Entrainment, Impingement and Thermal Impacts at Indian Point Nuclear Power Station

Pisces Conservation Ltd,
November 2007

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November 2007

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1. Summary

- The entrainment and impingement mortality of fish caused by the Indian Point power plant is reviewed and quantified.
- Entrainment and impingement mortality each year is in the order of billions and hundreds of thousands of fish respectively.
- The data used recently by Entergy to assess this impact are old, having been gathered between 1980 and 1990. Since then, the estuary has changed considerably, with several species declining in abundance, and some species, most notably striped bass, increasing. There have been large changes in the river environment and important biological invasions.
- For the 6 fish species for which data are available—American shad, bay anchovy, river herring (comprising 2 species alewife and blueback herring), striped bass, and white perch—the station entrain 1.2 billon eggs and larvae a year.
- Entrainment data for Atlantic tomcod are not available, but are likely to be significant, with an estimated conditional mortality rate (CMR) indicating that 12% of the tomcod population are being killed by Indian Point each year.
- Entrainment occurs from February to September, with peaks in March for tomcod, and June for the other species.
- Modern data suggest that striped bass entrainment is likely to have increased by over 750% from the level at the time when the data was gathered.
- The Indian Point stations impinge over 1 million fish a year, and kill between two and five hundred thousand, dependent upon the assumptions used in calculation. They kill individuals from several species that are in decline.
- Peak impingement occurs in over winter, in December and January, and in mid summer.
- The impingement of only eight species has been considered in detail: American shad, Atlantic tomcod, bay anchovy, alewife, blueback herring, spottail shiner, striped bass, and white perch.
- The temperature regime in the Indian Point cooling water discharge and the receiving waters of the Hudson River are reviewed.
- In recent years (2000 to 2007), the discharge temperature regularly exceeded 90°F, and in summer frequently exceeded 100°F. A temperature exceeding 100°F will produce lethal conditions for aquatic life of all kinds, including algae, crustaceans and fish.
- Fish can perceive small differences in temperature, and show behavioural avoidance of even mildly stressful temperatures.
- The spatial and vertical extent of the Indian Point plume is sufficient to raise concerns about the passage of fish and impacts on the benthic life of the river.
- The background temperature of the river is increasing, and this will result in increased harm from thermal pollution if present levels of heat discharge continue into the future.
- Absolute temperatures of riverine heated effluents of 26°C (78°F) or more are potentially lethal to rainbow smelt and Atlantic tomcod.
- There are no data on the movement or migration of fish in the vicinity of the Indian Point plume. It is therefore not possible to quantify the effect of this discharge on fish movement or passage.

- The impact of the mortalities caused by impingement and entrainment and thermal discharges on the fish populations of the Hudson is large.
- Entergy’s assessment of entrainment and impingement and thermal discharge is inadequate.
- The impacts that Indian Point is having on the Hudson River fish species are not quantified fully.
- When considering all aspects of the impact of Indian Point on the aquatic ecology of the Hudson estuary, Entergy's reliance on old data results in an inadequate quantification of the impact that Indian Point currently has on the aquatic environment. Further, the use of such old analyses to project into the future would be a serious error.

2. Introduction

The use of direct cooling at power stations kills fish in several ways, most directly through impingement and entrainment. Water taken into the station for cooling is screened to remove large objects, including fish. Fish can sustain injury or death by entering intakes with the cooling water flow and then making physical contact with screens or filters; the death of fish in this way is termed impingement mortality. Water that passes through the screens, and then through the cooling system to be discharged back into the environment, holds small fish, fish eggs and larvae, and other microscopic organisms. These suffer injury or death through physical contact, rapid pressure or temperature change, and chemical poisoning from biocides and other chemicals introduced into the water. The death caused by passage through a power station is termed entrainment mortality.

A heated discharge released to surface waters also has damaging effects. Animals in the receiving water can be suddenly exposed to hot water and biocides in the mixing zone, resulting in death or injury. In addition, the heating of the local environment can influence the distribution and movement of fish and other organisms. Finally, there is the risk that the temperature of the receiving water is raised to a level that excludes some fish and other organisms from living in the area. This is becoming more likely as average summer water temperatures increase.

This document examines the estimates of the numbers of fish impinged and entrained at Indian Point power plant, on the Hudson River. A previous report, *The status of fish populations and the ecology of the Hudson* (Pisces Conservation 2007) gives supporting information.

Indian Point 2 has six two-speed circulating water pumps, designed to pump 140,000 gpm (US gallons per minute) at full speed and 84,000 gpm at reduced speed. Indian Point 3 has six variable-speed circulating water pumps, designed to pump between 64,000 and 140,000 gpm.

This gives the station the ability to intake 2.4 billion gallons of cooling water per day. This is the largest intake on the Hudson estuary and produces the largest plume of heated effluent.

3. Entrainment

Very large numbers of fish are entrained at Indian Point; calculations for five fish species estimate over 1 billion individuals of those species alone to be entrained each year (Table 1). The figures given in Table 1 are the total numbers of entrainable life stages, including eggs, yolk-sac larvae, post-yolk-sac larvae (PYSL), and some juveniles, for the species studied. These data come from utility-sponsored studies on entrainment. (DEIS Appendix VI-1-D-2). Data were collected from 1972 to 1987, with the exception of 1982. The data used in the Draft Environmental Impact Statement (DEIS), prepared by the prior owners of Indian Point, were collected from 1981-1987. The calculations in Table 1 are the average number of fish entrained per year from 1981-87. The original data are in DEIS appendix VI-1-D-2. The Draft Environmental Impact Statement (FEIS), prepared by the prepared by the New York State Department of Environmental Conservation (NYSDEC) included this calculation of annual number of fish entrained at Indian Point to assess the magnitude of the impact (FEIS, Table 1, page 2)

Number of Fish entrained	
American shad	13,380,000
Bay anchovy	326,666,667
River herring	466,666,667
Striped bass	158,000,000
White perch	243,333,333
Total of 5 species	**1,208,046,667**

Table 1: The annual number of fish entrained at Indian Point - based on in-plant sampling 1981-1987; no Atlantic tomcod were sampled, as sampling started too late for young Atlantic tomcod to be caught (From FEIS page 2).

The species for which entrainment mortality has been quantified form only a very small proportion of the total species present in the estuary. As was noted in the FEIS (page 53):

> *Finally, although impingement and entrainment mortality is measured, it is typically measured only for several of the 140 species of fishes found in the Hudson. Information about the impact on the full suite of aquatic organisms is limited.*

The impact on other species is un-quantified and may be significant.

3.1. Numbers of fish entrained

Considerable ecological changes have taken place over the last 20 years, so that entrainment numbers derived from the DEIS can no longer give a reliable guide to present entrainment. In this section, we attempt to estimate recent numbers entrained. Table 2 gives the total entrainment estimates given in the DEIS (DEIS Appendix VI-1-D-2, Table 2).

Species	Eggs	Yolk-sac	PYSL	Juveniles	Total	Years	Average
River herring	1,955,720	935,220,000	1,865,420,000	2,083,000	2,804,678,720	6	467,446,453
Bay anchovy	309,750,000	160,080,000	1,482,500,000	5,799,200	1,958,129,200	6	326,354,867
White perch	8,235,740	46,979,000	1,398,400,000	9,284,500	1,462,899,240	6	243,816,540
Striped bass	1,518,500	89,866,000	850,000,000	6,229,000	947,613,500	6	157,935,583
American shad	119,400	7,290,000	59,000,000	465,190	66,874,590	5	13,374,918
					Total		1,208,928,361

Table 2: The number and stage of some of the main species entrained at Indian Point between 1981 and 1987.

The numbers in Table 1 are slightly different from those in Table 2, since the data in the earlier table have been rounded to three significant figures during the calculation of the averages. For example, for striped bass the total would be 948,000,000 / 6 giving 158,000,000 rather than 947,613,500 / 6 which gives 157,935,583).

The data available do not include Atlantic tomcod, which breeds earlier in the year than the other species. The estimated Conditional Mortality Rate (CMR)[1] for this species is high, at over 12% (Indian Point Energy Center Applicant's Environmental Report Operating License Renewal Stage). This species is already in decline in the estuary (Pisces 2007).

3.2. Annual pattern of entrainment and the conditional mortality rate

There are two main periods of fish entrainment, spring/summer when most species breed and have larvae in the water, and February/March when the tomcod breed (Figure 1). When assessing the impact of any pumping regime on entrainment reduction, it is important to consider the annual pattern of entrainment. Conditional mortality rates (CMR) measure the proportion of the available population living in the Hudson Estuary that is killed by entrainment or impingement (Table 3). In the DEIS, CMR were used instead of simple estimates of the number of animals killed, because they allow insight into the level of impact on the population.

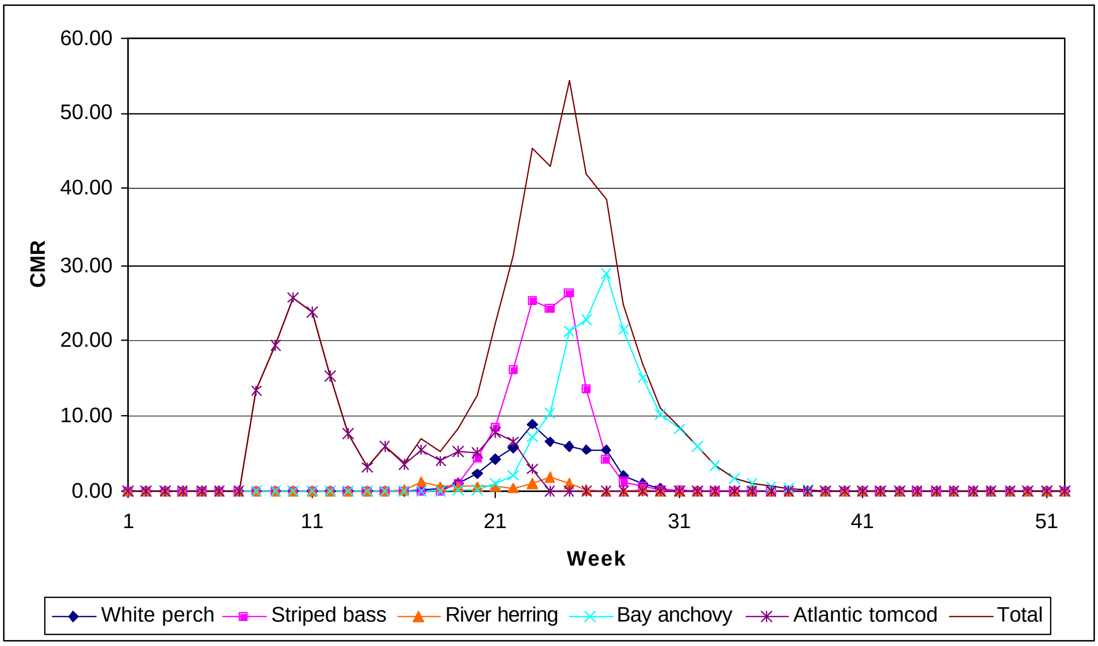

Figure 1: Plot showing the seasonal pattern in entrainment. From Table 3.

[1] CMR - is the probability of a fish dying due to the power plant. It is expressed as a percentage and measures how many fewer Hudson River fish exist at the end of their first year of life (actually at September 1) than would exist if not for the loss to entrainment.

			Entrainment CMR x 1000					
Starting date of week	**Week No.**	**SPDES Permit Flow (gpm)**	**White perch**	**Striped bass**	**River herring**	**Bay anchovy**	**Atlantic tomcod**	**Total**
5-Jan	1	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
12-Jan	2	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
19-Jan	3	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
26-Jan	4	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
2~Feb	5	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
9-Feb	6	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
16-Feb	7	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
23-Feb	8	1008	0.00	0.00	0.00	0.00	13.33	**13.33**
1-Mar	9	1008	0.00	0.00	0.00	0.00	19.22	**19.22**
8-Mar	10	1008	0.00	0.00	0.00	0.00	25.75	**25.75**
15-Mar	11	1008	0.00	0.00	0.00	0.00	23.80	**23.80**
22-Mar	12	1008	0.00	0.00	0.00	0.00	15.21	**15.21**
29-Mar	13	1008	0.00	0.00	0.00	0.00	7.65	**7.65**
5-Apr	14	1008	0.00	0.00	0.00	0.00	3.18	**3.18**
12-Apr	15	1008	0.00	0.00	0.00	0.00	5.91	**5.91**
19-Apr	16	1008	0.08	0.00	0.15	0.00	3.67	**3.90**
26-Apr	17	1008	0.22	0.00	1.19	0.00	5.56	**6.97**
3-May	18	1008	0.53	0.07	0.73	0.00	4.01	**5.34**
10-May	19	1024	0.96	1.09	0.64	0.26	5.39	**8.34**
17-May	20	1152	2.34	4.53	0.71	0.14	5.03	**12.75**
24-May	21	1344	4.21	8.50	0.58	1.07	7.84	**22.21**
31-May	22	1440	5.83	16.16	0.44	2.03	6.62	**31.08**
07-Jun	23	1616	8.90	25.32	0.99	7.22	2.97	**45.39**
14-Jun	24	1680	6.67	24.13	1.85	10.47	0.00	**43.13**
21-Jun	25	1680	5.85	26.26	1.03	21.13	0.00	**54.26**
28-Jun	26	1680	5.43	13.62	0.31	22.63	0.00	**41.97**
5-Jul	27	1680	5.42	4.30	0.10	28.75	0.00	**38.57**
12-Jul	28	1680	2.15	1.23	0.10	21.36	0.00	**24.83**
19-Jul	29	1680	1.12	0.61	0.20	15.00	0.00	**16.94**
26-Jul	30	1680	0.41	0.31	0.10	10.20	0.00	**11.02**
2-Aug	31	1680	0.10	0.20	0.00	8.26	0.00	**8.56**
9-Aug	32	1680	0.00	0.00	0.00	6.01	0.00	**6.01**
16-Aug	33	1680	0.00	0.00	0.00	3.36	0.00	**3.36**
23-Aug	34	1680	0.00	0.00	0.00	1.63	0.00	**1.63**
30-Aug	35	1680	0.00	0.00	0.00	1.02	0.00	**1.02**
6-Sep	36	1680	0.00	0.00	0.00	0.71	0.00	**0.71**
13-Sep	37	1680	0.00	0.00	0.00	0.51	0.00	**0.51**
20-Sep	38	1680	0.00	0.00	0.00	0.20	0.00	**0.20**
27-Sep	39	1584	0.00	0.00	0.00	0.10	0.00	**0.10**
4-Oct	40	1456	0.00	0.00	0.00	0.00	0.00	**0.00**
11 -Oct	41	1456	0.00	0.00	0.00	0.00	0.00	**0.00**
18-Oct	42	1456	0.00	0.00	0.00	0.00	0.00	**0.00**
25-Oct	43	1456	0.00	0.00	0.00	0.00	0.00	**0.00**
l-Nov	44	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
8-Nov	45	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
15-Nov	46	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
22-Nov	47	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
29-Nov	48	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
6-Dec	49	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
13-Dec	50	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
20-Dec	51	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
27-Dec	52	1008	0.00	0.00	0.00	0.00	0.00	**0.00**
Total			**50.22**	**126.32**	**9.12**	**162.08**	**155.15**	**502.89**

Table 3: Conditional mortality rates (CMR) of fish entrained at Indian Point, from DEIS

In the Indian Point Energy Center Applicant's Environmental Report Operating License Renewal Stage (page 4 - 12) it is noted that entrainment impacts are large:

> *The estimated average annual CMR due to entrainment for American shad is 0.64%, for Atlantic tomcod is 12.04%, for bay anchovy is 10.38%, for river herring is 1.20%, for striped bass is 7.82%, and for white perch is 4.94%.*

First it should be noted that in the FEIS (Fish populations 3 - page 62) the CMR figure for white perch is stated as 21%. In general, these numbers are notably high, especially when it is remembered that several of the species under consideration are showing long-term declines in abundance in the Hudson. The CMR numbers indicate that Indian Point is killing an appreciable proportion of the Atlantic tomcod, white perch and bay anchovy populations in the estuary. These deaths will be contributing to the decline of these species.

In the DEIS, it was argued that even mortality rates of this magnitude were unlikely to have any impact on the adult population. In an unpublished report by Barnthouse *et al* (2002), it is stated:

> *As long as key populations are relatively stable, the mix of species present remains relatively constant, and important functional relationships continue, the river can be said to be healthy and can continue to persist in spite of the deaths of individuals*

In this statement, the key populations are presumably common species, and as shown in Pisces (2007), many of these species are showing long term trends. With many species in decline, it is unclear how the observation of a general trend is to be shown to be unrelated to the power plants, if there are direct observational data demonstrating that the power plants are killing the species. For example, it is clear that tomcod are killed by cooling water systems. The Atlantic tomcod population is in decline. It would be almost certain that if these individuals were not killed, the population would be larger.

What is clear, from these data and analyses presented in the DEIS, is that entrainment and impingement, primarily the former, are eliminating a significant portion of the most abundant species in their egg and larval stages. It is probable that similar levels of impact will be felt by the many rarer species that spawn or spend part of their life stages in the lower Hudson River. (see FEIS p. 59).

3.3. Adjusting entrainment estimates with new data

A number of approaches were taken to estimate current entrainment at Indian Point. The 2005 Year Class Report for the Hudson River Estuary Monitoring Program (ASA 2007) estimates the abundance of various species in the Hudson for each year, from the mid 1970s until 2005. To examine the changes in entrainment that must have occurred since 1987, these data were used in conjunction with the estimates of entrainment from 1981-7 (DEIS Appendix VI-1-D-2, Table 2). No more recent entrainment data were available.

The 2005 Year Class Report calculates an index for each of the entrainable stages (egg, larvae, post yolk sac larvae and juvenile fish) for each year. This is an index calculated for the whole Hudson estuary. As the number of fish entrained at Indian Point must be related to the number of fish in the estuary, it is possible to make an estimate of how the number of selected entrained species has changed over time. Details of some of the trends are given in the Pisces Conservation report *The status of fish populations and the ecology of the Hudson* (Pisces 2007).

Of the 5 taxa of fish whose entrainment data are presented in the DEIS, only three could be analysed. River herring is a combination of two fish species, blueback herring and alewife, precluding calculation without further information. Bay anchovy are only recorded as juveniles in the river survey. Since most of the animals entrained at Indian Point are eggs or larvae, this index was unsuitable to estimate entrainment.

The three species for which estimates could be made were American shad, striped bass and white perch. To make the estimate of entrainment in each year, the average number of fish entrained for each life stage for 1981-87 (only including sampled years) was calculated. The average index for each life stage, for the appropriate years, was then calculated. The average number entrained, divided by the average index, gives the number of fish entrained per index unit.

The indices for each life stage and year were multiplied by this factor to estimate the entrainment. The results are given in Figure 2 and Figure 3.

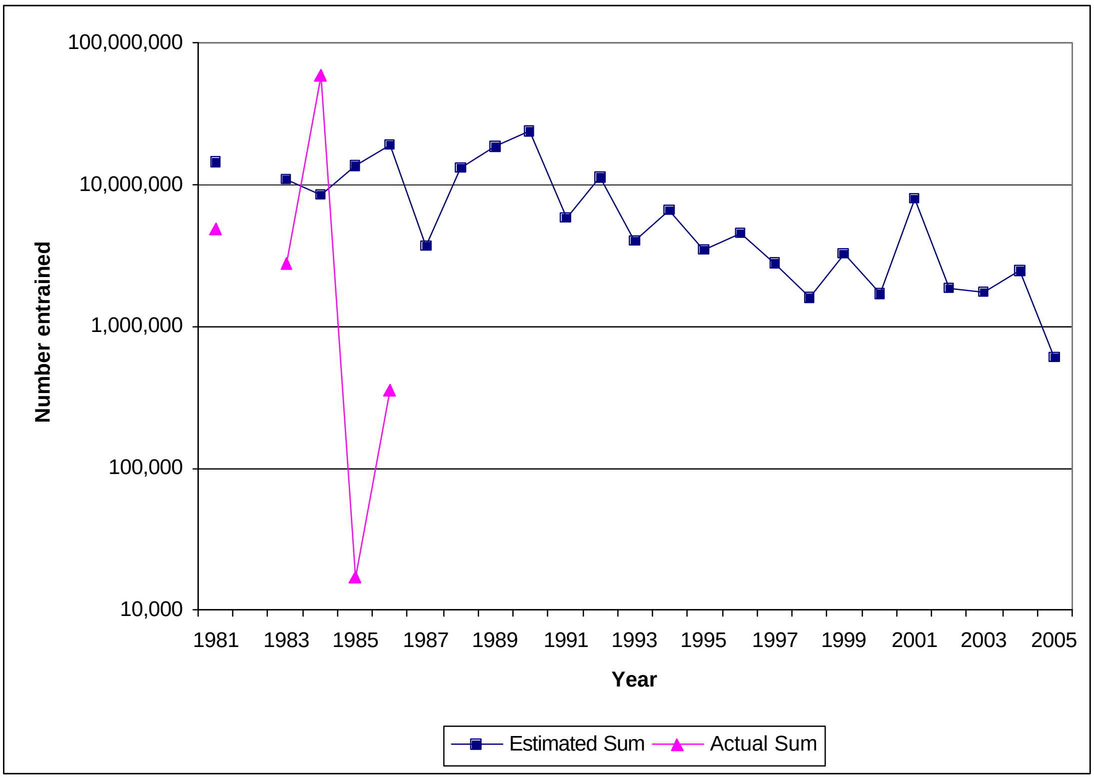

Figure 2: The actual and estimated number of all life stages for American shad at Indian Point. Log scale.

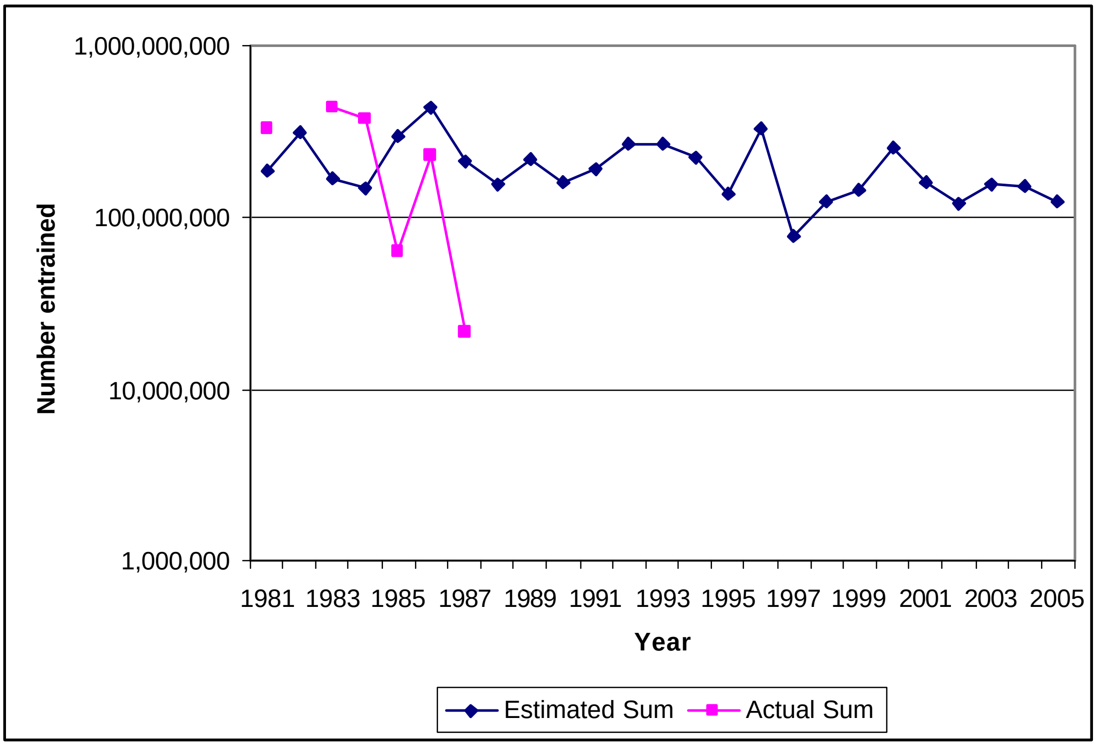

Figure 3: The actual and estimated number of all life stages for white perch at Indian Point. Log scale.

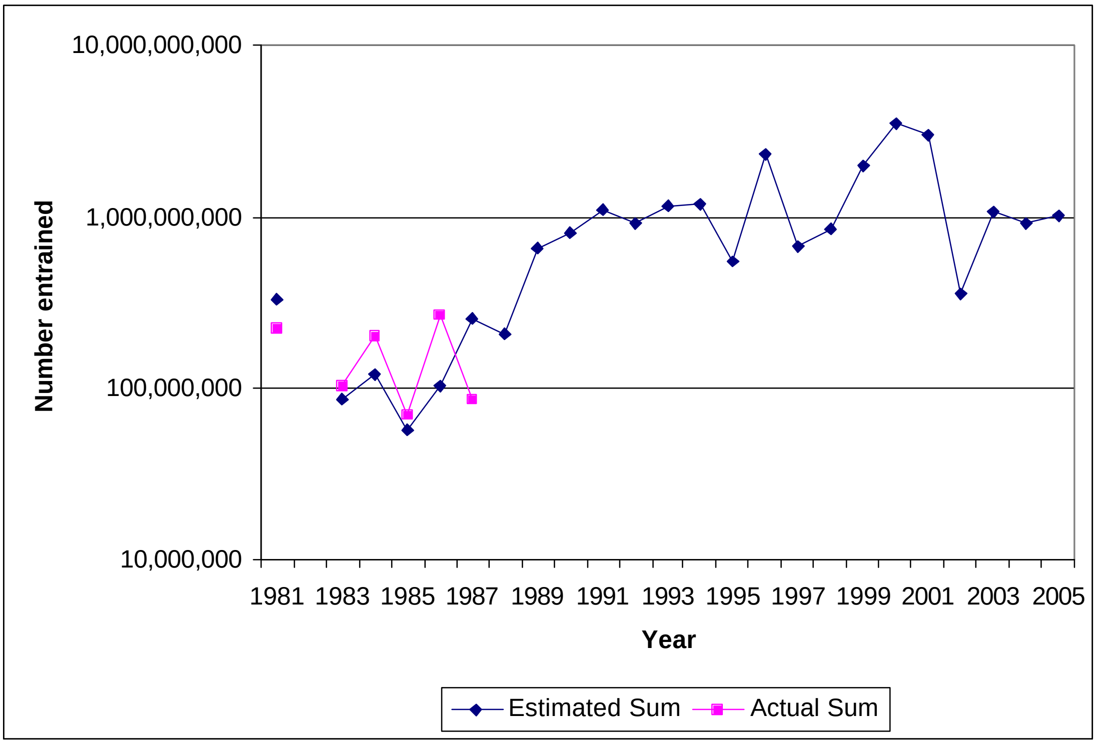

Figure 4: The actual and estimated number of all life stages for striped bass at Indian Point. Log scale.

The fit of the American shad (Figure 2) relationship is poor. American shad breed in the upper regions of the estuary and the numbers found at Indian Point may be related to river flows and vary greatly between years. White perch (Figure 3) also release eggs in the upper estuary, but spread steadily throughout the estuary as they grow. The relationship is better than that for American shad, but is still poor. The relationship for striped bass (Figure 4) is good, as the bass breed close to Indian Point. This is demonstrated in Figure 5, which shows the river regions where various striped bass life stages are found in the estuary.

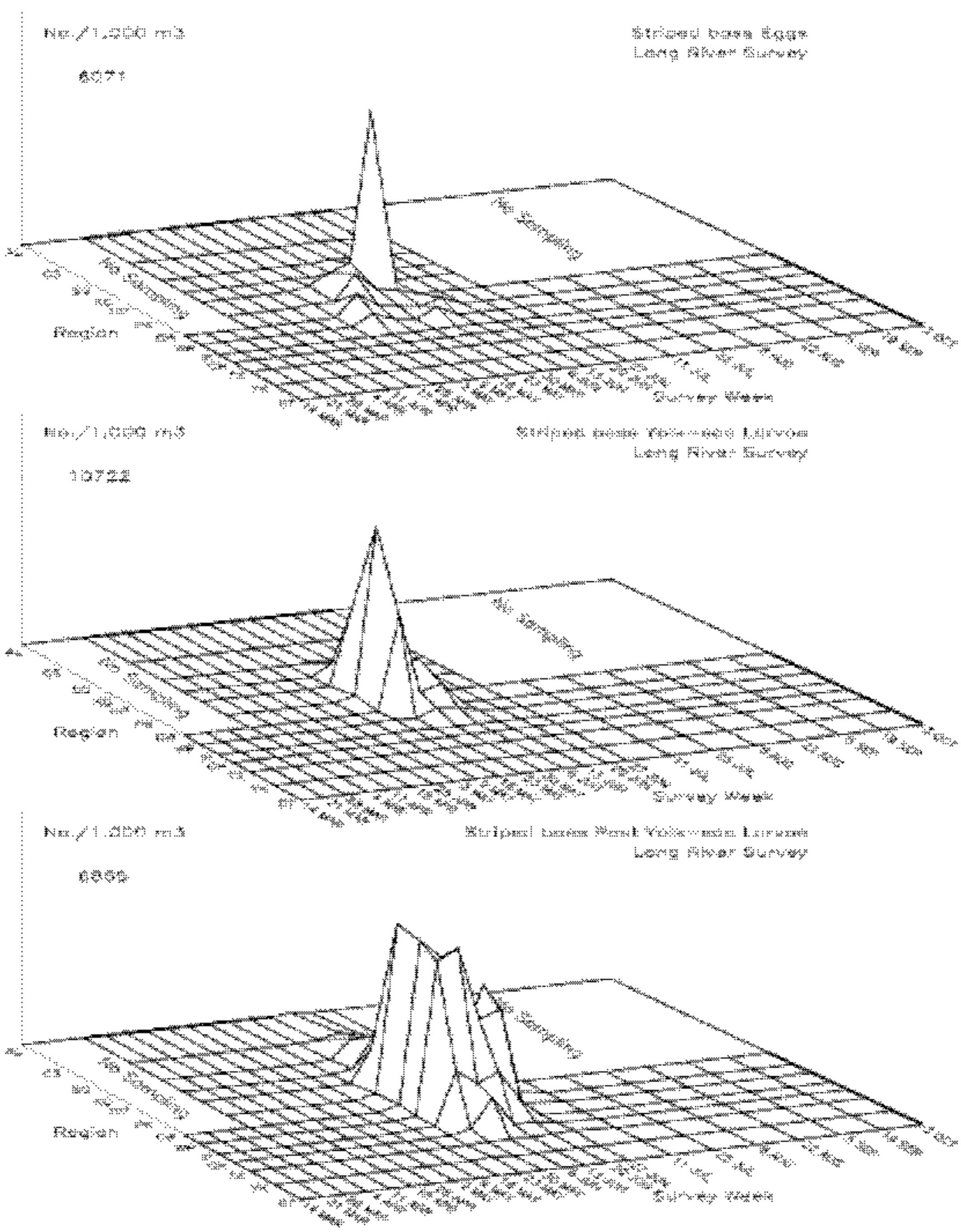

Figure 5: Spatio-temporal distribution of egg, yolk-sac and post yolk-sac larval striped bass in the Hudson River, based on the 2005 Long River Survey. From 2005 year class report figure 4-1.

The striped bass calculations demonstrate that present entrainment estimates based on the old estimates in the DEIS would be underestimated. The average number of striped bass entrained in 1981-7 was 46 million. Using the estimates presented in Figure 4, the average number entrained between 1987 and 2005 was 366 million, an increase of over 750%.

To analyse the relationships fully, data are needed on the density of the fish in the vicinity of the power plant. The year class reports do give the densities of each life stage in each part of the estuary for each week. We believe that these data are gathered for the year class reports; if so, a much more detailed and accurate calculation could be made of the number of fish entrained. We conclude that the entrainment impact has not been quantified to the best extent possible.

3.4. Entrainment - Conclusions

The data used recently by Entergy to assess this impact are old, having been gathered between 1980 and 1990. Since then, the ecology of the estuary has changed considerably, with several species declining in abundance, and some species, most notably striped bass, increasing. There have been large changes in the river environment, and important biological invasions.

For the five fish species for which data are available, the Indian Point stations entrain over 1.2 billon eggs and larvae a year. Entrainment data for Atlantic tomcod are not available, but are likely to be significant, with an estimated conditional mortality rate (CMR) indicating that 12% of the Atlantic tomcod population are being killed by Indian Point each year.

Efforts have not been made to assess current entrainment levels, using the year class reports and existing entrainment data. A rough approximation of the number of striped bass entrained indicates that the number may have increased by 750% over old estimates. Reliance on 20-year old data, in an estuary that has undergone many significant environmental and ecological changes, makes any prediction of the impact highly imprecise. The data were collected before many significant recent ecological changes in the Hudson had occurred, including the arrival of zebra mussels, the closure of several fisheries and the recovery in striped bass numbers.

In a system that is under stress from many sources, the entrainment of 1.2 billion fish attributable to Indian Point is significant. With CMR for Indian Point as high as 12% for Atlantic tomcod, 10% for bay anchovy, 1% for river herring, 8% striped bass and 5% for white perch, the mortalities caused by Indian Point are large.

Closed-cycle cooling, required under the draft SPDES permit for Indian Point, represents about a 95% reduction in water use relative to the existing once-through system. This alone would also reduce entrainment mortality by 95% and could, if needed, allow other entrainment reducing technologies to be used. We know of no alternative technology(s) that will result in equivalent protection for aquatic resources to the level which can be achieved by closed cycle cooling.

4. Impingement

4.1. Numbers impinged at Indian Point power station

Before 1990, fish impinged on the cooling water filter screens would invariably have been killed. The installation of Ristroph screens and fish return systems at Indian Point between 1990 and 1991 reduced this mortality for some species.

Surveys of the impingement at Indian Point were undertaken from 1981 to 1990, and the number of fish impinged was known with good accuracy for this period. Only data for the top 8 species were presented in the DEIS in detail. Because the sampling was undertaken regularly throughout the year, estimates of the total annual catch for the common species were made (Table 4).

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Average
American shad	94,529	1,131	8,670	782	2,630	7,746	3,186	479	9,755	32	12,894
Alewife	26,656	1,565	7,715	8,427	5,741	3,170	3,488	1,652	1,633	2,415	6,246
Tomcod	377,320	84,314	142,717	139,136	84,581	65,841	1,356,287	18,046	14,525	111,647	239,441
Bay anchovy	605,163	111,301	193,056	107,527	19,711	59,187	28,065	29,299	10,408	-	116,372
Spottail shiner	2,267	1,032	1,237	2,604	2,148	1,588	3,310	1,793	7,906	-	2,389
White perch	1,315,592	1,113,621	362,652	614,593	780,545	756,219	647,111	747,660	759,042	505,537	760,257
Blueback herring	248,616	1,091	83,450	15,872	28,050	19,146	77,992	26,141	59,477	21,248	58,108
Striped bass	47,719	20,841	28,011	13,838	77,953	8,833	31,302	234,229	326	-	46,305
Totals	**2,717,862**	**1,334,896**	**827,508**	**902,779**	**1,001,359**	**921,730**	**2,150,741**	**1,059,299**	**863,072**	**640,879**	**1,242,013**

Table 4: The number of fish impinged annually at Indian Point from 1981 to 1990 for 8 species. Data from DEIS V1-2-D.

Impingement numbers can still be calculated after the installation of fish return systems, by intercepting the impinged fish before they are returned to the estuary.

4.2. Estimates of the number killed by impingement

4.2.1. Survival rates – Indian Point estimates

Once Ristroph screens and a fish return system were added to the station in 1990-1, some of the impinged fish survived. A key aspect to consider when analysing fish survival data from Ristroph screens is the time after impingement and handling when survival was measured (see section 4.2.2). Some early studies quoted high survival after 10 to 15 minutes in a holding tank. This is clearly of little interest, as most injured fish will take considerably longer to die.

The minimum time at which survival rates are likely to give a fair indication of the eventual survival of the impinged fish will be after 8 hours; Fletcher (1990) gives estimates for the survival of common species at Indian Point in the Hudson Estuary after this time period (Table 5).

Fish species	Survival %
Bay anchovy	77
American shad	65
Blueback herring	74
Striped bass	91
White perch	86
Atlantic tomcod	83
Alewife	38

Table 5: Eight-hour survival rates for Indian Point (Fletcher, 1990).

4.2.2. Survival rates – effects of timing of measurement

The survivals presented in Table 5, and similar results, have been highly influential in guiding the EPA to the conclusion that Ristroph screens could achieve reductions in mortality of at least 70 to 80%. However, there are a number of factors that will likely reduce eventual survival below that observed after 8 hours. It has been found that stressed and damaged fish can take a number of days to die. Experiences in angling and fish farming demonstrate that quite minor damage may lead to bacterial and fungal infections, resulting in eventual death. For example, in an experiment where fish were simply caught from a tank using different types of netting, and returned to a lake, Barthel *et al* (2003) found that the fish often took 2 or 3 days to die.

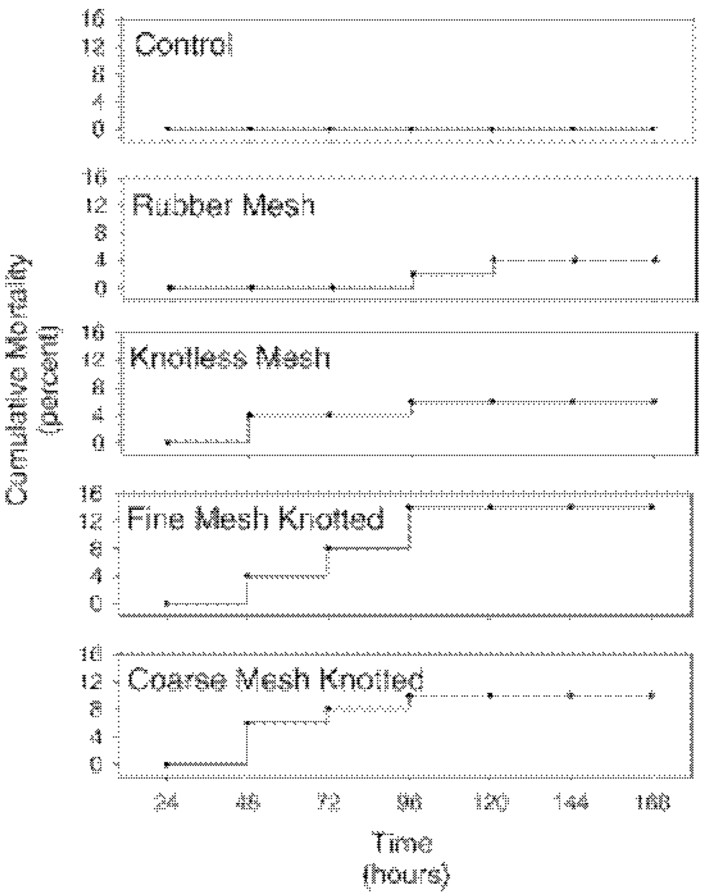

Figure 6: Cumulative mortality for bluegill exposed to four different netting treatments. (Barthel *et al,* 2003)

There is also the problem with all fish return systems that exhausted, disorientated and damaged individuals can be picked off by predators on their return to the main water body. It is normal to observe large predatory fish and piscivorous birds patrolling and feeding at water discharges.

The progressive decline in survival with time following impingement is demonstrated in data collected at Roseton Generating Station in the Hudson estuary (Table 6). Apart from spottail shiner, all other species showed a marked decline in the rate of survival between 2.5 and 96 hours after impingement. This clearly indicates the need to use survival estimates over periods of at least 96 hrs if the post-impingement survival is to be correctly estimated.

Species	Number	Survival Rate through time					
		0 hr	2.5 hr	8 hr	24 hr	48 hr	96 hr
American shad	575	0.689	0.252	0.123	0.080	0.071	0.068
Alewife	1839	0.662	0.229	0.151	0.096	0.073	0.060
Bay anchovy	1093	0.282	0.169	0.110	0.032	0.014	0.004
Blueback herring	8973	0.753	0.335	0.204	0.110	0.090	0.071
Striped bass	899	0.889	0.740	0.578	0.494	0.405	0.345
Spottail shiner	331	0.958	0.931	0.915	0.897	0.873	0.831
White perch	899	0.950	0.909	0.828	0.727	0.648	0.583

Table 6: Data from 1994 impingement mortality studies at Roseton (dualflow screens) (NAI 1995).

When the Roseton survival rates are plotted against time, it can be seen how many individuals are likely to die after 8 hours of survival (Figure 7). A dotted red line has been added to the graph to show the time at which the survival of impinged fish at Indian Point is used in the DEIS. (Note, these are not the survival figures used for Indian Point in the DEIS – but are presented to show the effect of the passage of time on the survival rate).

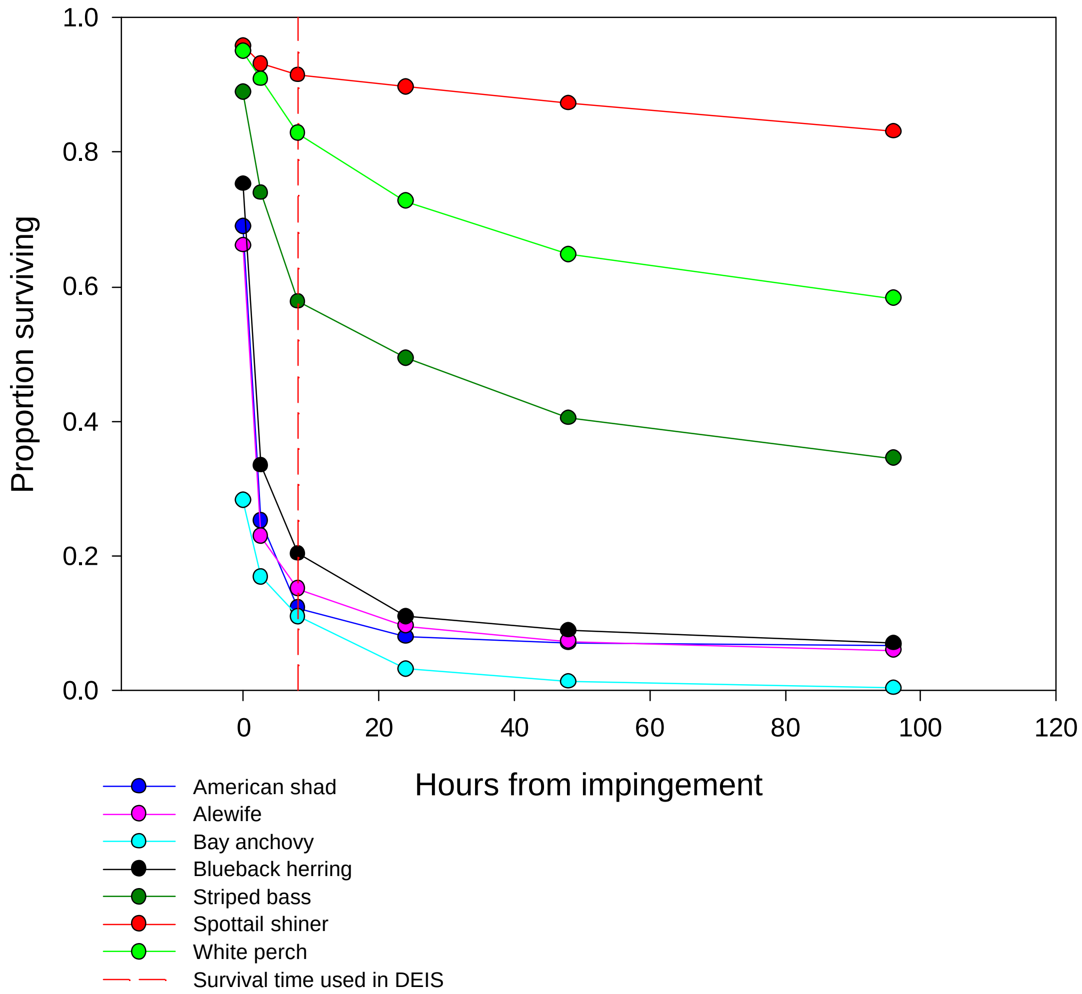

Figure 7: The proportion of fish surviving after 0, 2.5, 8, 24, 48 and 92 hours after impingement at Roseton. (NAI 1995)

4.2.3. Environmental factors affecting survival rates

Temperature and salinity can also change survival rates after impingement. Injured fish are more likely to die at low temperatures and salinities (Muessig *et al.* 1988; Figure 8). Salinity is probably important because damage to the skin results in a loss of osmotic control. While these studies were carried out on conventional, rather than Ristroph, screens, this will not detract from the insight gained into the effects of salinity and temperature upon injured individuals.

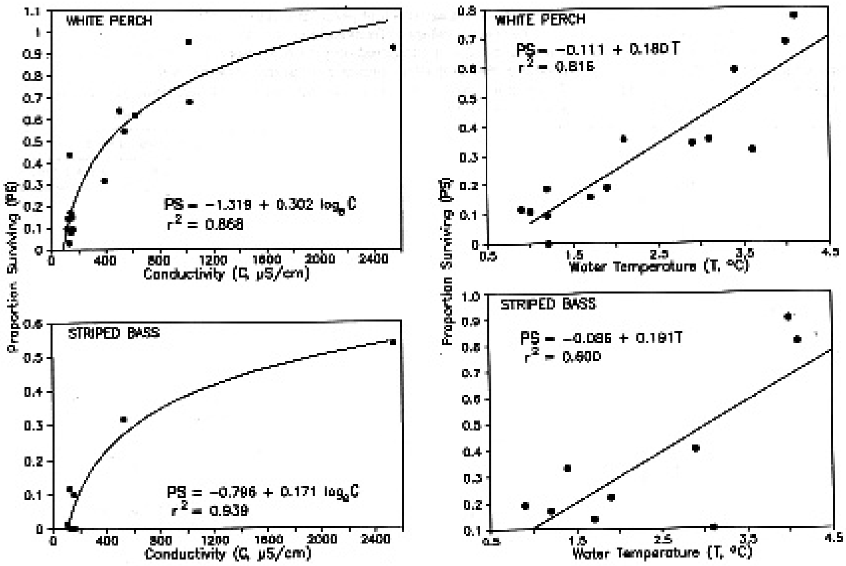

FIGURE 66.—Extended survival of impinged white perch and striped bass related to specific conductance, for temperatures above 4.5°C.

FIGURE 67.—Extended survival of impinged white perch and striped bass related to water temperature, for water temperatures less than 4.5°C.

Figure 8: The survival of white perch in relation to water temperature and salinity following impingement. Reproduced from Muessig et al. (1988)

The results of Muessig *et al*'s studies in Figure 8 above indicate that short-term survival rates at intermediate water temperatures and salinities are unlikely to fully reflect the eventual mortality rate for species that are easily injured. For example, for both striped bass and white perch, the survival is much lower at low water temperatures than at high

4.2.4. Survival rates – the PSEG estimates

As only 8-hour survival figures for the Ristroph screens are given in the DEIS, data from other sources were examined. The most recent review of likely survival rates appeared in PSEG Power New York Inc's *Bethlehem Energy Center SPDES Modification, Alternative Cooling Systems Study for Ristroph screens,* (PSEG (from LMS 1998a)); the post-impingement survival rates presented there are given in Table 7 below. This gives the best available survival estimates for American east coast estuarine and marine fish.

Family	Species	Percent Survival	
		Conventional	Ristroph type
Acipenseridae	Atlantic sturgeon	60	80
	Shortnose sturgeon	60	80
Anguillidae	American eel	70	95
Bothidae	Summer flounder	70	95
Catostomidae	White sucker	50	70
Centrarchidae	Black crappie	30	40
	Bluegill	80	80
	Largemouth bass	75	90
	Longear sunfish	70	80
	Pumpkinseed	75	80
	Redbreast sunfish	70	80
	Rock bass	70	80
	Smallmouth bass	75	90
	White crappie	30	40
Clupeidae	Alewife	0	10
	American shad	0	10
	Blueback herring	0	10
	Gizzard shad	5	10
	AW/BBH	0	10
Cyprinidae	Bluntnose minnow	50	90
	Carp	50	80
	Common shiner	50	90
	Creek chub	50	90
	Emerald shiner	50	90
	Fallfish	50	90
	Golden shiner	45	90
	Goldfish	50	80
	Rosyface shiner	50	90
	Silvery minnow	50	90
	Spotfin shiner	50	90
	Spottail shiner	50	90
	Unidentified shiner	50	90
Cyprinodontidae	Banded killifish	85	90
	Mummichog	85	90
Engraulidae	Bay anchovy	0	80
Esocidae	Chain pickerel	70	90
	Northern pike	70	90
	Redfin pickerel	70	90
Gadidae	Atlantic tomcod	10	70
Gasterosteidae	Fourspine stickleback	70	90
	Threespine stickleback	70	90
Ictaluridae	Brown bullhead	65	90
	Channel catfish	70	90
	Tadpole madtom	70	90
	White catfish	75	90
	Yellow bullhead	70	90
Osmeridae	Rainbow smelt	0	85
Percichthyidae	Striped bass	25	70
	White bass	25	70
	White perch	25	70
Percicidae	Logperch	65	80
	Tessellated darter	90	100
	Walleye	65	80
	Yellow perch	65	80
Percopsidae	Trout-perch	15	20
Petromyzontidae	Lamprey spp.	70	95
Salmonidae	Brown trout	60	80
Sciaenidae	Freshwater drum	20	25
Soleidae	Hogchoker	90	95
Umbridae	Central mudminnow	60	80

Table 7: The post-impingement survival of fish on conventional and Ristroph screens Used at Bethlehem Energy Centre (BEC). From PSEG.

4.2.5. Using survival rates to estimate Indian Point impingement mortality

To quantify the impact of impingement at Indian Point, the estimates for impingement in the 1980s were used. By applying mortality rates (1-survival) for each species, the number of individuals of the common fish species killed were computed (see Table 8). Both the mortality rates used in the DEIS and those used in the PSEG Bethlehem power plant were used for the calculations.

		DEIS Mortality Rates		PSEG Mortality Rates	
	Impinged	**Mortality Rate**	**Killed**	**Mortality Rate**	**Killed**
American shad	12,894	0.35	4,513	0.90	11,605
Alewife	6,246	0.62	3,873	0.90	5,622
Tomcod	239,441	0.17	40,705	0.30	71,832
Bay anchovy	116,372	0.23	26,765	0.90	104,735
Spottail shiner	2,389	0.16	370	0.10	239
White perch	760,257	0.14	106,436	0.30	228,077
Blueback herring	58,108	0.26	15,108	0.90	52,297
Striped bass	46,305	0.09	4,167	0.30	13,892
Total	**1,242,013**		**201,938**		**488,298**

Table 8: The mean number impinged and killed using the estimates of mortality of Ristroph screen for Indian Point. Mortality rates from Fletcher (1990) (see Table 5) and PSEC (LMS) (see Table 7). Impingement data from DEIS V1-2-D and VI-2-B.

While the number of fish impinged and killed is large, irrespective of the survival rate applied, the estimate using 8 hr survival rates is less than half that using the rates from the PSEG report. The biggest difference in mortality rates is for the bay anchovy, which is estimated at only 23% in the DEIS and 90% in the PSEG report.

4.3. Seasonality

The impingement of fish at Indian Point is seasonal, with two peaks per year, one in winter (December and January) and second in summer (June and July). This is true for both the total number impinged and for the estimate of the number killed when survival is taken into account (Figure 9 and Figure 10).

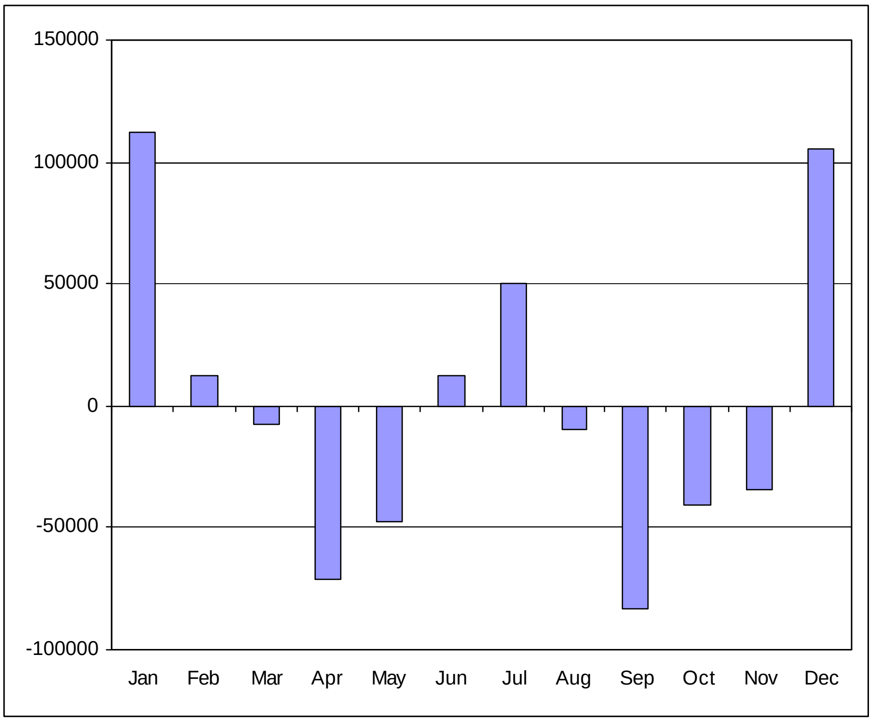

Figure 9: The difference from mean number of fish killed by impingement each month at Indian Point. Data for 8 species (see text) - 8 hr survival DEIS VI-2-D and VI-2-B.

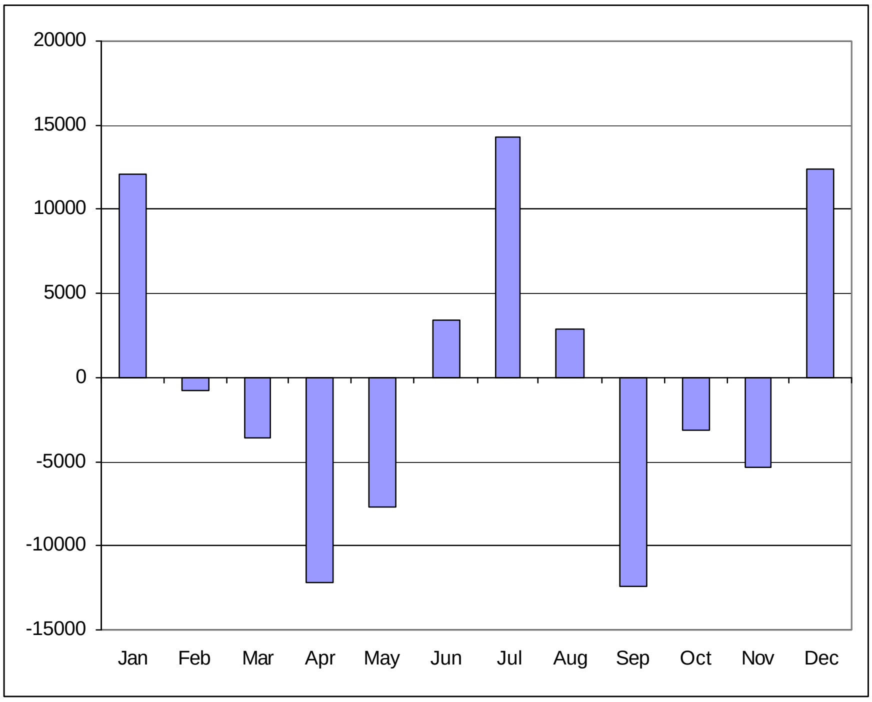

Figure 10: The difference from mean number of fish killed by impingement each month at Indian Point. Data for 8 species (see text) – DEIS VI-2-D and BEC (PSEG) hr survival (Table 7)

4.4. Impingement - Conclusions

The number of fish impinged at Indian Point, as estimated in the DEIS, is large, at over 1.2 million fish. Not all these fish die, but even so, the average number that do die exceeds 200,000, using the most optimistic survival figures, and 400,000 using more conservative survival values. The DEIS' impingement mortality estimate is unlikely to be a reliable estimate of current or future impingement, as it is based on the number of fish being impinged between 1981 and 1990. It is over 17 years since any impingement monitoring data have been published, and the fish community of the Hudson has greatly changed over this time. For further information see *The status of fish populations and the ecology of the Hudson* (Pisces 2007). The data presented by the power plant concentrate on a few abundant species. The impact of impingement on less abundant species is unknown. There is therefore a need to obtain new estimates of the number of fish impinged, and their survival rates.

Closed-cycle cooling, required under the draft SPDES permit for Indian Point, represents about a 95% reduction in water use relative to the existing once-through system. With closed-cycle cooling, the smaller volumes of water pumped and the much lower velocities involved would almost eliminate impingement on the station cooling water intake screens. We know of no alternative technology(s) that will result in equivalent protection for aquatic resources to the level which can be achieved by closed cycle cooling.

5. Thermal Issues

5.1. Introduction

This section describes the thermal impact of the Indian Point generating station cooling water discharge, and briefly reviews the impact of heated water on aquatic life. The impact of a thermal discharge is related to the background temperature of the water body, and the potential effects of thermal pollution become more serious as the background temperature increases. We therefore also briefly review the background temperature of the Hudson River and the recent increase in water temperatures.

The principal reason for establishing and enforcing thermal water quality criteria is to limit the impact of water temperature on aquatic organisms. The limits on surface width and cross-sectional area in which elevated water temperatures are permissible are designed to ensure zones of passage and regions of habitability for aquatic organisms using the estuary. Similarly, the establishment of the 90°F maximum surface water temperature is in recognition of the thermal tolerance limits of various resident and migratory species.

The relevant criteria governing thermal discharges are summarised below:

704.1 Water quality standards for thermal discharges.

(a) All thermal discharges to the waters of the State shall assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water.

704.2 Criteria governing thermal discharges.

(a) *General criteria*. The following criteria shall apply to all waters of the State receiving thermal discharges, except as provided in section 704.6 of this Part:

(1) The natural seasonal cycle shall be retained.

(2) Annual spring and fall temperature changes shall be gradual.

(3) Large day-to-day temperature fluctuations due to heat of artificial origin shall be avoided.

(4) Development or growth of nuisance organisms shall not occur in contravention of water quality standards.

(6) For the protection of the aquatic biota from severe temperature changes, routine shut down of an entire thermal discharge at any site shall not be scheduled during the period from December through March.

(b) There are also criteria for specific water bodies:

(5) Estuaries or portions of estuaries.

(i) The water temperature at the surface of an estuary shall not be raised to more than 90 degrees Fahrenheit at any point.

(ii) At least 50 percent of the cross sectional area and/or volume of the flow of the estuary including a minimum of one-third of the surface as measured from water edge to water edge at any stage of tide, shall not be raised to more than four Fahrenheit degrees over the temperature that existed before the addition of heat of artificial origin or a maximum of 83 degrees Fahrenheit whichever is less.

(iii) From July through September, if the water temperature at the surface of an estuary before the addition of heat of artificial origin is more than 83 degrees Fahrenheit an increase in temperature not to exceed 1.5 Fahrenheit degrees at any point of the estuarine passageway as delineated above, may be permitted.

(iv) At least 50 percent of the cross sectional area and/or volume of the flow of the estuary including a minimum of one-third of the surface as measured from water edge to water edge at any stage of tide, shall not be lowered more than four Fahrenheit degrees from the temperature that existed immediately prior to such lowering.

704.3 Mixing zone criteria.

The following criteria shall apply to all waters of the State receiving thermal discharges, except as provided in section 704.6 of this Part.

(a) The department shall specify definable, numerical limits for all mixing zones (*e.g.*, linear distances from the point of discharge, surface area involvement, or volume of receiving water entrained in the thermal plume).

(b) Conditions in the mixing zone shall not be lethal in contravention of water quality standards to aquatic biota which may enter the zone.

(c) The location of mixing zones for thermal discharges shall not interfere with spawning areas, nursery areas and fish migration routes.

Under Section 316(a) of the Clean Water Act, and Part 704 of the NYSDEC water quality regulations, regulators are permitted to allow thermal discharges in excess of the established criteria if it can be demonstrated that such a discharge will assure "*the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water receiving the thermal discharge.*"

As noted in the FEIS, it seems clear that Indian Point's thermal discharge does not meet applicable thermal criteria. Furthermore, as the FEIS points out from the DEIS there is no mixing zone definition for Indian Point generating station discharges.

> *Indian Point:* As of the 1987 - 1992 SPDES permit term, thermal discharges from Indian Point did not meet applicable thermal criteria. … These provisions alone [in the SPDES permit based on the Hudson River Settlement Agreement and Consent Orders], however, are not sufficient for Indian Point to meet thermal criteria. Thermal modelling indicates that the thermal discharge from Indian Point causes water temperatures to rise more than allowed, which is four degrees (F.) over the temperature that existed before the addition of heat, or a maximum of 83°F, whichever is less, in the estuary cross sections specified in 6 NYCRR §704.2(b)(5).2 A mixing zone was not specified in the previous SPDES permit for the Indian Point facility.

(FEIS page 19).

5.2. The thermal footprint of Indian Point

5.2.1. The near field

The term "Near field" is used here to describe the area in the vicinity of the outfall where there is a discrete thermal plume.

Infrared images highlight the surface extent of the thermal plume released from Indian Point (Figure 11). The image below, taken from the FEIS, shows the high proportion of the width of the river that is impacted by the Unit 3 discharge of Indian Point. The following quotation describes the concern:

> "*The surface extent of thermal discharges from the HRSA plants is also a concern. Figure 8 is an aerial thermal image of the plume from Indian Point, Unit 3 only, on the east side of the Hudson plus the smaller plume from Lovett on the west bank. In this image, the two plumes came very close to meeting on the surface, even with Indian Point running at less than its full capacity.*"

(FEIS, Chapter 5 p 71)

In summary, the surface extent of the thermal plume produced by Indian Point covers a high proportion of the width of the river.

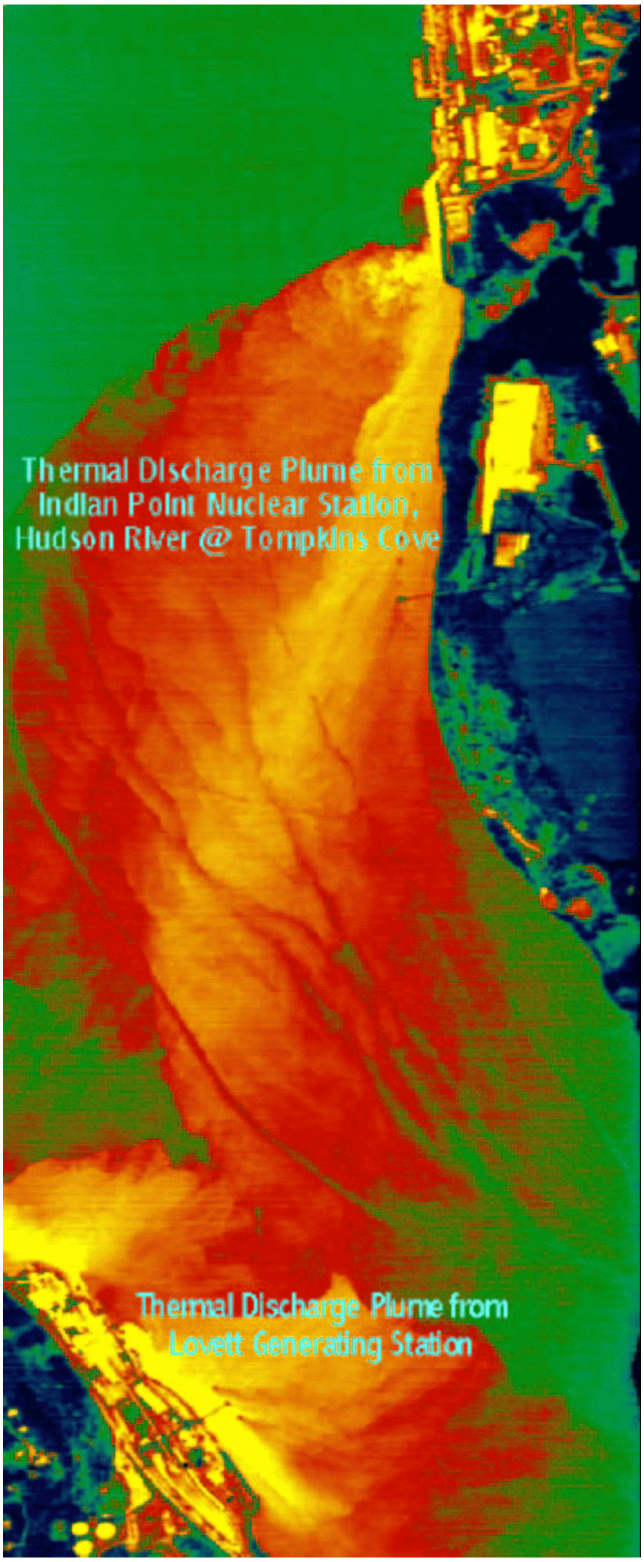

Figure 11: The extent of the thermal plume from the cooling water discharge of Indian Point Unit 3, and the Lovett generating station.

The FEIS also expresses concern about the vertical distribution of the thermal plume. In general, heated effluents are buoyant, and thus the impacts are mostly restricted to the surface waters and any area of bank which the plume contacts. However, if the plume is sufficiently large then heated water will penetrate to the bed of the river and impact bottom-living and deep-water species. Such deeper water penetration of the thermal plume is always a matter for concern, as it may lead to damage to the benthic food chain and also not allow migrating fish to pass under the heated water plume. It is clear that almost the entire vertical water column in the vicinity of Indian Point holds water heated above background temperatures (Figure 12). The FEIS states:

> "*A study by HydroQual, Inc., examined passive particle movement and also investigated thermal and salinity profiles in several river reaches, including the portion of the Hudson River where the HRSA plants are located. Figures 6 and 7 of this FEIS (following pages), excerpted from that study, show two vertical temperature profiles of the Hudson River from NYC to just above the northernmost of the HRSA plants, one during a spring and the other during a neap tide. Based on these representations, it appears that there may be times and conditions where effluent-warmed waters occupy nearly the entire vertical water column.*"

(FEIS, Chapter 5 p 71)

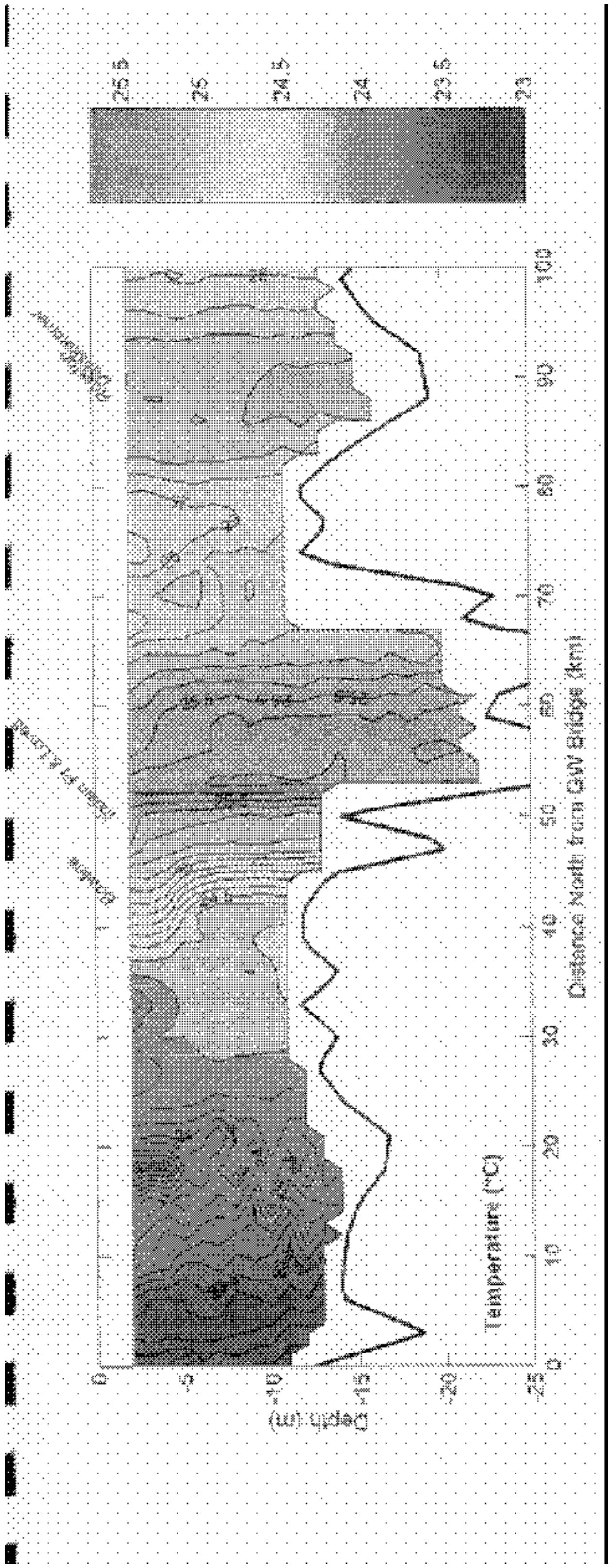

Figure 12: Temperature profile of the Hudson River, NYC to Newburgh, during a neap tide. From the FEIS and originally HydroQual, 1999.

In any event, the FEIS states on page 71:

> *Thermal discharges were inadequately addressed in the DEIS. The DEIS asserts, with no supporting evidence, that "... [t]he surface water orientation of the plume allows a zone of passage in the lower portions of the water column, the preferred habitat of the indigenous species." Other data and analyses cast doubt on this assertion.*

The FEIS goes on to say, on page 72:

> *Given the extent of warming shown in the HydroQual graphs, combined with the recent dramatic declines in tomcod and rainbow smelt as discussed previously, the Department believes it prudent to seek additional thermal discharge data for each facility, including a mixing zone analysis, and anticipates requiring triaxial thermal studies as conditions to each of the SPDES renewals. Depending on the results of those analyses, additional controls may be required to minimize thermal discharges.*

Having briefly introduced evidence on the spatial extent of the thermal plume, we now move on to consider the temperature of the discharge. The average maximum temperatures for each calendar month for the years 2000 to 2007 are given in Table 9. Note that for the summer months the maximum is regularly in excess of 90 degrees Fahrenheit, while the regulations clearly state "*The water temperature at the surface of an estuary shall not be raised to more than 90 degrees Fahrenheit at any point*". Further, there are occasions when the temperature exceeds 100°F; this is a temperature at which many aquatic organisms living in the estuary will suffer acute harm or death.

Figure 13 shows a plot of the maximum daily discharge temperatures at Indian Point, with the 90° and 100°F reference temperatures shown in red. Note that 90°F has been exceeded for extended periods every summer since 2001. Furthermore, 100°F has been exceed in 3 of the 7 summers for which data are plotted.

Month	2000	2001	2002	2003	2004	2005	2006	2007
1	66.38	57.35	70.53	68.45	70.78	70.74	74.78	70.25
2	63.63	67.61	69.76	65.41	69.57	71.88	71.39	67.76
3	64.08	70.57	69.91	65.20	70.46	69.17	69.59	63.29
4	70.05	71.52	74.75	66.00	71.89	72.86	75.54	69.90
5	77.01	78.07	79.85	79.20	82.64	81.92	79.82	83.80
6	79.40	88.82	86.41	84.40	91.81	92.08	89.17	93.30
7	88.66	97.27	98.29	96.68	97.21	87.89	96.95	
8	89.19	100.01	101.29	96.45	97.21	103.58	101.20	
9	86.83	96.11	94.91	94.38	90.27	99.66	94.24	
10	80.62	83.70	85.24	82.56	81.88	83.89	85.34	
11	75.87	77.70	68.06	78.00	76.52	77.68	81.20	
12	64.05	76.80	73.23	74.30	73.95	75.50	77.25	

Table 9: The average maximum discharge temperature (°F) of the Indian Point cooling water discharges for the years 2000 to 2007. Missing numbers are months for which no data are available. (Indian Point Daily Temperature Reports 2000-07)

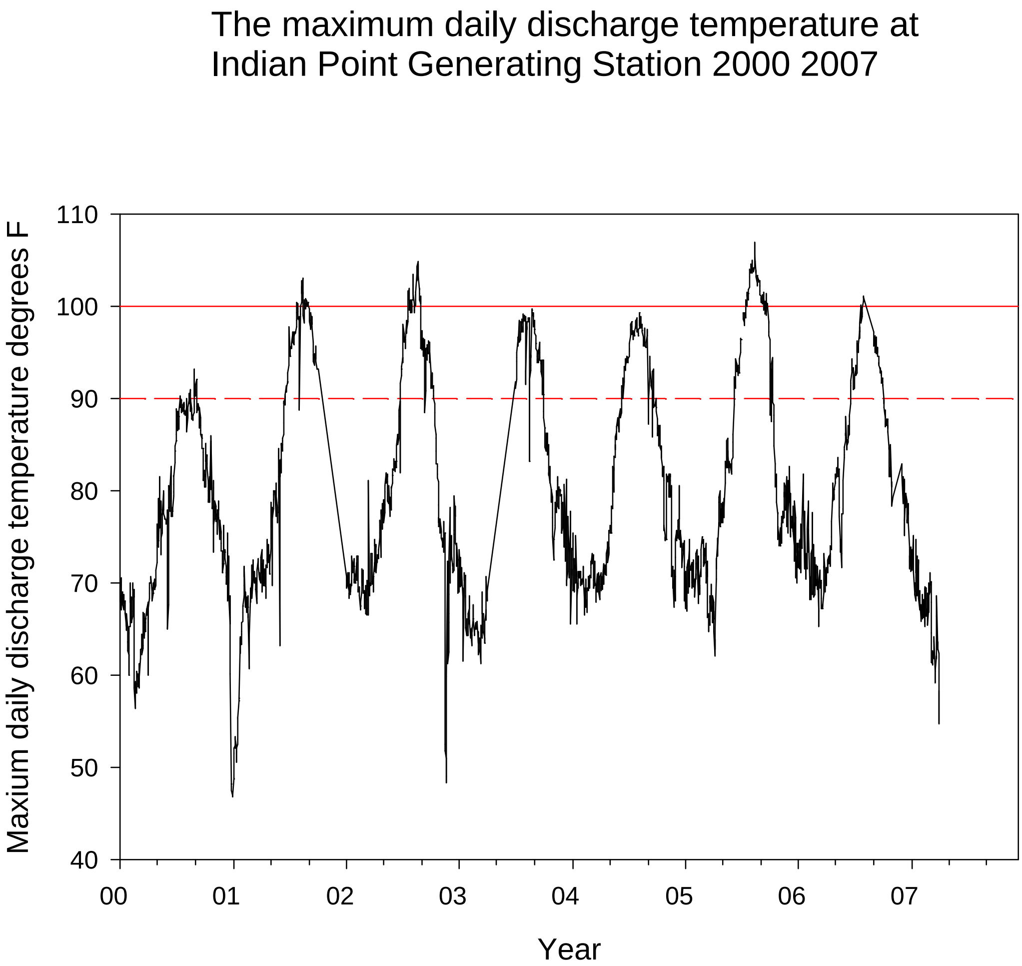

Figure 13: Plot of the maximum daily discharge temperatures at Indian Point 2000-2007. The 90° and 100°F reference levels are shown in red.

5.2.2. The far field

Far field predictions can be made using existing temperature measurements or modelling methods. The Massachusetts Institute of Technology dynamic network model was used in the DEIS for Indian Point, Bowline and Roseton generating stations. In the DEIS this far field model is referred to as the FFTM (Far Field Thermal Model).

There are a variety of natural and anthropogenic heat inputs into the Hudson Estuary, and to assess the far field impact of Indian Point we need to be able to distinguish the impact of Indian Point from these other sources. Fortunately, this is possible and we can give a reasonable estimate of the increase in the far field temperature caused by the Indian Point discharge. The table below is copied from the DEIS, and gives the heat loads from the principal anthropogenic sources. Note that Indian Point at this time injected considerably more heat into the system than the other sources considered at this time.

FACILITY	CAPACITY HEAT LOAD (BBTU/day)
Albany Steam Station	67.7
Danskammer Point	34.3
Roseton	136.0
Peekskill WHR	11.5
Indian Point	328.0
Lovett	71.0
Bowline Point	120.0
World Trade Center	19.9

Table 10: Capacity Heat Loads (Table 23 from DEIS appendix VI-3-A).

The Massachusetts Institute of Technology dynamic network model was reported in the DEIS for a range of power plant discharge scenarios. A typical output is presented in Figure 14. A comparison of lines 3 and 5 show the appreciable effect of Indian Point generating station, which was predicted to increase river temperature by > 1°F for more than 10 miles of estuary.

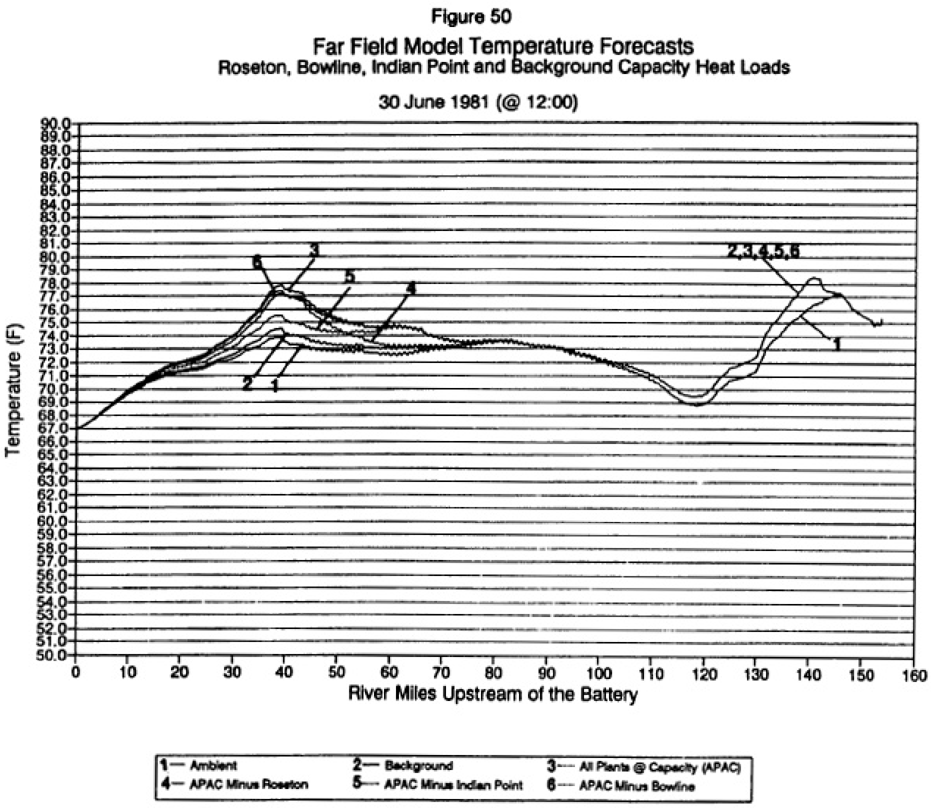

Figure 14: A sample of the results presented for the far field temperature effects of the Hudson Estuary power plants. From the DEIS for Roseton, Bowline and Indian Point generating stations.

5.3. The change in the background temperature of the Hudson River

Water temperatures in the Hudson are increasing. This is clearly demonstrated by the statistically significant increase in mean average annual water temperature measured at Poughkeepsie Water Treatment Facility (Figure 15). The mean annual temperature in recent years is about 2°C (3.6°F) above that recorded in the 1960s.

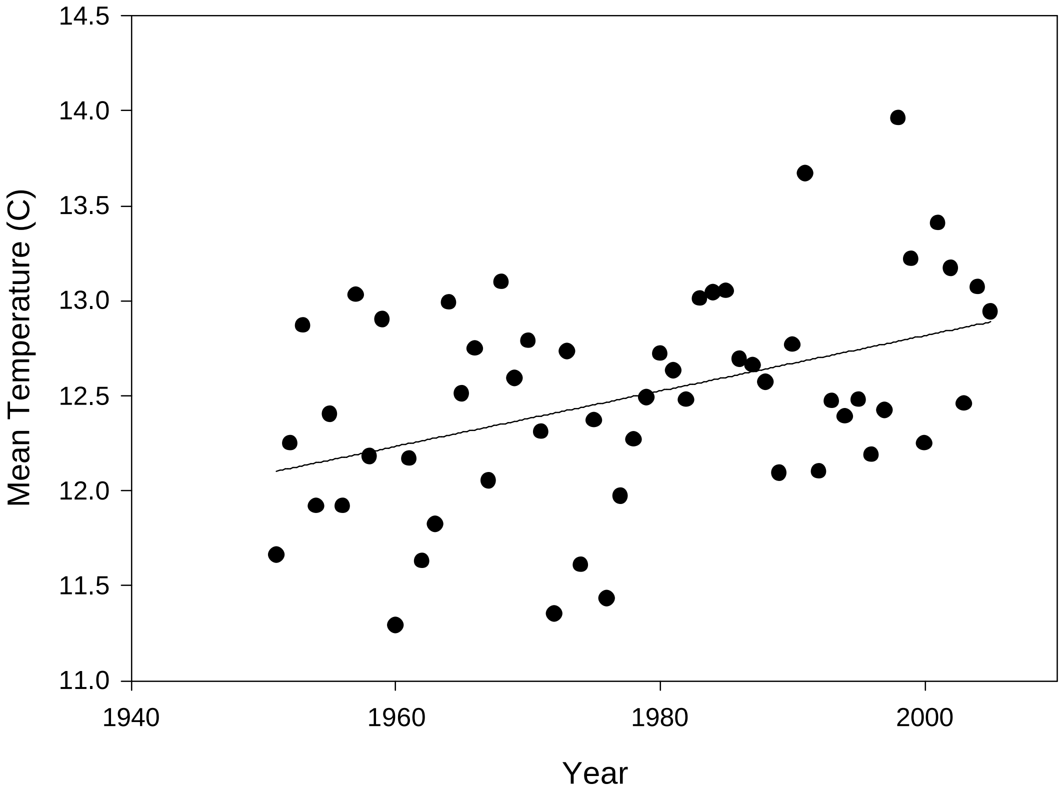

Figure 15: Average annual water temperature (°C) as measured at Poughkeepsie's Water Treatment Facility, 1951 to 2005. (a = 0.0146, b = -16.32, F = 11.1157, p = 0.0016) – Data from 2005 Year Class Report – Appendix B Table B - 6.

Examination of the daily temperatures for 2005 plotted against the mean, minimum and maximum temperatures from 1951 to 2004, show that the temperature for several summer months in 2005 was close to the maximum ever recorded. However, in the winter, it also reached some of the lowest temperatures recorded over a 53 year period. In summary, the temperature regime is becoming more extreme.

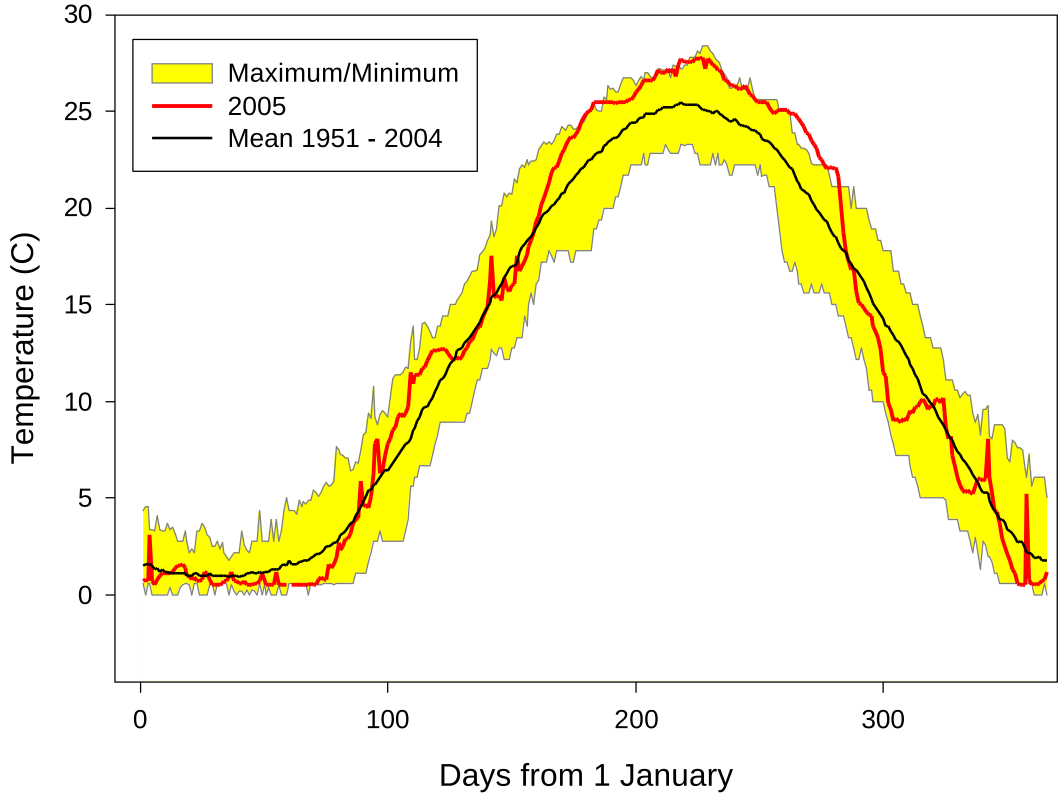

Figure 16: Poughkeepsie Water Treatment Facility data; mean, minimum, and maximum temperature (°C) for each day of the year, 1951 to 2004, with 2005 data plotted in red. – Data from 2005 Year Class Report – Appendix B Table B - 5.

5.4. The effects of heated water on river life

While the term entrainment is commonly used to describe the process in which planktonic animals are drawn into and pass through the condenser circuits of power plants, the term can also be used to describe the capture of organisms in an effluent discharge. When Indian Point discharges warm water into the river, it mixes with the receiving waters. Any small organisms in the receiving water with which it mixes will also be subjected to sudden changes in temperature that are potentially harmful. The importance of these impacts will be in part determined by both the temperature and volume of the discharge. Other factors may also become important. For example, in a tidal body of water, some organisms or populations may be repeatedly exposed to the discharge as the water body in which they live oscillates with the tide past the discharge point.

5.4.1. The temperature sensitivity of aquatic life

Almost all aquatic life is affected by thermal discharges. Below is presented a summary of the impacts on aquatic life in general, and rather more detailed data on thermal tolerance of fish.

5.4.1.1. Thermal impacts on plants

Several studies have shown that species diversity of phytoplankton decreases in areas consistently heated to over 30°C (mid 80s F). The available data indicate that phytoplankton productivity, as measured by carbon assimilation rates, declines with increasing temperatures above about 30°C. Figure 17 from Langford (1990) shows the rapid decline for phytoplankton in lakes. It is likely that a similar response would occur with Hudson River phytoplankton.

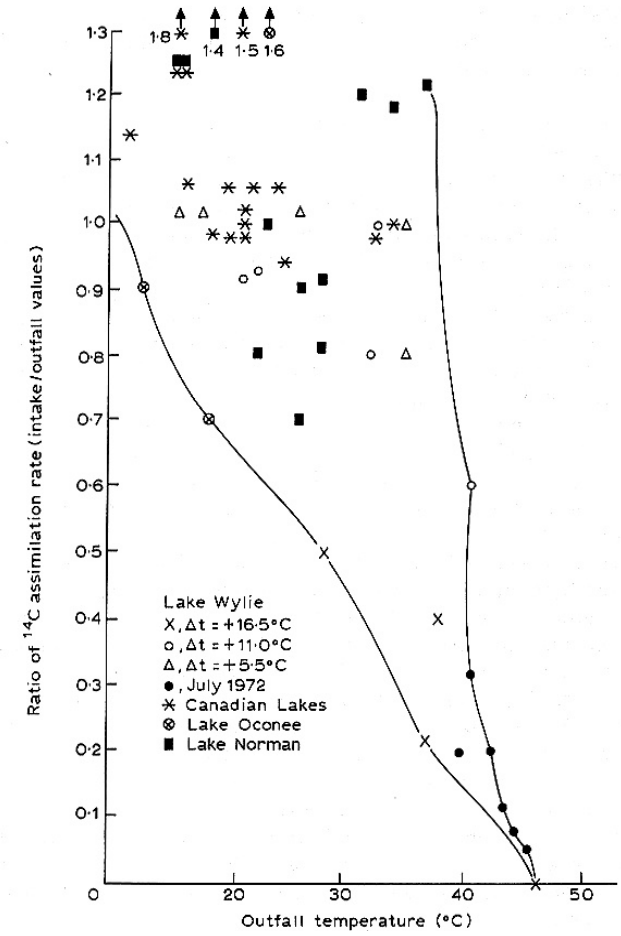

Figure 17: The effect of discharge temperature on the photosynthetic activity of phytoplankton. From Langford (1990).

5.4.1.2. Thermal effects on small crustaceans - zooplankton

When water temperatures reach 35 – 38°C (95 - 100°F) zooplankton abundance declines and mortalities occur (Langford, 1990). Effects on benthic invertebrate life have also been noted, but at Indian Point, the main effect of the discharge will be on planktonic life, because of the depth of the water, since the buoyant plume of heated water remains towards the surface.

5.4.1.3. The thermal tolerance of Hudson fish species

The effects of temperature on the biology and ecological requirements of fish have been extensively studied and reviewed. Temperature can affect survival, growth and metabolism, activity, swimming performance and behaviour, reproductive timing and rates of gonad development, egg development, hatching success, and morphology. Temperature also influences the survival of fishes stressed by other factors such as toxins, disease, or parasites. Many of these effects will occur well below the upper lethal temperature which is given below.

The published information on the temperature requirements of freshwater fishes is found in thousands of documents. It is convenient that several authors have condensed this information into reviews of the literature. The general reviews of fisheries biology by Carlander (1969, 1977) and Scott and Crossman (1973) include some temperature data. Several reviewers have focused on thermobiology, specifically, lethal and/or preference temperatures (Coutant 1977a; Cherry *et al* 1977; Kowalski *et al* 1978; Houston 1982). Others have widened their reviews to include data on growth, preference and lethal temperatures (Leidy and Jenkins 1977; McCauley and Casselman 1980; Jobling 1981). Comprehensive reviews on the whole range of temperature requirements for fishes (i.e., lethal, preference, growth, reproductive) were given by EPA (1974) and Brown (1974).

A summary of thermal effects literature is published each year for aquatic organisms in the June issue of the Journal of the Water Pollution Control Federation (Talmage and Coutant 1978, 1979, 1980; Cravens 1981, 1982; Cravens *et al* 1983; Harrelson *et al* 1984). The temperature requirements of Great Lakes fishes have been reviewed by a number of authors. Firstly, Reutter and Herdendorf (1976) presented lethal and preference temperatures for 46 species of Lake Erie fishes. Secondly, Spotila *et al* (1979) reviewed 80 species covering: thermal requirements for survival, temperature preference, growth, reproduction and early development. Finally, Wismer & Cristie (1988) made a general compilation of the available data.

Below, the upper temperature that a range of Hudson River fish can tolerate is tabulated. When no size is given, the values are for adults. Generally, young and small fish are more vulnerable to elevated water temperatures than adults. A temperature of 81°F (27.2°C) is the highest that most fish can withstand, indicating that they can just tolerate the maximum summer temperature. However, for some fish, such as the tomcod, it is too hot, and they must seek cooler waters (for example, head towards the ocean). The maximum temperature for the outfall can be 100°F, which is 37.8°C. As can be seen from the table below, this is well above the upper temperature that almost all species can tolerate.

Species	**Latin Name**	**Acclimatization temperature °C**	**Upper tolerance limit °C**
Carp	Cyprinus carpio	20	31-34
Large mouth bass	*Micropterus salmoides*	20	32.5
		30	36.4
Blue gill	*Lepomis macrochirus*	15	30.7
3 spined stickleback	*Gasterosteus aculeatus*	25-26	30.6
Yellow perch	*Perca flavescens*	15	27.7
Alewife	*Alosa pseudoharengus*	15	23
Rainbow smelt	*Osmerus mordax*		21
Sea lamprey	*Petromyzon marinus*		34
Tomcod	*Microgadus tomcod* (2 cm)		19-20.9
	(14-15 cm)		23.5-26.1
	(22-29 cm)		25.8-26.1
Common shiner	*Notropis cornutus*	15	30.3
Brown bullhead	*Ictalurus nebulosus*	15	31.8
Striped bass	*Morone saxatilis* - yolk sac		Mortalities start at 26
	- Post yolk sac		Mortalities start at 30
	- Early juveniles		Mortalities start at 34
American shad	*Alosa sapidissima*		28
White perch	*Morone americana*		32-34

Table 11: The upper temperature that a range of Hudson River fish can tolerate – for sources, see text.

When considering the effect of a heated outfall, we must take into account both the temperature and the exposure time. It is quite likely that larger fish will simply avoid entering the warm water plume, and thus will not suffer direct harm. However, these animals will be denied access to warmed areas. The thermal impacts will likely be felt most severely by the eggs and weakly swimming early life stages. Maximum temperatures in the discharge may exceed 35°C. It therefore seems inevitable that the heated discharge will result in the death of, or harm to, any American shad, Atlantic tomcod and river herring early life stages in the region of the discharge.

5.4.2. The influence of the discharge on fish migration.

One of the reasons for the limitation on the cross sectional area and surface width that can be thermally polluted is because of long-held concerns that thermal pollution can interfere with fish migration.

5.4.2.1. The response of fish to temperature

Water has a relatively high thermal capacity, and a fish will gain (or lose) heat quite rapidly by conduction across its entire body surface. Moreover, it must pass this fluid over its gills, in considerable volumes, since the concentration of oxygen in water is comparatively low. Gills are richly supplied with blood and have a substantial surface area to optimize gas exchange. These features also make for efficient heat exchange, and the blood rapidly distributes heat throughout the body (Crawshaw, 1979).

Most organisms can acclimate (i.e. metabolically adjust) to temperatures above or below those to which they are normally subjected. Baldwin and Hochachka (1970) correlated thermal acclimation and the switch to alternative metabolic pathways with changes in the proportions of iso-enzymes. However, as the temperature of the fish rises, coordination in the central nervous system can break down, which eventually manifests itself as "distress" symptoms; ultimately "heat death" will ensue. It was recognised many years ago that various reflexes disappear in a consistent sequence (e.g. Fisher, 1958).

As early as the 1930s, Bull (1936) demonstrated, from a range of marine species covering a number of taxa (not salmonids) and ecotypes, that fish could detect and respond to a temperature front of 0.03 to 0.07°C. Fish will therefore attempt to avoid stressful temperatures by actively seeking water at the preferred temperature, but this becomes increasingly a matter of chance once coordination begins to break down. If an uncoordinated fish is moved to cooler water it may recover, but the chances of recovery decrease with duration of exposure.

At less than stressful levels, increasing temperatures allow increased rates of metabolism, and (notably with regard to migratory activity) increased swimming speeds, but decreased endurance (Turnpenny & Bamber, 1983; Beach, 1984). The temperature at which locomotory activity becomes disorganized, and thus the fish loses its ability to escape from adverse conditions, has been termed the Critical Thermal Maximum (CTM).

Once temperatures exceed 40°C (104°F), heat death ensues: enzymes are inactivated, proteins denature or coagulate and fats melt. The last comprehensive review of this subject, from the molecular to whole organism level, was that of Rose (1967).

The response of fish to temperature is complex. Fish have natural thermal niches (preferenda) and in the temperate zone, freshwater species are either:

cold water species, such as salmon, trout, tomcod & smelt;
cool water species;
warm water species, such as carp;

This categorization tends to fall along taxonomic lines, in that related species and genera have similar thermal niches (Hokanson, 1977).

Superimposed upon this thermal selectivity are temporal variations in preferenda that can be correlated with the age or developmental stage of the fish, its physiological condition, or with various environmental variables. Young fish generally have higher thermal preferences and greater tolerances than do older fish. Feeding activity, reproductive or migratory behaviour and stress (anoxia, turbidity, salinity changes and chemical pollutants) might substantially alter normal thermal responses.

Some species are better than others at adapting their physiology or behaviour: in general, estuarine species are fairly resilient, since they are subject to regular environmental fluctuation.

For any fish there are temperatures that it prefers, temperatures to which it can acclimate, temperatures that it would seek to avoid but at which it can survive for various periods of time, and temperatures that are lethal. Moreover the ability of individuals to survive is not the same as the ability of the species to continue; increased temperatures may advance or delay breeding seasons, encourage breeding in the wrong place, or inhibit fish migration.

5.4.2.2. Temperature and dissolved gases

Indirect effects of temperature on fish include reduced solubility of gases, particularly of oxygen, an effect which can be exacerbated by the elevated temperature simultaneously increasing the rate of oxygen removal by pollutants such as sewage. The sort of temperature elevations that are encountered outside the immediate vicinity of a power station discharge are of between 1° and 3°C, which would decrease the solubility of oxygen by only about 0.5 ppm. Were the water to be 100% saturated with oxygen then this reduction in solubility would lead to outgassing. However most rivers are by no means fully saturated and so this slight decrease in solubility has no effect. On the other hand, the rate at which flowing water absorbs oxygen increases with temperature (Truesdale and Vandyke, 1958) whilst the rate of outgassing is sufficiently slow that any slight supersaturation is redissolved as the temperature decreases through mixing.

As would be predicted, the significant upward trend in temperature of the Hudson River has resulted in a statistically significant downward trend in Dissolved Oxygen (DO) (Figure 18 and Figure 19). The sharp decline in DO in 2004 and 2005 is particularly notable.

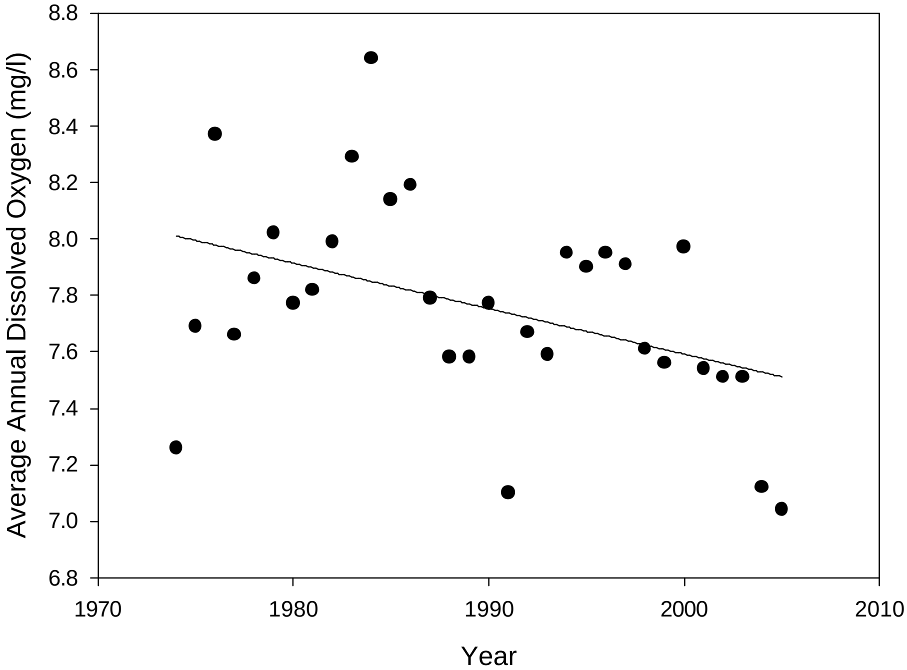

Figure 18: Average annual dissolved oxygen (mg/l) from Long River/Fall Juvenile Surveys, 1974 to 2005 - (a =-0.0161, b = 39.7804, F = 6.4047, p = 0.0169) – Data from 2005 Year Class Report – Appendix B Table B - 14.

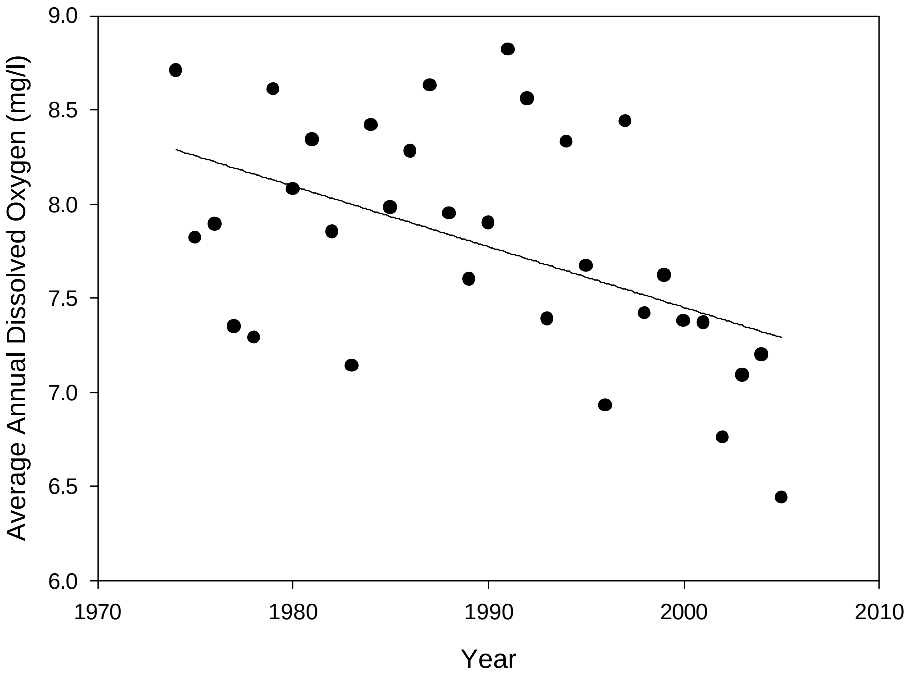

Figure 19: Average annual dissolved oxygen (mg/l) from beach seine surveys, 1974 to 2005 -(a =-0.0322, b = 71., F =9.5142, p = 0.0044) – Data from 2005 Year Class Report – Appendix B Table B - 16.

Given the considerable efforts that have been taken to reduce organic pollution, and the great improvement in water quality in the vicinity of New York City, these declines in DO are disappointing, and potentially important indicators of a decline in water quality for fish.

The distribution of DO within the water column is complex. It can be affected by many factors including tidal flow, riverine metabolism, stratification and atmospheric diffusion. A typical profile of DO versus depth is shown in Figure 20.

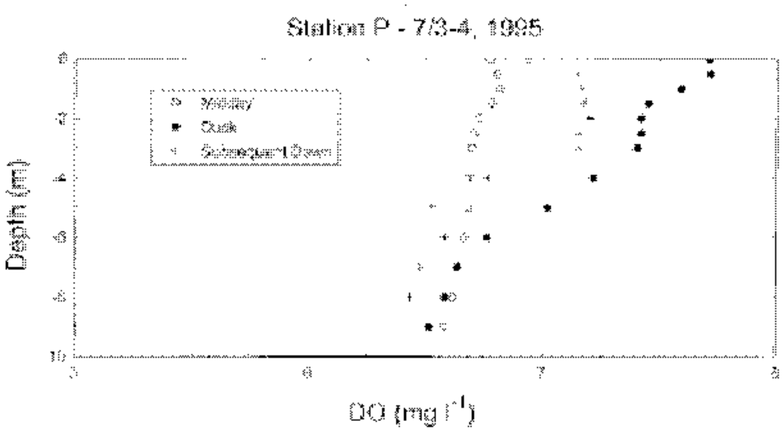

Figure 20: Typical depth profiles of DO measured on 3–4 July 1995 at Haverstraw Bay. Profiles for three sample times are shown for each station. (Swaney *et al* 1999)

This figure shows that the amount of oxygen in the water is often higher at the surface, and is increased during daylight hours as result of oxygen released by photosynthesis. The levels of DO are often reduced overnight as oxygen is metabolised by the organisms in the river.

5.4.2.3. Temperature and migration

Many of the studies of the effects of temperature on migration have been on salmonids, and as such are not relevant to the Hudson. However, shad species which do migrate though the Hudson show similar temperature responses to salmonids. For example the temperature preferences of American shad in Canada are characterised as follows:

> *"The American shad lives for several years at sea before returning to spawn in the stream or river where it hatched. Shad avoid cold temperatures, preferring to stay in water that is 8°C or warmer. Much of their migration and behaviour is determined by water temperature and currents. Each spring, schools of shad, using their sense of smell, begin to migrate up coastal rivers and tributaries when water temperatures reach 12°C. Spawning in the Maritimes occurs during June and July in water temperatures of 13-20°C. Migration stops in temperatures over 20°C."*
>
> Source http://www.gov.ns.ca/fish/sportfishing/species/shad.shtml

Almost all migratory fish are suspected of using temperature as a trigger to initiate migration. Once migrating, the degree to which they are responsive to temperatures they experience en route is more difficult to determine. However, it is clear that fish such as striped bass are sensitive to water temperature at almost all stages in their life-cycle, including both up-stream and down-stream migrants.

5.5. Heat Shock

Thermal issues are likely to become ever more important over the coming years as we are clearly following a warming trend in river temperature (see Figure 15). It is therefore complacent of Entergy to state on p 4-24:

> "*Entergy concludes that continued operation in the manner required by the current SPDES permit and the associated agreement to continue implementation of the fourth Consent Decree ensures that thermal impacts will satisfy the requirements of CWA 316(a) and will thus remain SMALL during the license renewal term.*"

It is appropriate for Entergy, when considering the future, to model scenarios with higher river temperatures than those observed in the recent past or even the present. We have not been presented with an analysis sufficient to prove that future thermal impacts will be small.

5.6. Thermal issues - Conclusions

The cooling water discharge is large and affects the receiving waters of the Hudson River. In recent years (2000 to 2007), the discharge temperature regularly exceeded 90°F and in summer frequently exceeded 100°F. A temperature exceeding 100°F will produce lethal conditions for aquatic life of all kinds, including algae, crustaceans and fish.

Indian Point's thermal discharge does not meet applicable thermal criteria. Furthermore, there is no mixing zone definition for Indian Point generating station discharges. The plume can spreads over a large proportion of the river.

There is an upward trend in the background temperature of the river, and a corresponding trend down in dissolved oxygen. This will result in increased harm from thermal pollution, if present levels of heat discharge continue into the future. Absolute temperatures of riverine heated effluents of 26°C (78°F) or more are potentially lethal to smelt and tomcod. The spatial and vertical extent of the Indian Point plume is sufficient to raise concerns about the passage of fish and impacts on the benthic life of the river.

Fish can perceive small differences in temperature, and show behavioural avoidance of even mildly stressful temperatures. However there are no data on the movement or migration of fish in the vicinity of the Indian Point plume. It is therefore not possible to quantify the effect of this discharge on fish movement or passage.

The changes in the flora and fauna of the Estuary indicate that it would be unwise to allow the statutory temperature limits to be exceeded.

Closed-cycle cooling, required under the draft SPDES permit for Indian Point. Under the closed-cycle cooling alternative, the amount of heat injected into the river would be greatly reduced, and thermal impacts would be confined to the discharge canal. Thus, closed-cycle cooling would likely eliminate thermal pollution concerns at Indian Point. We know of no alternative technology(s) that will result in equivalent protection for aquatic resources to the level which can be achieved by closed cycle cooling.

6. Critique of Entergy analysis given in Indian Point Energy Center Applicant's Environmental Report Operating License Renewal Stage

We discuss below the sections of the Environmental Report relevant to aquatic ecology.

6.1. Section 2.2 - Aquatic and Riparian Communities

This section starts with a standard description of the general physical environment. There can be no doubt that temperature issues (page 2-6) are becoming more important because of climate change. It was therefore notable that the report quotes average water temperatures between 1951 and 1997. This part of the report is therefore 10 years out of date. Further, there is no consideration at all of temperature trends over the last 50 years. Trends become important when considering the future impacts of the thermal plume. It is legitimate to ask how much higher the background temperature of the river is likely to get over the next 10 to 15 years and what effect this could have on the temperature of the plume.

In the section 2.2.2 - Plankton Communities, it is again apparent how out of date this document is. In the final paragraph of page 2-10 Entergy quote work on the phytoplanktonic species present in 1972. Given the large-scale changes in water quality since this time, such data cannot be considered reliable. As a general point, this document both relies on old data and notes the considerable changes that have occurred. The switch from using old data to stating that the system is under rapid change is not justified in the text. The viewpoint is picked for convenience to support their argument.

In the paragraph which follows, at the top of page 2-11, a reference is made to the 1972 FES. What is so striking is the complete lack of reference to the far more recent FEIS.

6.2. Section 2.2.3 - Macroinvertebrate Communities

Page 2-12 states:

> "*Recent studies have shown that the zebra mussel invasion is associated with a decline in open-water shad and herring (pelagic particle feeders), while the littoral fish such as sunfish (benthic feeders) have prospered [IES].*"

This type of statement is a standard way of asserting that declines in species are due to agents other than the power plants. It is an assertion without any underlying empirical or theoretical support.

There is another point of importance here. The zebra mussel is a filter feeder and is well know to radically change the ecosystems it invades. One of the first impacts is on the phytoplankton (which it consumes) and the zooplankton, which it affects by competing for their food. We therefore find here one of the classic inconsistencies that runs through this document, in that it quotes and uses data on the phytoplankton from the 1970s but notes that there have been major changes in the macro-invertebrates which feed on these phytoplankton. It is self-evident that if the zebra mussel has become abundant, then the phyto- and zooplankton must have changed. There are in fact studies which state exactly this. Below is an account of the recent changes linked to zebra mussel. The important point to note is that zebra mussels have changed the system, and data pre-1992 are now of historical interest only.

6.2.1. The arrival of the Zebra mussel

Prior to 1992, the nutrient-rich Hudson River estuary supported abundant phytoplankton populations that constituted a ready food supply for large populations of freshwater zooplankton, including rotifers, cladocerans, and copepods, on a seasonal basis. The introduction and population explosion of zebra mussel (*Dreissena polymorpha*) has depleted the standing stock of phytoplankton and has impacted other components of the food chain. Benthic invertebrates are relatively abundant but the species diversity is low, primarily oligochaetes and chironomids.

In 1986, the Zebra mussel, an inhabitant of fresh and brackish Eurasian waters, arrived via the Great Lakes in the ballast water of ships. First seen in the Hudson at Catskill in May 1991, Zebra mussels now inhabit the Mohawk River and the Hudson River from Albany to Haverstraw Bay. Within little more than a year of their arrival the biomass of the mussels was greater than that of all other heterotrophic animals in the Hudson, and reached an estimated 550 billion individuals, at an average density of 4,000 / m^2 over the freshwater tidal river. A secondary estimate was that, as filter feeders, the mussel population could filter the entire volume of the freshwater Hudson in 1 to 3 days. Their presence poses a number of very considerable threats to the ecosystem of the Hudson:

- Zebra mussels tend to colonize on rocky substrates in shoal areas, replacing or smothering any existing community that is in these habitats. Taxa of particular concern include Unionid and Sphaeriid clams. They also out-compete native mussel species for food and space, leading to a decline in native mussel populations.
- Phytoplankton and detritus are major food sources for lake and river food webs. Excessive removal of the phytoplankton by zebra mussels reduces the zooplankton species that feed upon them and can result in fisheries-related impacts.
- Mussels can filter large amounts of water and reduce the available food in the water column. Their filtering activity increases water clarity and hence light penetration. This, too, can dramatically change the benthic community structure.
- Zebra mussels cause significant biofouling in water intakes. This requires higher levels of biocide to combat the problem and this could lead to secondary effects in relation to the biocide chemical being released in to the environment.

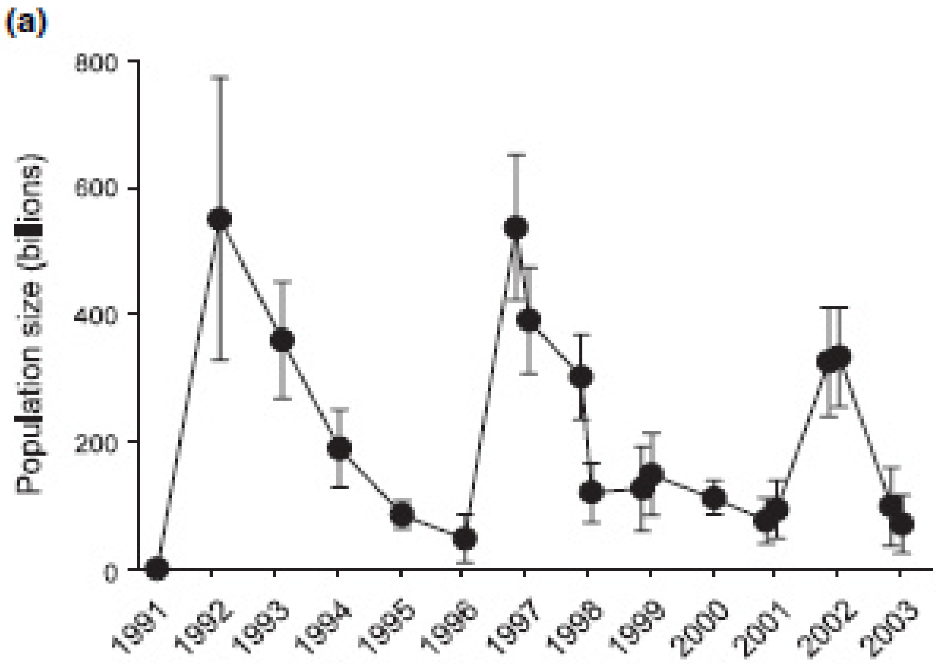

Figure 21: The estimated population of Zebra mussels in the Hudson (from Strayer and Malcom 2006).

Given their considerable numbers and their ecological effects, (lakes and rivers colonized by the mussels often see 50-75% declines in phytoplankton and small zooplankton biomass, rise in water clarity of 50-100%, drop of more than 50% in filter-feeding zooplankton and native bivalves, and increase in macrophyte beds and animals associated with mussels), it is inevitable that their presence will have a profound effect on the food web of the Hudson. This is illustrated in Figures 21a and 21b below (from Pisces Conservation, 2003), which represent a very simplified Hudson river food web, before and after the introduction of Zebra mussels. In Figure 21b, elements of the food web increased by the changes are shown in shades of magenta; and elements suffering a decrease in abundance or strength by shades of light blue.

Long-term reduction of zebra mussels by natural predators has yet to be demonstrated, but at least 17 species of North American fish have been documented to consume attached zebra mussels and quagga mussels (*Dreissena bugenis*). Additional species are likely to consume zebra mussels (particularly fish in the sturgeon, sucker, and catfish families), but cases remain undocumented. Although numerous and widespread, the efficacy of molluscivorous fish as a control mechanism for zebra mussels is unclear. However, zebra mussels are more susceptible to fish predation than native unionids or *Corbicula* spp. because *Dreissena* shells are weaker, adults are smaller in size, and most individuals are exposed to predators. (Kirk, *et al*, 2001).

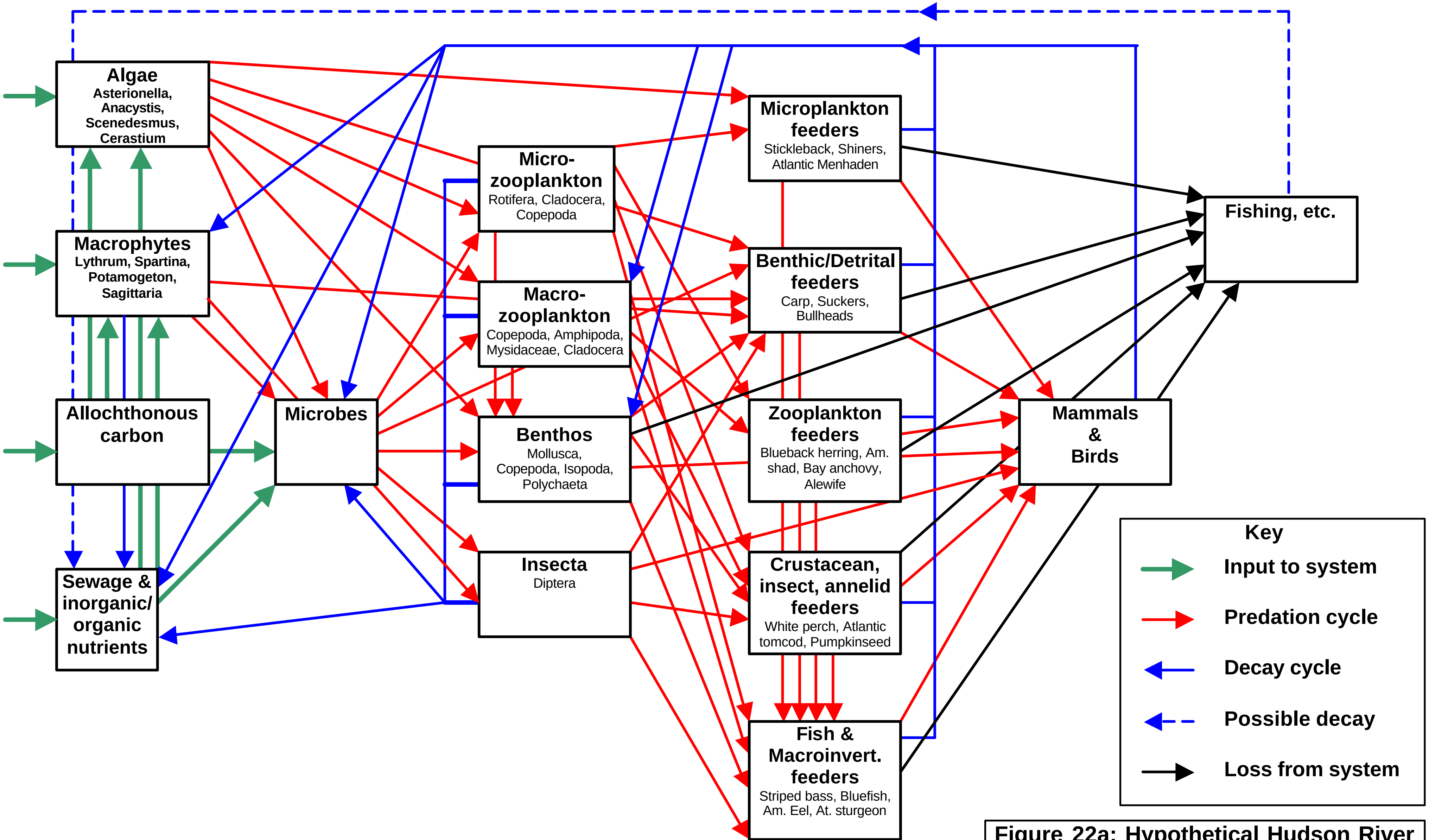

Figure 22a: Hypothetical Hudson River food chain, prior to invasion by Zebra mussel

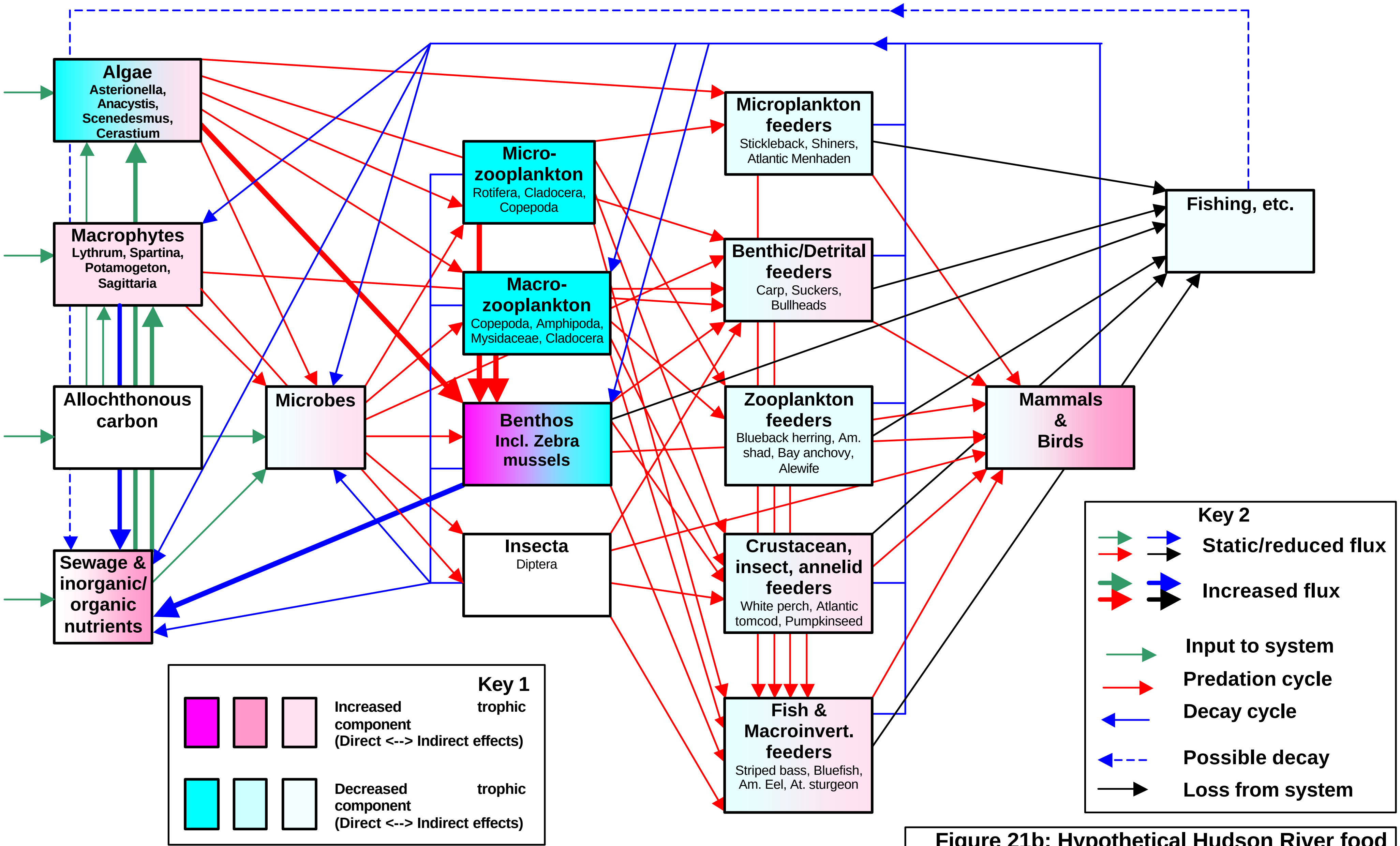

Figure 21b: Hypothetical Hudson River food chain, after invasion by Zebra mussel

6.3. Section 2.2.5 Fish Communities

This section is misleading. There is continued reference to the DEIS, and not the FEIS, and furthermore, there is almost no reference to data collected after 1997. This use of data more than 10 years old is unacceptable when more recent data have been collected and circulated.

For example, p 2-15 states: "*The DEIS emphasized an examination of long-term trends (1974-1997) primarily for the following two life stages of fish representative of impingement (YOY) and entrainment (PYSL).*"

There is an attempt to mislead on the health of fish populations. Yet again this is based on old data and carefully crafted statements. In fact, many species have been in decline. An example of a serious decline is Atlantic tomcod – there are many other species that have also declined. Below is a graph for tomcod abundance.

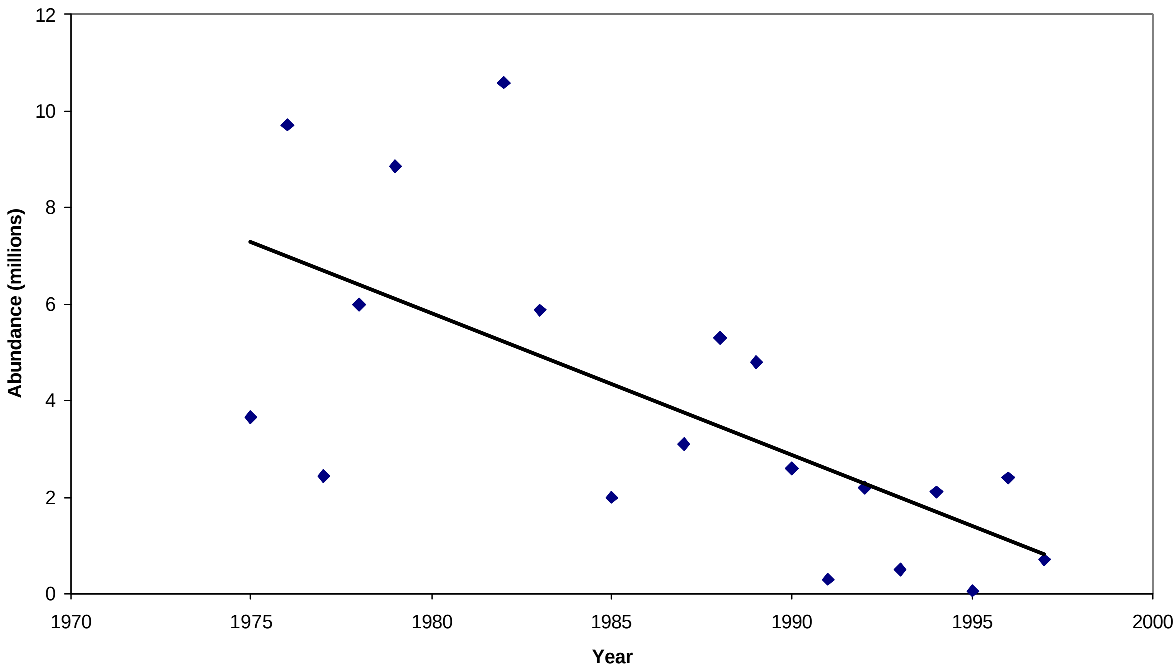

Figure 23: The change in estimated abundance of Atlantic tomcod at age 1. A linear regression has been fitted to the data to show the trend of declining number.

An example of a misleading statement of this type is on p 2-16:

> "*During the 24-year monitoring period from 1974 to 1997, species richness and overall abundance of PYSL increased in most areas of the estuary. Analysis of the long-term trends in the larval fish community in both the marine brackish regions and the freshwater zone revealed an overall increase in the total number of taxa collected. Increases in overall abundance were due to increases in the abundance of larval striped bass in all areas of the estuary and increases in the abundance of larval bay anchovy in brackish areas. [CHGEC, Section V.D.3.i]*"

When more recent work is quoted, no specifics are given, but rather general, misleading and inaccurate statements are made. For example at the bottom of 2-16:

> "*The recent 2004 annual year class report continues to confirm that the conclusions developed in the DEIS are still relevant and supported [ASA].*"

This statement is gives the reader the impression that the DEIS assertion that populations are healthy and flourishing is supported by recent studies. The opposite is in fact the case.

The fish community of the Hudson Estuary has been continuously changing since systematic recording began in the 1980s. There are clear indications both at the community and individual population level that the populations of fish in the estuary are becoming less stable and showing greater year to year variation in abundance. In the report on the status of fish population in the Hudson (Pisces Conservation 2007), of the 13 key species subject to intensive study, three species, striped bass, blue fish and spottail shiner have shown a trend of increasing abundance since the 1980s. The other 10 species have declined in abundance, some greatly. Apart from the species that have been intensively studied in the estuary many other important species of fish are also showing long-term declines in abundance. For example, the American eel has greatly declined.

There has been a recent increase in average water temperature and a decrease in dissolved oxygen levels. This may be influencing some of the changes observed, and will increase the impact of thermal discharges. All the evidence points to the Hudson ecosystem presently being in a state of change, with declining stability. Neither the ecosystem as a whole, nor many of the individual species populations, are in a healthy state.

6.4. Section 4.1 - Water Use Conflicts

When considering entrainment there is clearly an attempt to justify once through cooling. On p 4-13 appears a typical statement:

> "*The results of the studies performed from 1974 to 1997, the period of time covered in the DEIS, are referenced and summarized in the DEIS, and have not shown any negative trend in overall aquatic river species populations attributable to plant operations.*"

The important point to note is the phrase "*attributable to plant operations*". There have been many negative trends in aquatic life, but rather than address these issues, they avoid them by simply claiming they are not attributable to the plant. It is clear that species losses are multi-factorial. If more are killed than are produced, then the population of an animal will decline. When this happens, every unnatural activity that is contributing to the mortality must take on some of the responsibility. Further, those that kill the most must take on more of the responsibility. Indian Point kills members of the species that are in decline so it must bear some guilt; since it kills more than most other agents, it must bear a high proportion of the guilt and the responsibility for remedial action.

Exactly the same approach is taken with respect to impingement. On p 4-19 it is stated:

"*Therefore, withdrawal of water from the Hudson River for the purposes of once-through cooling at the site does not have any demonstrable negative effect on representative Hudson River fish populations, nor does it warrant further mitigation measures.*"

This is an extraordinary statement, and contradicts the conclusions of the FEIS that the system and many of its fish are in serious trouble. Species such as the American shad are demonstrably in decline. These declines are clearly because the fish have been unable to produce sufficient young to replace the dying adults. It is known that fish are killed by Indian Point, yet the declines are held to be nothing to do with the station.

7. Discussion

Indian Point has the largest water intakes and discharges on the Hudson. It is known that it killed billions of fish by entrainment and hundreds of thousands by impingement when these were last measured in the 1980s. Since then the ecology of the Estuary has altered, with many species showing large changes in abundance.

Quantifying the impact of entrainment and impingement at Indian Point by simply looking at the numbers of fish killed is not fully quantifying the effect. NYSDEC's position in the FEIS is that the fish kills at a power plant cannot be compared to selective cropping (i.e. removal by fishing or hunting). Instead of one or two species being affected, the entire community is impacted. Indeed, even the thermal impact can be considered in this way. NYSDEC state:

> *These "once-through cooling" power plants do not selectively harvest individual species. Rather, impingement and entrainment and warming of the water impact the entire community of organisms that inhabit the water column.*
>
> *For example, these impacts diminish a portion of the forage base for each species that consumes plankton (drifting organisms in the water column) or nekton (mobile organisms swimming through the water column) so there is less food available for the survivors. In an intact ecosystem, these organisms serve as compact packets of nutrients and energy, with each trophic (food chain) level serving to capture a diffuse resource and make it more concentrated. Ichthyoplankton (fish eggs, larvae and very small fish which drift in the water column) and small fish feed on a base of zooplankton (drifting animal life) and phytoplankton (drifting plant life). The loss of these small organisms in the natural community may be a factor that leads to harmful algal blooms. The small fish themselves serve as forage for the young of larger species, which serve as forage for larger individuals, and so on up the food chain, more correctly understood as a "trophic pyramid".*
>
> *Once-through cooling mortality "short-circuits" the trophic pyramid and compromises the health of the natural community. For example, while an individual bay anchovy might ordinarily serve as food for a juvenile striped bass or even for a common tern, entrainment and passage through a power plant's cooling system would render it useful only as food to lower trophic level organisms. It could no longer provide its other ecosystem functions of consuming phytoplankton, digesting and concentrating it into its tissues, and ranging over a wide area,*

> *distributing other nutrients as manure. This is just a single example from a very complex natural system, where the same basic impact is multiplied millions of times over more than one hundred fish species.* (FEIS page 53-54.)

When considering all aspects of the impact of Indian Point on the aquatic ecology of the Hudson estuary, the reliance by Entergy on old data in their recent reports results in an inadequate quantification of the impact that Indian Point currently has on the aquatic environment. Further, the use of such old analyses to project into the future would be a serious error.

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