells).

Year	Region 4 Abundance (millions)	Number Entrained (millions)	Number At Risk (millions)	EMR
1981	1,882	3,188	5,070	
1983	587	2,168	2,755	
1984	1,057	961	2,018	
1985	1,116	745	1,861	
1986	3,521	585	4,106	
1987	6,384	185	6,569	
Wt. Ave.(3)		**1,870**	**4,830**	**0.386**

(1) USNRC 2010. Table I-41, Appendix I
(2) USNRC 2010. Table I-42, Appendix I
(3) USNRC 2010. Table I-43, Appendix I

Most hogchoker spawning occurs in the fall, after the in-river ichthyoplankton monitoring program stopped sampling (1981, and 1982-1987) (Figure 6, below). However, the entrainment sampling programs continued sampling after the in-river sampling had ended. Therefore, in most weeks when hogchoker eggs and larvae were at risk to entrainment, no data were collected on the in-river abundance of larvae.

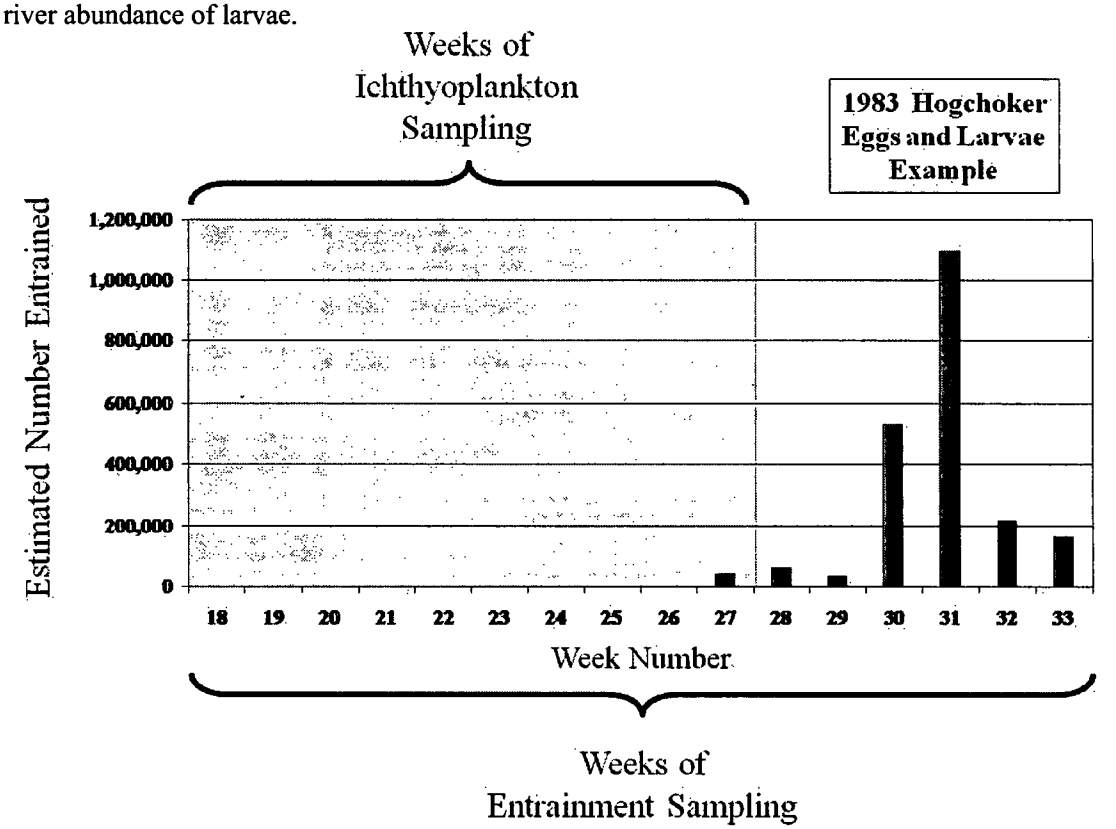

Figure 6. Graph depicting overlapping weeks of entrainment and ichthyoplankton sampling (grey shading) in 1983. Green bars are estimates of number of hogchoker eggs and larvae entrained. Conditional mortality rates estimates based on estimates of numbers entrained require concurrent data from entrainment sampling and in-river ichthyoplankton sampling.

The FSEIS method for computing the inputs for EMR estimates added entrainment losses over all weeks of entrainment sampling, and added standing crop over all weeks of in-river sampling. For hogchoker, this method caused EMR estimates to be severely biased high because the in-river abundance of eggs and larvae was not recorded, but the entrainment losses were (Figure 6). Those biases can be reduced by calculating loss-to-abundance ratios using only data from weeks during which both entrainment and in-river sampling occurred.

Corrected EMR estimates computed using equation (1), riverwide population abundances and consistent, within-year data are listed in Table 4, below. The average of corrected EMR estimates for the six years is less than 0.001 (or less than 0.26% of the FSEIS EMR).

Table 4. Year-specific entrainment conditional mortality rate estimates for **hogchoker**. Corrected EMR estimates based on consistent weeks of entrainment and river-wide abundance sampling.

Year	Average Population Abundance (millions)	Number Entrained (millions)	Corrected EMR Estimate
1981	744.87	0.021	0.000
1983	2,236.34	0.064	0.000
1984	95.91	0.120	0.001
1985	1,881.81	0.003	0.000
1986	262.44	0.030	0.000
1987	997.95	0.064	0.000
Average			**<0.001**

3. Rainbow Smelt

The FSEIS EMR estimate of 0.258 for rainbow smelt (USNRC 2010, Appendix I Table I-43 at page I-59) is based on entrainment loss data and in-river abundance data from 1984 and 1987 (Table 5).

Table 5. Shaded cells indicate years of data used in the FSEIS to estimate EMR for **rainbow smelt**. The reported 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 is based on data from two year (shaded cells).

Year	Region 4 Abundance (millions)	Number Entrained (millions)	Number At Risk (millions)	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.(3)		**7,074**	**27,402**	**0.258**

(1) USNRC 2010. Table I-41, Appendix I
(2) USNRC 2010. Table I-42, Appendix I
(3) USNRC 2010. Table I-43, Appendix I

Rainbow smelt spawn early in the year, before the seasonal ichthyoplankton monitoring program started sampling (1981, and 1982-1987) (Figure 7, below). Therefore, in most weeks when rainbow smelt eggs and larvae were at risk to entrainment, no data were collected on the in-river abundance of eggs and larvae.

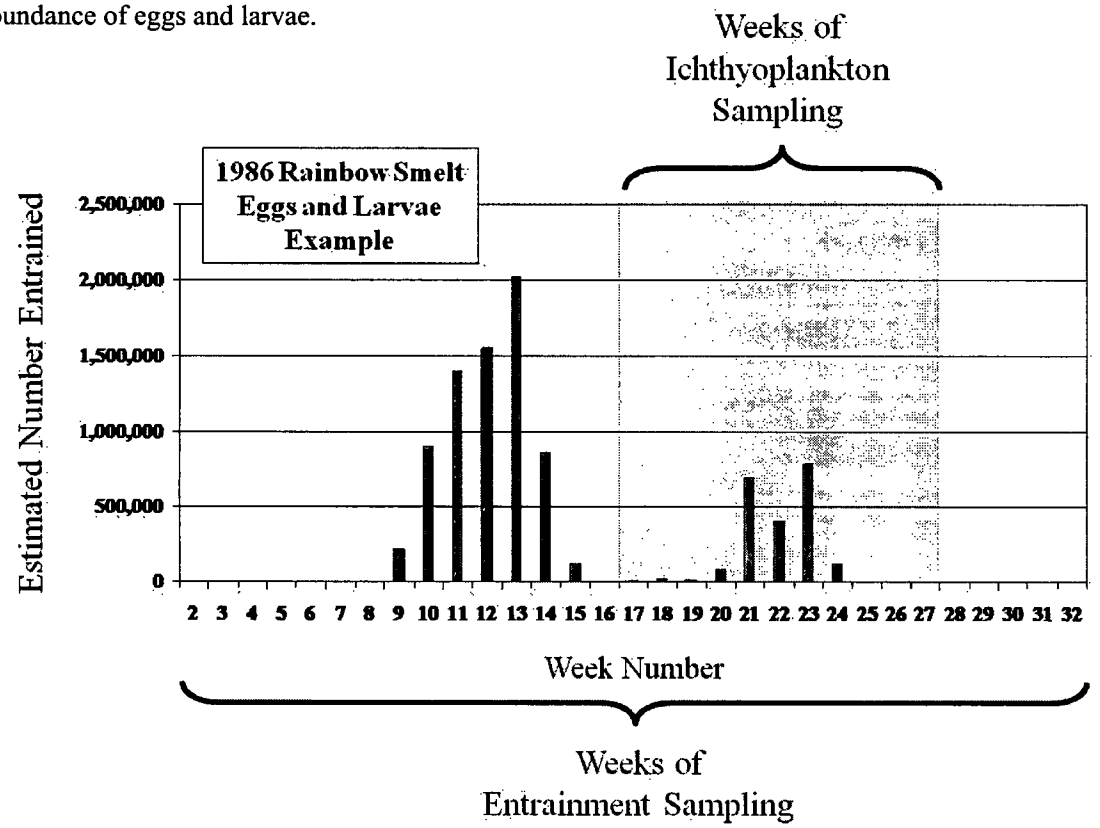

Figure 7. Graph depicting overlapping weeks of entrainment and ichthyoplankton sampling (grey shading) in 1986. Green bars are estimates of number of rainbow smelt eggs and larvae entrained. Conditional mortality rates estimates based on estimates of numbers entrained require concurrent data from entrainment sampling and in-river ichthyoplankton sampling.

In most years, entrainment sampling did not begin until mid-spring. However, in 1986 the entrainment sampling program began sampling in January. To account for entrainment that occurred early in the season in other years, the FSEIS method assumed that early season entrainment observed in 1986 was applicable to all other years.

As noted above, the FSIES method added entrainment losses over all weeks of entrainment sampling, and added standing crop over all weeks of in-river sampling. For rainbow smelt, this method caused EMR estimates to be severely biased high because in-river sampling was not conducted during weeks early in the year when eggs and larvae were present, but the entrainment sampling was conducted during that time period (Figure 7). Those biases can be reduced by calculating loss to abundance ratios using only data from weeks during which both entrainment and in-river sampling occurred.

Corrected EMR estimates computed using equation (1), riverwide population abundances and consistent, within-year data are listed in Table 6, below. The average of corrected EMR estimates for the six years is 0.068 (or 26.4% of the FSEIS EMR).

Table 6. Year-specific entrainment conditional mortality rate estimates for **rainbow smelt**. Corrected EMR estimates based on consistent weeks of entrainment and river-wide abundance sampling.

Year	Average Population Abundance (millions)	Number Entrained (millions)	Corrected EMR Estimate
1981	0.34	0.000	0.000
1983	0.85	0.001	0.002
1984	8.78	1.043	0.189
1985	1.25	0.037	0.044
1986	68.38	3.861	0.083
1987	12.89	0.768	0.087
Average			**0.068**

4. Spottail Shiner

The FSEIS EMR estimate of 0.352 for spottail shiner (USNRC 2010, Appendix I Table I-43 at page I-59) is based on entrainment loss data from 1984, and on in-river abundance data from 1981 and 1983 (Table 7, below).

Table 7. Shaded cells indicate years of data used in the FSEIS to estimate EMR for **spottail shiner**. The reported 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 is based on data from two year (shaded cells).

Year	Region 4 Abundance (millions)	Number Entrained (millions)	Number At Risk (millions)	EMR
1981	5.810	0.000	5.810	
1983	0.103	9.130	9.233	
1984	0.016	3.930	3.946	
1985	215.000	0.000	215.000	
1986	0.039	0.000	0.039	
1987	0.017	0.000	0.017	
Wt. Ave.(3)		**2.948**	**8.377**	**0.352**

(1) USNRC 2010. Table I-41, Appendix I
(2) USNRC 2010. Table I-42, Appendix I
(3) USNRC 2010. Table I-43, Appendix I

A large portion of the spottail shiner population in the Hudson River is found in the shorezone that is sampled by the BSS. As noted above, the FSEIS estimates of entrainment losses were too high by a factor of 1000, the FSEIS in-river abundance estimates based on the LRS and FJS were also too high by a factor of 1000, but FSEIS in-river abundance estimates based on the BSS apparently were not affected by that error. For all inputs to the spottail shiner EMR estimates to be consistent, the abundance estimates based on the BSS would have to be multiplied by 1000 as well (or the other inputs would have to be divided by 1000). Because a large portion of the spottail shiner population is sampled by the BSS, this discrepancy caused the EMR for spottail shiner to be severely biased high (Figure 8, below).

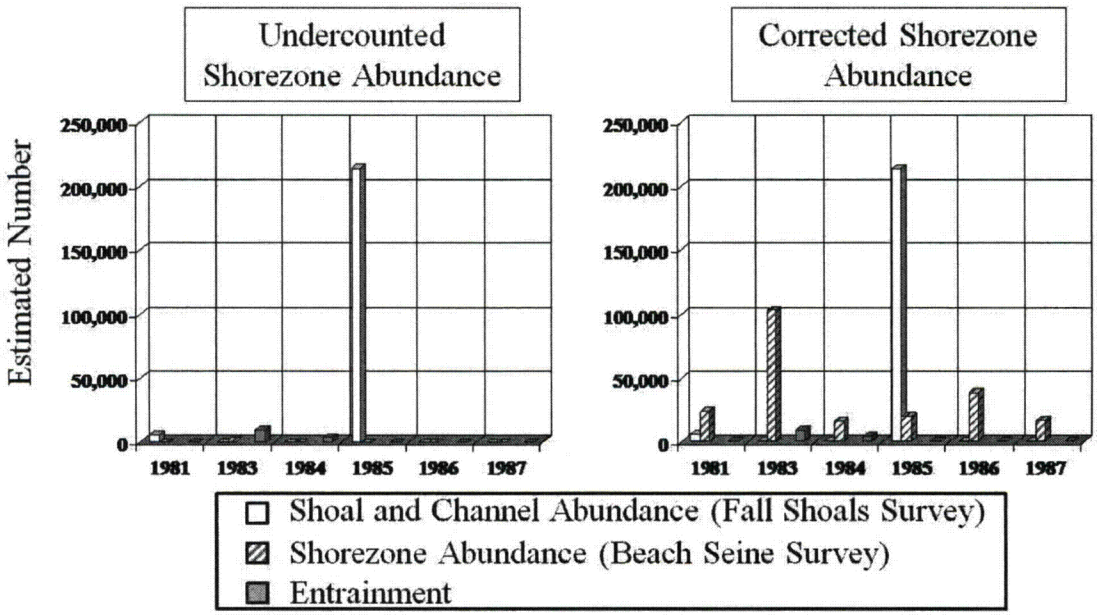

Figure 8. Shorezone abundance (from beach seine sampling) of spottail shiner was under-represented in EMR calculations in comparison to numbers entrained. Numbers entrained (USNRC 2010. Appendix I Table I-42) were overestimated by a factor of 1000, as were estimates of shoal and channel abundance (Appendix I Table I-41). Shorezone abundance was not overestimated. Except for 1985, most spottail shiner were found in the shorezone. Note that data from 1985 were not included in USNRC's EMR estimate for spottail shiner.

Corrected EMR estimates computed using equation (1), riverwide population abundances and consistent, within-year data are listed in Table 8, below. Also listed in Table 8 are year-specific entrainment CMR estimates for spottail shiner from the 1999 DEIS. The average of corrected EMR estimates for the six years is 0.009 (or 2.6% of the FSEIS EMR). The average of entrainment CMR estimate for spottail shiner from the DEIS is 0.022 (or 6.3% of the FSEIS EMR).

Table 8. Year-specific entrainment conditional mortality rate estimates for **spottail shiner**. Corrected EMR estimates based on consistent weeks of entrainment and river-wide abundance sampling.

Year	Average Population Abundance (millions)	Number Entrained (millions)	Corrected EMR Estimate	DEIS Entrainment CMR Estimate(1)
1981	0.58	0.000	0.000	0.034
1983	0.20	0.009	0.044	0.032
1984	0.32	0.004	0.012	0.016
1985	0.35	0.000	0.000	0.018
1986	0.19	0.000	0.000	0.016
1987	0.18	0.000	0.000	0.015
Average			**0.009**	**0.022**

(1) From CHG&E et al (1999).

5. White Perch

The FSEIS EMR estimate of 0.076 for white perch (Table I-43, page I-59, Appendix I) is based on entrainment loss data from 1981 and 1983, and on in-river abundance data from 1981 and 1986 (Table 9, below).

Table 9. Shaded cells indicate years of data used in the FSEIS to estimate EMR for **white perch**. The reported 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 is based on data from two year (shaded cells).

Year	Region 4 Abundance (millions)	Number Entrained (millions)	Number At Risk (millions)	EMR
1981	794,963	48,743	843,706	
1983	913,526	68,418	981,944	
1984	437,750	29,734	467,484	
1985	91,594	11,137	102,731	
1986	757,411	71,501	828,912	
1987	68,591	8,297	76,888	
Wt. Ave.(3)		**63,499**	**840,008**	**0.076**

(1) USNRC 2010. Table I-41, Appendix I
(2) USNRC 2010. Table I-42, Appendix I
(3) USNRC 2010. Table I-43, Appendix I

Corrected EMR estimates computed using equation (1), riverwide population abundances and consistent, within-year data are listed in Table 10, below. Also listed in Table 10 are year-specific entrainment CMR estimates for white perch from the 1999 DEIS. The average of corrected EMR estimates for the six years is 0.070 (or 92.1% of the FSEIS EMR). The average of entrainment CMR estimates for white perch from the DEIS is 0.063 (or 82.9% of the FSEIS EMR).

Table 10. Year-specific entrainment conditional mortality rate estimates for **white perch**. Corrected EMR estimates based on consistent weeks of entrainment and river-wide abundance sampling.

Year	Average Population Abundance (millions)	Number Entrained (millions)	Corrected EMR Estimate	DEIS Entrainment CMR Estimate(1)
1981	875.17	48.044	0.100	0.065
1983	921.87	68.606	0.154	0.172
1984	1,070.26	30.906	0.058	0.089
1985	1,108.61	11.325	0.018	0.006
1986	1,833.77	71.446	0.068	0.041
1987	764.36	8.300	0.019	0.007
Average			**0.070**	**0.063**

(1) From CHG&E et al (1999).

d. Comparison of EMRs to Natural Mortality Rates

Natural mortality rates for the first year of life for these five species of fish can provide a context for understanding the magnitude of the EMR estimates discussed above. Natural mortality rate estimates, expressed in terms of instantaneous rates[1], are 8.55 for hogchoker, 8.95 for rainbow smelt, 9.83 for white perch, and to 10.03 for spottail shiner and river herring (USEPA, 2006). The average corrected EMRs for the five species are very small in comparison. The average corrected EMRs, expressed as instantaneous rates, range from less than .001 for hogchoker to 0.070 for rainbow smelt.

In addition, the estimates of EMRs are less than naturally occurring year-to-year variability in first year mortality. For example, the estimated average difference in first year mortality (expressed in terms of instantaneous rates) from one year to the next is 1.08 for blueback herring, 1.01 for spottail shiner, and 0.94 for white perch[2]. The average corrected EMRs for blueback herring and spottail shiner are equivalent to roughly 1% of the average year-to-year variability in natural mortality rates for these species. The average corrected EMR for white perch is equivalent to 7.5% of the average year-to-year variability in natural mortality.

Given the high natural mortality rates and high degree of year-to-year variability in first year mortality rates for these species, it is hard to understand how the effects of the EMRs would be "clearly noticeable and [are] sufficient to destabilize important attributes" of these fish populations.

[1] Natural and fishing mortality rates are commonly expressed as instantaneous rates (Ricker, 1975). An instantaneous mortality rate is equal to minus one times the natural logarithm of conditional survival. For example, if the conditional natural survival rate is 10%, then the instantaneous natural mortality rate is 2.3 (i.e., 2.3=-ln(0.1)).

[2] Estimates are based on the year-specific indices of first year survival reported in Barnthouse et al (2008), and species-specific estimates of first year survival reported by USEPA (2006).

D. Conclusions

The information presented in the FSEIS does not support the conclusion that potential environmental impacts of entrainment and impingement associated with IPEC license renewal are LARGE for five fish species: blueback herring, hogchoker, rainbow smelt, spottail shiner and white perch.

- The two-LOE approach (i.e., trends and SOC) is not suitable for addressing and, as applied, did not address the question of whether entrainment and impingement are sufficient to cause destabilization of important attributes of the resource.

- No evidence is presented to demonstrate that trends in juvenile fish abundance were caused by IPEC entrainment and impingement. Rather, a connection between trends and entrainment and impingement is assumed based on results from the SOC analysis.

- The exponential model underlying the SOC analysis is not suitable for projecting fish abundance.

- Conditional mortality rates, a critical input to the SOC analysis that lead to conclusions of high SOC and hence LARGE impacts, for four of the five species were severely overestimated due to data analysis discrepancies.

The FSEIS did not demonstrate that entrainment and impingement at IPEC are sufficient to cause destabilization of fish populations in the Hudson River, and did not demonstrate that entrainment and impingement at IPEC was the cause of observed declines in fish populations. Therefore, the LARGE findings are not supported.

E. References

ASA 2001. 2000 Year Class Report for the Hudson River Estuary Monitoring Program. Prepared by ASA Analysis & Communication, New Hampton, New York. Prepared for Dynegy Roseton L.L.C. Newburgh, New York. Prepared on behalf of Dynegy Roseton L.L.C. Entergy Nuclear Indian Point 2 L.L.C. Entergy Nuclear Indian Point 3 L.L.C. Mirant Bowline L.L.C.

ASMFC. 2003. Fishery Management Report No. 41 of the Atlantic States Marine Fisheries Commission. Amendment 6 to the Interstate Fishery Management Plan for Atlantic Striped Bass. February 2003

Barnthouse, L.W., D.G. Heimbuch, W. VanWinkle, and J. Young. 2008. Entrainment and Impingement at IP2 And IP3: A Biological Impact Assessment. January 2008

Central Hudson Gas and Electric Corporation, Consolidated Edison Company of New York, New York Power Authority, and Southern Energy New York. 1999. Draft environmental impact statement: state pollutant discharge elimination system permits for Bowline Point, Indian Point 2 & 3, and Roseton steam electric generating stations. Central Hudson Gas and Electric Corporation, Consolidated Edison Company of New York, New York Power Authority, and Southern Energy New York Pearl River, New York.

Heimbuch, D.G. 2009. Potential Effects of Striped Bass Predation on Juvenile Fish in the Hudson River. Transactions of the American Fisheries Society 137:1591–1605, 2008

NYSDEC. 2003. Final Environmental Impact Statement by the New York State Department of Environmental Conservation as lead agency Concerning the Applications to Renew New York State Pollutant Discharge Elimination System (SPDES) permits For the Roseton 1 & 2, Bowline 1 & 2 and Indian Point 2 & 3 steam electric generating stations, Orange, Rockland and Westchester Counties. Prepared by NYS Department of Environmental Conservation NYS DEC, Division of Environmental Permits 625 Broadway, Albany, NY 12233-1750

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 382 p.

United States Environmental Protection Agency. 2006. Regional Benefits Analysis for the Final Section 316(b) Phase III Existing Facilities Rule. USEPA Office of Water. Washington, D.C. EPA-821-R-04-007.

United States Nuclear Regulatory Commission. 2010. Generic Environmental Impact Statement for License Renewal of Nuclear Plants Supplement 38 Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3. Final Report. December 2010. Office of Nuclear Reactor Regulation NUREG-1437, Supplement 38.