VI. Environmental Impacts

VI. ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

A. Introduction

The proposed action is renewal of SPDES permits for the Roseton Units 1 and 2, Indian Point Units 2 and 3, and Bowline Point Units 1 and 2 Generating Stations with provisions for protection of Hudson River fishes similar to those have existed for the last 18 years, as described in Section IV.A.2. The potential environmental impacts of the proposed action are those associated primarily with the aquatic biota of the Hudson River. The potential aquatic impacts can be classified in one of four categories: 1) entrainment of small aquatic organisms, principally eggs and early life stages of fish, into the condenser cooling system along with the water used to condense steam from the turbines; 2) interception of larger aquatic organisms, principally small fish, by the screen systems that keep debris from entering the cooling systems; 3) changes in the local environment near the power plants due to the addition of heat that may cause changes in biotic communities; and 4) direct changes in biological function due to the discharge of heat or chemicals.

The utilities have conducted extensive studies of Hudson River fish populations and the effects of operating the Bowline Point Units 1 and 2, Indian Point Units 2 and 3 and Roseton Units 1 and 2 power plants on those populations annually since 1974. Data from these studies, along with other information, were used to help assess the potential environmental impacts of the proposed action.

In this section, the effects of operating the Bowline Point Units 1 and 2, Indian Point Units 2 and 3 and Roseton Units 1 and 2 power plants are presented along with an assessment of the potential for impacts on fish populations, fish communities, aquatic ecosystems, wildlife, and air quality.

B. Aquatic Impacts

1. Entrainment Effects

a. Description of Entrainment

Power plant water intakes are usually equipped with intake screens to prevent clogging of the condenser cooling system and pumps. Along with the water, however, organisms smaller than the screen openings (usually 0.25- to 0.5-in. mesh) can be drawn into the system, a process called entrainment. Planktonic organisms (phytoplankton, microzooplankton, macrozooplankton, and ichthyoplankton) are susceptible to entrainment because their small size and limited swimming ability allow passage through the mesh of the traveling screens and prevent escape from the entrained water mass. Some of the entrained organisms are young life stages of fish, in part from recreationally and commercially significant species. Organisms pass through the circulating pumps and are carried with the flow through the intake conduits toward the condenser units. The cooling water and entrained organisms are drawn through one of the many condenser tubes used to cool the turbine exhaust steam. The cooling water and organisms then enter the discharge canal or conduit for return to the water.

During their passage through the plant, entrained organisms experience a variety of stresses, some of which may cause death. The stresses encountered by the entrained organisms were described by Schubel and Marcy (1978) and are summarized below.

i. Physical

Organisms can be exposed to physical stresses at a variety of points throughout the cooling water system. The initial point is passage through the trash racks and intake screens. Organisms just small enough to go through the screens may incur abrasions or compression as they are pulled through the mesh. Damage may also occur during passage from the traveling screens to the pumps.

Passage through the pump is where greatest severe shocks occur, creating an almost instantaneous jump in pressure; direct collision with the impeller will occur for some 3.5% of the entrained organisms. Velocities and shear forces can also remain relatively high during passage through the condenser tubes. Finally, depending upon the nature of the discharge structure, turbulence and shear may be encountered when the cooling water is returned to the water body.

ii. *Thermal*

Entrained organisms can be exposed to elevated temperatures during passage through the condenser tubes, where the rise in cooling water temperature is almost instantaneous, and in the discharge canal or conduit, where organisms may be exposed to elevated temperatures for periods ranging from less than a minute to more than 30 minutes, depending on the type and length of the discharge structure.

iii. *Chemical*

To prevent fouling during certain times of the year, some power plants inject intermittent pulses of biocide into the coolant. Some organisms may be directly exposed to chlorine.

iv. *All Stresses Combined*

Organisms that survive entrainment may be exposed to additional thermal and biocidal stress after they are returned to the source water. If a diffuser is present, as it is for the subject stations, mixing with the ambient water is rapid and exposure duration is reduced, but the organisms may be exposed to shear stresses as they are discharged through the diffuser. However, the shear stresses generated at the diffuser and when the dilution water from the river is mixed with the discharge plume should be considerably less than those encountered by the organisms during passage through the plant and well below the lethal range.

b. ***Quantification of Entrainment Effects***

The simplest, and least informative, measure of entrainment is the number of organisms entrained through the cooling system. The concept is very simple: sample a known volume of the cooling water flow, count the organisms in the sample, and extrapolate the result up to the entire flow. In practice, there are many factors such as sampling efficiency, temporal variability of organism entrainment, spatial variability at the sampling location, extrusion and destruction of organisms, volume measurement accuracy, and organism identification that must be accounted for in the estimation process.

A more difficult, but also more useful, measure of entrainment is the number of various organisms actually killed during the entrainment process. In addition to the estimates of numbers entrained, an assessment of their ability to survive the process is required. Survival estimates require highly specialized sampling programs that examine organisms both before and after entrainment. Sampling must be done in a way that is not harmful to the organisms at the cooling water intake and at the point at which they exit the cooling water system.

Estimates of the numbers killed by entrainment can be integrated with estimates of the abundance of organisms in the river to estimate the proportional reduction of the population. This type of estimate is usually expressed as the conditional mortality rate (CMR), i.e. fraction of the population killed by entrainment if there were no other sources of mortality operating. Two models, which both require sampling of the populations in the river, are available to calculate entrainment CMR. These models are described in Appendix VI-1.

The most biologically relevant assessment of entrainment at the species level is done by examining the effects of entrainment mortality on the dynamics of the populations as a whole. This type of assessment requires information on population abundance through time, so that an empirical description of population trends can be made. If information on natural birth and death processes is also available, a model can be constructed to predict the future time course of population abundance. This predictive ability allows a comparison of population abundance through time under various hypothetical levels of entrainment mortality.

Each increase in the level of quantification incorporates additional information, and thus is potentially more useful and relevant as a way to assess the impacts of power plant entrainment. However, along with the increasing information needs, there may also be additional assumptions that must be made to fill in for incomplete data or unknown functional relationships among the variables.

Over the course of the last 25 years, the utilities have collected data required for all of these levels of complexity. The assessment of entrainment effects in this section focuses on the population level and also includes a description of the CMR for seven fish taxa that comprised over 92% of all fish collected in entrainment samples at Roseton Units 1 and 2, over 94% of those at Indian Point Units 2 and 3, and over 97% of those at Bowline Point Units 1 and 2 (Appendix VI-1-A). Translation of the conditional mortality rates into effects on older life stages has been done for three of these species (striped bass, Atlantic tomcod, and American shad). Lower level assessment measures (numbers entrained and number killed by entrainment) are presented in Appendix VI-1-D.

i. Conditional Mortality Rates

Since future operation schedules of the Bowline Point Units 1 and 2, Roseton Units 1 and 2, and Indian Point Units 2 and 3 power plants are subject to uncertain demand and other unpredictable events, entrainment CMRs under the Proposed Action were calculated for several operational patterns that would address and satisfy the guaranteed level of reduction in mortality. It is unlikely that any of these operational patterns (scenarios) will actually occur, but they are nevertheless useful for examining the range of entrainment CMR that could occur for the seven taxa under the Proposed Action. The conditional morality rates under the Proposed Action, like the guaranteed level of FPPs, were calculated using the empirical estimates of through-plant mortality for the target species (Appendix VI-1). Comparable conditional mortality rates using an assumption of 100% through-plant mortality are contained in Appendix VI-1-D.

It is also important to keep in mind that the estimates of conditional mortality rate presented are those that could occur if the utilities just met the guaranteed level of fish protection and accumulated only the minimum required number of FPPs. As occurred under the 1981 and 1987 permits, operating schedules and forced outages are likely to result in a somewhat greater number of FPPs being accumulated than are required under the Proposed Action. However, to present a conservative estimate of the potential impacts, the analysis assumes that only the minimum number of FPPs will occur.

Entrainment conditional mortality rates under the Proposed Action were estimated from the expected weekly conditional mortality rate under the Settlement Agreement flow limits and full operation at each unit based on 1991-1997 data on the spatial and temporal distributions of entrainable life stages. These recent years were selected because, based on more extensive sampling, they are felt to provide a more accurate depiction of future fish distributions than would the entire 24-year data set.

Rather than using planned operating schedules to determine future mortality estimates, four possible ways in which the guaranteed level of fish protection could be achieved were examined for resultant conditional mortality rates on the seven target taxa. (Even though the guarantee is based on only five, the taxa selected in technical workshops, the mortality rates, additional taxa, American shad and spottail shiner were also calculated.) The "Early" scenario depicts resulting conditional mortality rates for the seven taxa if the outage-related FPPs were achieved through single-unit operation as early in the year as possible at each station. The "Design" scenario depicts the conditional mortality rates that would result from the set of flow reductions and outages used to determine the guaranteed level of FPP (Appendix IV-1). The "Late" scenario depicts conditional mortality rates that would result if all requisite FPPs were accumulated as late in the year as possible at all stations. The "Minimum Outage" scenario depicts conditional morality rates that would occur if all FPPs were accumulated through single-unit operation at the time when the maximum FPPs are available.

Conditional entrainment mortality rates under the Proposed Action for the four compliance scenarios are presented in Table VI-1. Taxon-specific conditional mortality rates do not vary greatly among the four scenarios. Total CMR for striped bass ranged from 0.1366 (Minimum Outage) to 0.1546 (Early), less than a 0.02 difference among the scenarios. Other taxa showed similarly small variations in conditional mortality rates among the

TABLE VI-1

ENTRAINMENT CONDITIONAL MORTALITY RATES FOR SEVEN TAXA UNDER FOUR SCENARIOS FOR MEETING THE GUARANTEED LEVEL OF FISH PROTECTION POINTS. OUTAGES ARE LIMITED TO THE MINIMUM NECESSARY TO MEET THE GUARANTEE. CONDITIONAL MORTALITY RATES ARE BASED ON ESTIMATED THROUGH-PLANT MORTALITY RATES. BOLD TYPE INDICATES THE MINIMUM RATE FOR THE TAXON

	[illegible]				
	EARLY	[illegible] DESIGN [illegible]	Late	Minimum Outage	Average
Bowline Point					
Striped Bass	0.0087	**0.0063**	0.0074	0.0086	0.0077
White Perch	0.0031	**0.0021**	0.0027	0.0031	0.0027
Atlantic Tomcod	**0.0618**	0.0787	0.0825	0.0623	0.0713
American Shad	0.0002	**0.0001**	0.0002	0.0002	0.0002
Bay Anchovy	0.0478	0.0339	**0.0281**	0.0474	0.0393
River Herring	0.0013	**0.0010**	0.0013	0.0013	0.0012
Spottail Shiner	0.0051	0.0041	**0.0034**	0.0051	0.0044
Indian Point					
Striped Bass	0.1160	0.1105	0.1150	**0.0995**	0.1069
White Perch	0.0475	0.0439	0.0458	**0.0429**	0.0435
Atlantic Tomcod	**0.1116**	0.1373	0.1439	0.1434	0.1395
American Shad	0.0020	**0.0016**	0.0018	0.0019	0.0018
Bay Anchovy	0.1462	0.1310	**0.1169**	0.1360	0.1322
River Herring	0.0089	**0.0079**	0.0087	0.0081	0.0081
Spottail Shiner	0.0372	0.0301	**0.0237**	0.0370	0.0316
Roseton					
Striped Bass	0.0353	**0.0301**	0.0344	0.0329	0.0332
White Perch	0.0656	0.0617	0.0669	**0.0616**	0.0639
Atlantic Tomcod	**0.0099**	0.0179	0.0181	0.0178	0.0159
American Shad	0.0047	**0.0039**	0.0045	0.0047	0.0045
Bay Anchovy	0.0113	0.0112	**0.0067**	0.0113	0.0101
River Herring	0.0341	0.0314	**0.0301**	0.0329	0.0321
Spottail Shiner	0.0130	0.0123	**0.0084**	0.0130	0.0117
Total*					
Striped Bass	0.1546	0.1427	0.1517	**0.1366**	0.1432
White Perch	0.1128	0.1048	0.1120	**0.1046**	0.1071
Atlantic Tomcod	**0.1748**	0.2194	0.2288	0.2110	0.2136
American Shad	0.0069	**0.0057**	0.0065	0.0068	0.0064
Bay Anchovy	0.1963	0.1698	**0.1475**	0.1863	0.1746
River Herring	0.0438	0.0400	**0.0397**	0.0421	0.0411
Spottail Shiner	0.0546	0.0459	**0.0353**	0.0544	0.0472

* $CMR_{Total} = 1-(1-CMR_{BP})(1-CMR_{IP})(1-CMR_{Ros})$

scenarios: white perch (0.1046-0.1128), American shad (0.0057-0.0068), river herring (0.03970-0.0438), and spottail shiner (0.0353-0.0546). Atlantic tomcod (0.1748-0.2288) and bay anchovy (0.1475-0.1963) exhibit the greatest variation because these species are vulnerable to entrainment early (tomcod) or late (anchovy) in the year and thus have large differences in CMR between the Early and Late scenarios. It should be noted that changes in conditional mortality rate on the order of a few percent are within the level of uncertainty in the estimation methods. The estimates are based on the observed spatial and temporal distributions of the fish populations from 1991 to 1997, and on river temperatures in those years. Since future distribution of fish cannot be predicted with certainty, small differences in predicted entrainment mortality are unlikely to be meaningful.

Consistent with the varied life history patterns of these taxa, the minimum CMRs occur for different scenarios for different taxa. For striped bass and white perch minimum CMR would occur under the Minimum Outage scenario. For bay anchovy, river herring and spottail shiner, the minimum CMR occurs under the Late scenario, while the Atlantic tomcod minimum occurs under the Early scenario and the American shad minimum occurs under the Design scenario.

Entrainment effects on three additional species of interest, Atlantic sturgeon, shortnose sturgeon, and blue crab, were not described quantitatively, but under the proposed action the impact of entrainment on these species is expected to be negligible. During entrainment sampling programs, very few entrainable-size sturgeon have been collected at any of the power plants. Entrainable life stages of sturgeon are also seldom collected in the river sampling programs, confirming that these species are not likely to be entrained. Blue crabs spawn in waters of higher salinities than are found in the Hudson; thus most entrainable stages are not found in the vicinity of the power plants.

2. Impingement Effects

a. Description of the Process

To keep condensers from clogging with solid materials and biota, Hudson River power plants use a combination of large mesh screens or bars to keep large debris out of the intake, and rotating belts of finer-mesh screens that exclude smaller materials. As the water passes through these screens, organisms larger than the mesh openings, juvenile and in some instances adult fish, can be intercepted by the screens (impinged). The number impinged relative to those entrained is a function of the mesh size on the traveling screens and the size of the organisms. Screenwash systems are employed to remove impinged fish from the screens and return them to the water body from which they came.

Some impinged fish survive, others die, either immediately (short-term mortality) or at a later time (latent or long-term mortality), depending upon the species and size of the fish, the water temperature and salinity, the design of the screens, the water velocity through the screen, the length of time the fish was on the screen, and the design and operation of the system to return the fish to the water. The causes of mortality in impinged fish seem to be exhaustion from attempting to escape impingement and the physical trauma imposed by the process itself, i.e., loss of protective scales and mucous membranes and bodily injury from contact with screens, high-pressure screenwash systems, and bypass structures. Since damage is often related to the length of time the fish remains impinged, continuous rotation of traveling screens reduces the time the fish are in contact with the screen and substantially increases post-impingement survival.

b. Quantification of Impingement Effects

As with entrainment, impingement effects can be estimated at various levels of complexity, with higher levels of complexity being more relevant, but also requiring more data. Sampling programs have been conducted at Roseton Units 1 and 2, Indian Point Units 2 and 3, and Bowline Point Units 1 and 2 to estimate not only the number of fish impinged, but also their mortality rates (Appendix VI-2-A). The information collected on the populations within the river allows the numbers killed by impingement to be expressed as a conditional mortality rate, thus translating the raw numbers killed into effects on the population of fish in the river of the same age. Unlike entrainment, impingement effects on a year class of fish may occur over a period of several years, thus the effects on the cohort (group of fish spawned in the same year) must be estimated over all ages at which they are vulnerable. In order to avoid a negative bias in the estimates, impingement CMRs are presented only for year classes whose vulnerable period was fully sampled. For this reason, the estimates of impingement effects are based on different numbers of year classes for the different species. Time series of population abundances can be used to assess the effects of past impingement, and the consequences of alternative future impingement loss rates can be examined through population models when they are available.

Impingement effects, similar to entrainment effects, were examined at the levels of conditional mortality rates and as effects on population trends. Estimates of numbers of fish killed by impingement in past years are provided in Appendix VI-2-D. Impingement CMR was estimated for the same taxa as was entrainment CMR. Blueback herring and alewives are not distinguishable as eggs and larvae, so for purposes of estimating entrainment impacts they are treated as a single taxon, river herring. They are treated separately for impingement, creating an eighth taxon for impingement.

From 1981-1990, these taxa represented 79% of fish collected in impingement sampling at Roseton Units 1 and 2, 89% of those at Indian Point Units 2 and 3, and 83% of those at Bowline Point Units 1 and 2 (Appendix VI-2-A).

The minimum, maximum, and average cohort conditional impingement mortality rates for past years are shown in Table VI-2. Average total conditional impingement mortality rates for Bowline Point Units 1 and 2, Indian Point Units 2 and 3, and Roseton Units 1 and 2vary from 0.018 for white perch to less than 0.001 for American shad.

For all of the species examined, total conditional impingement mortality is expected to be the same as or lower than that which occurred in past years due to the continued use of barrier nets and continuous screen rotation at Bowline Point Units 1 and 2; continued use of Ristroph screens and fish return systems at Indian Point Units 2 and 3; and continuous screen rotation and possible deployment of a sonic deterrence system at Roseton Units 1 and 2. For the species that are relatively hardy and resistant to impingement (e.g., striped bass, white perch, Atlantic tomcod), future impingement effects will be substantially lower than they were prior to installation and use of the present protective measures. The reduction is due to the installation of modified Ristroph screens and fish return systems at Indian Point Units 2 and 3, which significantly enhance the survival of impinged fish. For this reason, only years when these systems were operational were used to calculate CMR levels for future years. The maximum expected total impingement CMR for any taxon in the future is only 0.004 (for white perch).

It was not possible to quantitatively assess impingement effects on Atlantic sturgeon, shortnose sturgeon, and blue crab, but the effects should be negligible. Under past operating conditions, few sturgeon were impinged (see Section V.D), and many were released back to the river alive. Under the Proposed Action the numbers of these species impinged will not change substantially, and the probability of surviving the impingement process should be enhanced by the new screens and return systems at Indian Point Units 2 and 3. Large numbers of blue crabs are impinged primarily at Indian Point Units 2 and 3 and Bowline Point Units 1 and 2 (Section V.D), but typically survive the process. Studies are currently being conducted at Bowline Point Units 1 and 2 to verify this.

TABLE VI-2

IMPINGEMENT CONDITIONAL MORTALITY RATES FOR EIGHT TAXA*. AVERAGE OF HISTORICAL ESTIMATES ARE USED TO ESTIMATE EXPECTED VALUES UNDER THE PROPOSED ACTION.

	YEARS	MINIMUM	MAXIMUM	OVERALL AVERAGE	PROPOSED ACTION
Bowline Point					
Striped Bass	1984-1994	0.000	0.001	<0.001	
White Perch	1985-1990	0.000	0.001	<0.001	
Atlantic Tomcod	1986-1994	0.000	0.000	0.000	
American Shad	1985-1993	0.000	0.000	0.000	
Bay Anchovy	1985-1995	0.000	0.000	0.000	
Alewife	1985-1989	0.000	0.000	0.000	
Blueback Herring	1985-1989	0.000	0.000	0.000	
Spottail Shiner	1985-1995	0.000	0.000	0.000	
Indian Point					
Striped Bass	1984-1994	0.000	0.008	0.002	<0.001
White Perch	1985-1990	0.007	0.032	0.017	0.002**
Atlantic Tomcod	1986-1994	0.002	0.030	0.006	0.002
American Shad	1985-1993	0.000	0.000	0.000	0.000
Bay Anchovy	1985-1995	0.000	0.004	0.001	0.000
Alewife	1985-1989	0.001	0.002	0.001	0.001**
Blueback Herring	1985-1989	0.001	0.004	0.002	0.001**
Spottail Shiner	1985-1995	0.000	0.007	0.001	<0.001
Roseton					
Striped Bass	1984-1994	0.000	0.001	<0.001	
White Perch	1985-1990	0.001	0.002	0.001	
Atlantic Tomcod	1986-1994	0.000	0.003	<0.001	
American Shad	1985-1993	0.000	0.000	<0.001	
Bay Anchovy	1985-1995	0.000	0.001	<0.001	
Alewife	1985-1989	0.002	0.002	0.002	
Blueback Herring	1985-1989	0.000	0.001	<0.001	
Spottail Shiner	1985-1995	0.000	0.001	<0.001	
Total* **					
Striped Bass	1984-1994	0.000	0.008	0.002	0.001
White Perch	1985-1990	0.009	0.033	0.018	0.004**
Atlantic Tomcod	1986-1994	0.002	0.030	0.007	0.003
American Shad	1985-1993	0.000	0.000	0.000	0.000
Bay Anchovy	1985-1995	0.000	0.004	0.001	<0.001
Alewife	1985-1989	0.003	0.004	0.003	0.003**
Blueback Herring	1985-1989	0.001	0.005	0.002	0.001**
Spottail Shiner	1985-1995	0.000	0.007	0.001	<0.001

* Alewife and blueback herring are treated as separate Taxa for impingement, but as a single taxon, river herring, for entrainment.

** Cohort CIMR estimates for white perch, alewife and blueback herring reflecting impingement mortality after installation of modified Ristroph screens were not available. Estimates were derived by multiplying the pre-Ristroph screen average values at Indian Point by the estimate of Ristroph screen mortality (14%, 62%, and 26% respectively). Prior to the Ristroph screens, impingement mortality was considered to be 100%.

*** $CMR_{Total} = 1-(1-CMR_{BP})(1-CMR_{IP})(1-CMR_{Ros})$

3. Combined Effects of Entrainment and Impingement

a. Conditional Mortality Rates

The combined effects of entrainment and impingement for future years under the proposed action are generally not substantially different from those that have occurred in the past (Table VI-3). However, conditional mortality rates, if the utilities just met the minimum guaranteed level of fish protection points, would increase slightly for all 8 taxa. Striped bass could have the largest increase (from 0.104 to 0.144), followed by bay anchovy (from 0.140 to 0.175), and Atlantic tomcod (from 0.191 to 0.217). For the other taxa, the potential increase is less than 0.010.

b. Population-level Assessment

Conditional mortality rates are intended to represent the fractional reduction in abundance of the vulnerable age groups (primarily those fish hatched during the current year). However, they do not reflect the reduction in that group of fish or subsequent life stages or time periods if density-dependent mechanisms operate during or after the source of the impact, in this case entrainment or impingement. In such circumstances the actual reduction could be less, or greater, than the conditional mortality rate depending on the biological processes that operate for the species. The population-level effects at subsequent life stages, to and including adulthood, of power plant impacts can be assessed quantitatively through population models, which require both additional data and an understanding of the population regulatory processes. This understanding may be developed through examination of time series of abundance data for various life stages and through experimentation to elucidate the mechanisms of regulation.

Population level assessments, through the use of models, were conducted for four of the seven fish taxa. For striped bass, Atlantic tomcod, and American shad, models were constructed for the Hudson River populations based on past abundance data and information on biological characteristics (See Appendices VI-4-A, B, and C). For bay anchovy, an Individual-Based Model (Huston et al. 1989) was used to estimate effects on the production, consumption and biomass in the estuary (Appendix VI-4-D). For other taxa (white perch, river herrings, spottail shiner), only the time trends of population abundance were examined because the available data were not sufficient to construct a model of the population.

TABLE VI-3

ANNUAL COMBINED CONDITIONAL ENTRAINMENT AND IMPINGEMENT MORTALITY RATES UNDER THE PROPOSED ACTION

	CONDITIONAL MORTALITY RATE			
SPECIES	**ENTRAINMENT**	**IMPINGEMENT**	**TOTAL**	**HISTORICAL AVERAGE TOTAL[a]**
Striped bass	0.143	0.001	0.144	0.104
White perch	0.107	0.004	0.111	0.110
Atlantic tomcod	0.214	0.003	0.217	0.191
American shad	0.006	0.000	0.006	0.014
Bay anchovy	0.175	<0.001	0.175	0.140
Alewife	0.041	0.003	0.044	0.041
Blueback herring	0.041	0.001	0.042	0.040
Spottail shiner	0.047	<0.001	0.048	0.040

[a] Total for Roseton, Indian Point, and Bowline Point only from 1981 to 1997.

i. *Striped Bass*

Persistence. Operation of the three generating stations appears to pose no threat to the persistence of the Hudson River striped bass population. The historical pattern of potential reproduction, as indicated by the post-yolk-sac larvae (PYSL) index, shows a variable level of abundance without any upward or downward trend from the early 1970s to the late 1980s. When adult abundance increased in the late 1980s as fishing mortality decreased due to regulation of both sport and commercial harvests, the abundance of PYSL increased sharply. Although historical conditional mortality rates due to entrainment and impingement at all power plants were estimated to range up to 0.27 (Table V-18), these losses were not severe enough to cause a noticeable decline in stock abundance, even with the historical fishing mortality rates. The increases in adult stock size and potential reproduction (as measured by PYSL) after fishing was curtailed did not result in substantially larger year classes entering the population. This divergence of the juvenile abundance pattern from those of adults and PYSL suggests that density-dependent feedback is limiting the size of the Hudson River stock (SectionV-D).

Quantification of Impact. Modeling indicates that the Hudson River stock is relatively insensitive to entrainment, the primary source of mortality due to power plant operation. At a fishing mortality rate (F) of 0.3 (approximately the level anticipated for the near future) and power plant mortality of 0.2 (from all stations), the predicted spawning stock size would be 647,000 fish, only 5,000 below that which would be predicted with no power plant mortality (Figure VI-1). Similarly, the predicted effect on recruitment is a drop to 1,745,000 from 1,757,000 with no power plant mortality. Harvest would be essentially constant at 82,000 fish with or without power plant mortality as high as 0.2. The analysis also demonstrates the strong dependence of stock size and harvest, but not recruitment, on the fishing mortality rate. A fishing mortality of 0.3 would drop the stock size from 1.6 million to 0.6 million, approximately 1 million fish from what it would be in an unfished state. Harvest remains at or near the maximum levels for fishing rates between approximately 0.3 and 0.5. Regardless of the fishing rate over a reasonable management range, power plant mortality of up to 0.4 would have little effect on striped bass population dynamics.

The population reductions attributable to power plant operation would cause relatively small economic losses to the striped bass fisheries. Under the proposed action, the annual lost economic value to commercial and recreational fisheries for Hudson River striped bass each year would range from $0 to $37,000 under fishing mortality rates of F=0.5 or less, assuming power plant CMR of 0.20 (Appendix VI-5-B).

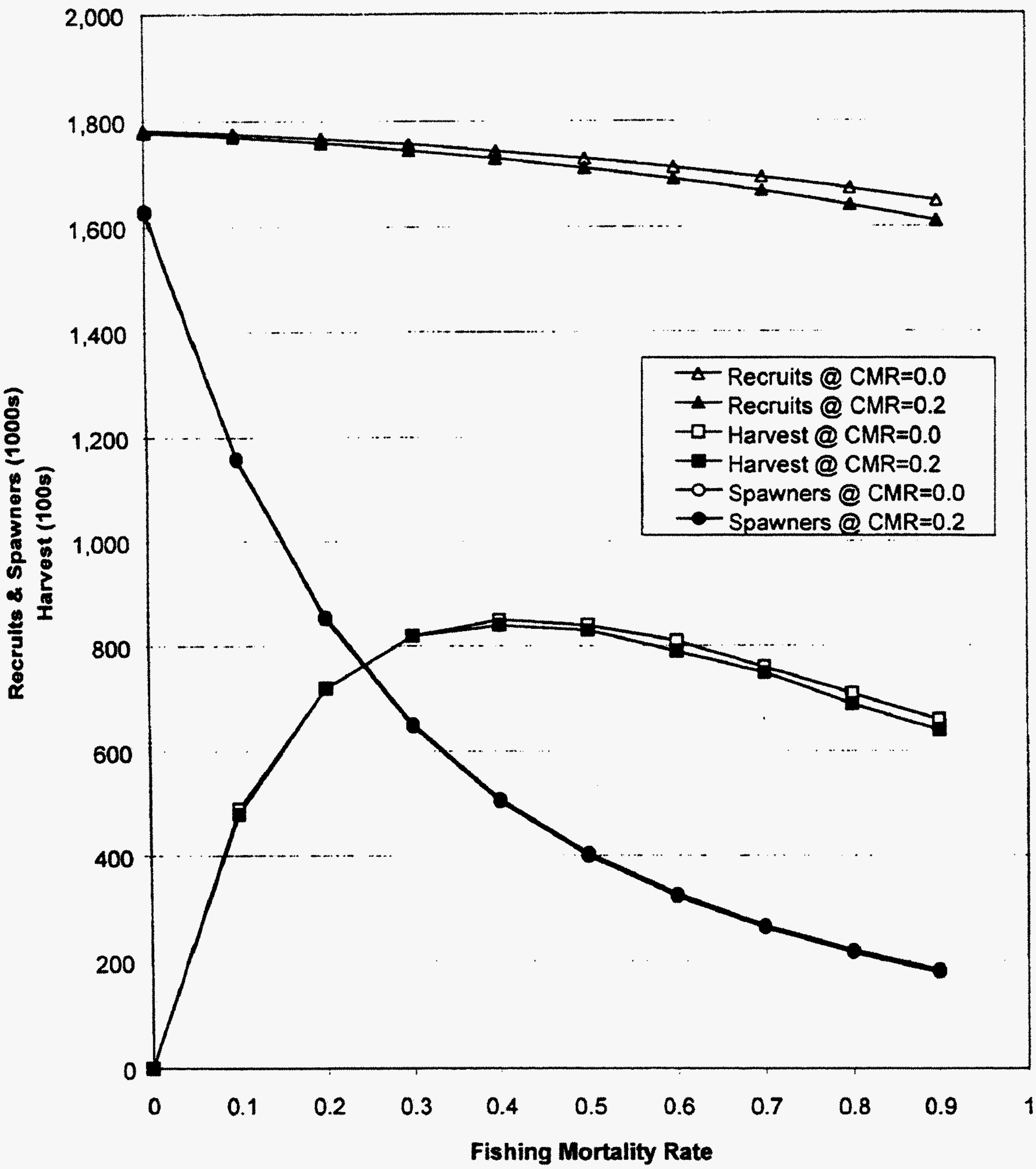

Figure VI-1. Recruitment, harvest, and spawning stock size of the Hudson River striped bass population under two levels of power plant entrainment mortality (0 and 0.20) and fishing mortality ranging from F=0 to F=1.

ii. White Perch

Persistence. The abundance of white perch in the Hudson River estuary since the early 1970s has fluctuated and the pattern of fluctuations has differed among age groups. Although abundance of PYSL increased at an average rate of about 3% per year, juvenile abundance has declined at an average rate of 7% per year. The juvenile trend is very similar to the trend in yearling abundance which has declined at a rate of 8% per year. The fact that the PYSL stage has increased in abundance while juvenile abundance has declined suggests that population regulatory mechanisms are acting to increase survival after the yearling stage and maintain reproductive potential in the stock.

The contrary trends in PYSL and juvenile abundance indicate an increasing temporal trend in early life stage mortality. A mortality index (the difference in the natural logarithms of PYSL and juvenile abundance indices) was negatively correlated with entrainment conditional mortality rate, suggesting that power plant mortality is not responsible for the trend. The mortality index was positively correlated to striped bass PYSL abundance, which could suggest increasing competition among these two species as the abundance of striped bass adults and early life stages increased. However, the complete explanation probably involves other factors since the trend in early life stage mortality appears to begin well before the striped bass stock began its increase in the mid-1980s.

Given that the white perch population has continued to maintain its spawning potential in the face of total CMR for entrainment and impingement of approximately 0.21 (Table V-20), a large increase in the abundance of a potential predator (adult striped bass) and a competitor for early life stages (larval striped bass), it would appear resilient enough to sustain its population in the future under similar levels of power plant mortality.

iii. Atlantic Tomcod

Persistence. The Hudson River tomcod stock reaches maturity within one year, and an increasing percentage of the population has the opportunity to spawn twice. It exhibits relatively wide fluctuations in year-to-year abundance. Although juvenile abundance has exhibited wide inter-annual fluctuations with no trend, adult abundance in recent years is distinctly lower than it was in the 1970s.

From at least the mid-1970s to the present Atlantic tomcod have persisted in the Hudson River, despite power plant entrainment and impingement, high incidence of liver tumors, and summer temperatures at some points within the river that approach their lethal limit. In spite of these stresses, periods of low abundance have typically been followed by sharp increases in the population, perhaps due to density-dependent feedback on growth rates and fecundity. This ability to rebound rapidly appears sufficient to ensure the persistence of the population under conditions similar to those it has experienced in the last 25 years, and particularly in the last decade.

Quantification of Impact. Strong density-dependent feedback appears to occur in the Hudson River population and probably results from changes in young-of-year survival and perhaps, individual growth and fecundity, that occur during the summer and fall, after the period when most power plant effects occur.

Based on the empirical pattern of egg deposition, PYSL and juvenile abundance, and recruitment observed in the Hudson River since 1991, the Atlantic tomcod population would appear to be robust to the effects of power plant entrainment (Appendix VI-4-B). A population model based on these data suggests that entrainment mortality could actually raise the equilibrium egg production by decreasing the competition at the early life stages and lowering the density-dependent mortality. Thus, if the processes regulating the tomcod population since 1991 continue in the future, entrainment and impingement mortality would appear to pose no threat to the Hudson River tomcod population.

iv. American Shad

Persistence. The Hudson River American shad population appears healthy and able to sustain itself under past, and future, levels of power plant effects like those in the proposed action. Although the adult stock has fluctuated over the period of record, recent indications are that the stock is recovering from a low point in the early 1990s, although recent year classes (1995-1997) appear low. Recruitment to the stock, as measured by juvenile abundance, has been variable, but without significant overall trend.

Quantification of Impact. The population model developed for American shad suggests that water withdrawal mortality on the order of the historical average rates of 0.24 would have substantial effects on the equilibrium level of 1-year-old abundance, when the stock is fished at or above the current level of fishing mortality, which may already be overexploiting the stock (Appendix VI-4-C). Under conditions of high density-dependent feedback, equilibrium abundance of 1-year olds would decline approximately 500,000, while under moderate and low density-dependence the declines would be about 800,000 and 1,500,000 respectively.

Most of the current water withdrawal mortality occurs at facilities upstream of Roseton Units 1 and 2. If this mortality remains the same in the future, mortality at Roseton Units 1 and 2, Indian Point Units 2 and 3, and Bowline Point Units 1 and 2 combined, estimated to be only 0.006 in the future, would reduce the abundance of 1-year-old fish by 12 to 37 thousand depending on the level of density-dependence.

The reduced 1-year-old abundance would be translated into a reduction in the maximum sustainable yield of the fishery of approximately 5 to 15 thousands pounds annually, depending on the level of density-dependence. The economic value of this reduction is approximately $5 thousand to $18 thousand (Appendix VI-6).

v. Bay Anchovy

Persistence. Bay anchovy is a marine species that uses the higher-salinity areas of the estuary as a spawning and nursery area during the summer. The species is believed to be composed of a single coastal stock; thus, abundance in the Hudson River is not dependent on reproductive success or mortality rates within the river. Therefore, the continued operation of the three subject stations poses no threat to the bay anchovy population

Quantification of Impact. The major concern about bay anchovy entrainment is what effects this mortality may have on other organisms that use bay anchovy as a food source. An Individual Based Model constructed at Oak Ridge National Laboratory was used to assess: the amount of production of anchovy biomass that would not occur as a result of entrainment mortality (production foregone); predatory demand for bay anchovy biomass; and seasonal trends in anchovy biomass in the river, biomass consumed by predators, and biomass entrained (Appendix VI-4-D).

From 1991 through 1997, average annual production foregone for bay anchovy was estimated to be 4,875 lb dry weight (dw) per year (19,500 lb wet weight). Yearly estimates ranged from 1945 lb dw/yr (7,779 lb ww/year) in 1996 to 9,814 lb dw/yr (39,257 lb ww/yr) in 1991 (Appendix VI-4-D). Average production foregone is about 0.7% of age 1-5 striped bass predatory demand and ranges from about 0.3% to 7% of bluefish predatory demand depending on the density of bluefish and the assumptions about bluefish activity levels.

Simulation of the biomass of anchovy in the river, biomass consumed by predators, and biomass entrained at power plants indicated that effects on anchovy biomass are less severe than suggested by the conditional mortality rate (Appendix VI-4-D). In the past, conditional mortality rates have sometimes been viewed as an estimate of the reduction in food supply for predators of bay anchovy (assuming no prey switching would occur). Even if anchovy were the only available prey for certain predators, the reduction in the available anchovy biomass approaches the CMR value for only a short period of time. For most of the time when anchovy are in the estuary, the reduction in biomass is much less than the ultimate CMR value. In addition, due to the timing of the actual biomass reduction, and the stocastic nature of prey encounters, changes in the amount of anchovy biomass consumed would be difficult to detect even at CMRs approaching 0.5 (Figure

VI-2). The amount of anchovy biomass diverted to alternate pathways through the food web due to entrainment mortality appears to be a very small fraction (<1%) of the total bay anchovy YOY biomass.

vi. Alewife and Blueback Herring

Persistence. The alewife and blueback herring are anadromous, passing through the estuary to spawn in the spring and early summer. For both, spawning occurs primarily outside the Hudson River, typically in tributaries, in the Mohawk River, and in the upper Hudson River. Although the larval stages are found within the estuary, an unknown, and possibly major, portion of the population remains in the spawning areas until emigration from the system occurs near the end of the summer.

Based on channel sampling in the FSS program, abundance of juvenile blueback herring increased by about 1% per year from 1979-1997, while alewife abundance decreased about 3% per year. Mean entrainment and impingement CMR at all Hudson River plants was estimated to be about 0.24 for these species (Table V-28), suggesting either that the populations can compensate for a relatively high level of power plant mortality, or that the CMR estimates are biased high due to the large fraction of the populations that is unavailable to the sampling program. The future level of mortality due to the Roseton Units 1 and 2, Indian Point Units 2 and 3, and Bowline Point Units 1 and 2 power plants would remain near the historical level of 0.04, which should not threaten the continued existence of these populations.

vii. Spottail Shiner

Persistence. Based on the utility beach seine program, the riverwide abundance of this freshwater minnow was relatively stable from 1974 to 1997. The average rate of change of juvenile abundance over the sampling period was –2% per year, although the inter-annual variability was such that this trend is not statistically significant. The species' habitat preferences keep most of the population out of the zone of influence of the three stations of interest. The average conditional mortality rate due to these power plants was about 0.040, and the average from all plants was about 0.160, most of that occuring within the Albany region. In the future, the projected CMR at the three subject stations is expected to be about 0.048, a level of effect that should pose no threat to the Hudson River population.

viii. Other Species

Conditional mortality rates were not calculated for several other species whose abundance trends were examined in Section V.D (bluefish, weakfish, hogchoker, white catfish, rainbow smelt, Atlantic sturgeon, shortnose sturgeon, blue crab and gizzard shad). These

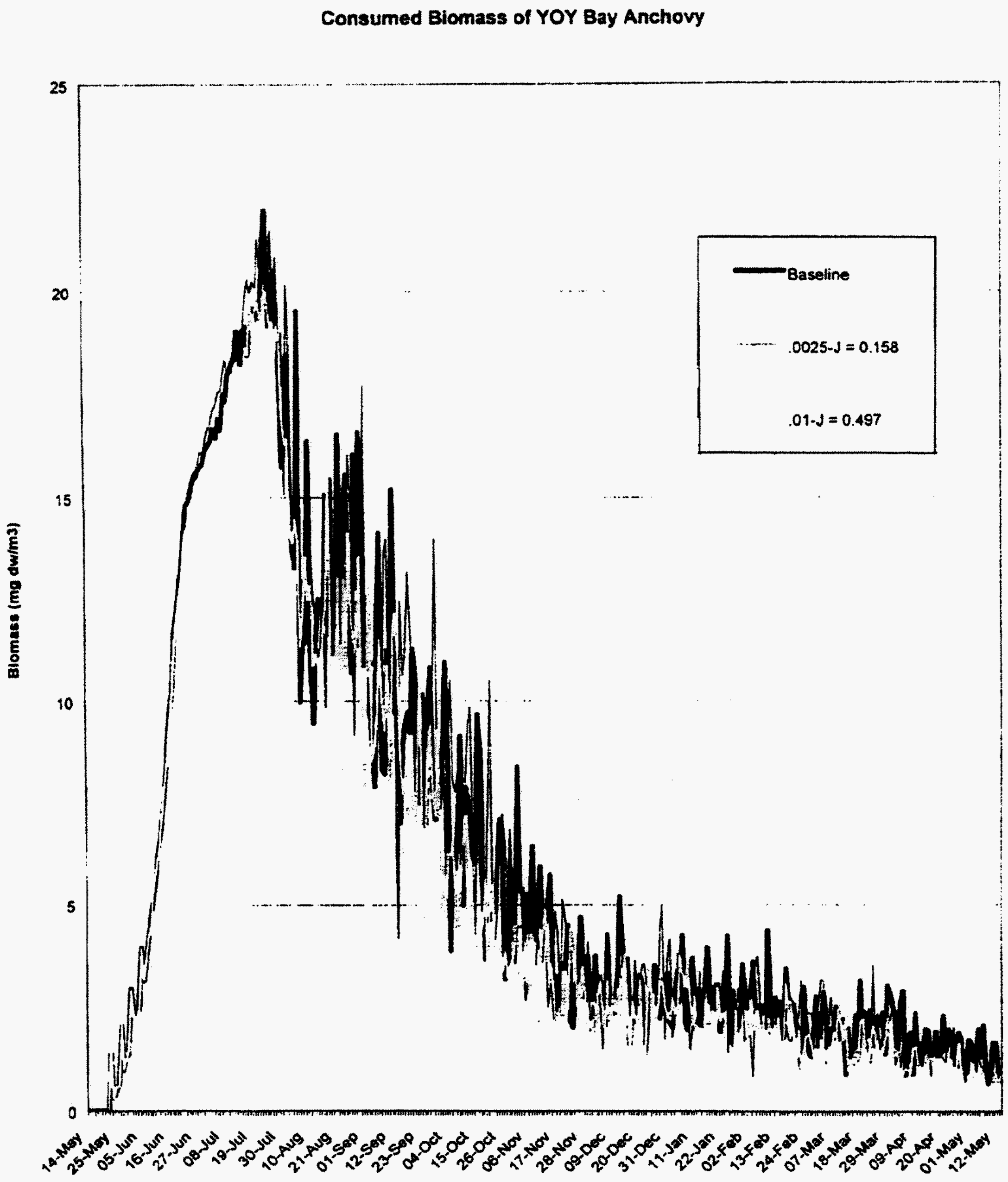

Figure VI-2. Consumed biomass of young-of-year bay anchovy under three levels of entrainment mortality (0, 0.158, and 0.497).

species are typically less vulnerable to impacts from the middle estuary power plants than are the previously discussed species due to their life history patterns and distributions. Entrainable life stages either occur infrequently in the middle estuary or are in habitats not subject to power plant withdrawals. Impingement effects are also low because the populations are not concentrated in areas subject to withdrawals and, for some species, impingement survival rates are high, e.g., blue crab, sturgeons, hogchoker.

Summary of Population Impacts. The pattern of abundance observed in selected Hudson River fish populations from 1974 through 1997 indicates that continued power plant operations, similar to those that have occurred historically, present no threat to the persistence of the affected populations.

4. Effects of Thermal Discharges

a. Background

The nature and likelihood of thermal effects from cooling water system (CWS) discharges depend on the extent to which the water body populations are exposed to the thermal discharge plume and the relationship between exposure and organism response. Living organisms do not respond to the quantity of heat but to degrees of temperature or to temperature changes caused by the transfer of heat.

The temperature exposure resulting from the stations' thermal discharges depends on the habitat preferences and seasonal distributions of organisms and on the distribution of heat discharged to the river. Dissipation of heat (decrease in volume or surface area within the warmer isotherms) occurs near the stations mainly as a result of the momentum of the discharge and dilution with the ambient current flow. Dissipation of heat further from the stations results mainly from heat exchange with the atmosphere, which is the final sink for artificial heat discharged to the river. The design of the CWS discharge, water body hydrology, and meteorology all influence the rate of decrease in temperatures within the thermal discharge plume.

Temperature is a normal part of the habitat structure experienced by all aquatic organisms, and spatial and temporal variations in water temperature are a natural feature to which the indigenous species have adapted. Potential effects from the Stations' thermal discharges depend on the temperature requirements of aquatic organisms and the nature of their responses to variations in water temperature as described below.

i. Adaptation to Temperature Changes

Over long periods, fish and other aquatic organisms adapt genetically and physiologically to a range of seasonal and daily temperatures that are characteristic of the climate of their geographical distribution. Thus, these organisms can survive within a range of temperatures specific to each species, called the "zone of thermal tolerance." For example, species residing in surface waters of arctic and Antarctic regions, and at high altitudes in temperate zones, are adapted to a relatively narrow annual range of seasonal cold to cool water temperature changes (NAS/NAE 1973). Similarly, species occupying tropical and sub-tropical waters adapt to a relatively narrow range of very warm water temperatures. Aquatic populations resident year-round in temperate zone waters, such as the Hudson River estuary, have had to adapt to the full range of seasonal temperature changes, from 32°F winter temperatures to summer temperatures up to 80 - 90°F (NAS/NAE 1973). Organisms also adapt physiologically to short-term daily changes in water temperature, thereby expanding their total temperature tolerance range. Laboratory studies show that thermal tolerance is enhanced when animals are maintained under a diurnally fluctuating temperature regime typical of temperate estuaries rather than at a constant temperature (Costlow and Bookhout 1971; Furch 1972; Hoss et al. 1975).

ii. Temperature Tolerance

As noted above, aquatic organisms can adjust to the thermal environment physiologically, thereby shifting their tolerance range, but this acclimation has limits and ultimately a water temperature may be reached that would be lethal (Figure VI-3). The upper and lower lethal limits of thermal tolerance are typically determined by laboratory experiments and are defined as the temperature resulting in death of 5, 50, or 95 percent of the test organisms (TL5, TL50, TL95). Immobilization or death resulting from sudden increases or decreases in water temperature beyond an organism's upper or lower tolerance limit is often referred to as "heat shock" or "cold shock," respectively.

The tolerance of organisms to extremes of temperature change is influenced by three factors: (1) their genetic ability to adapt to thermal changes within their characteristic temperature range; (2) the acclimation temperature prior to exposure to a change; and (3) the duration of exposure to the elevated or lowered temperature (Coutant 1972). The first factor, genetic ability to adapt to temperature changes, differs among species and among developmental stages within a particular species (Hochachka and Somero 1971). For example, striped bass tolerate higher temperatures than salmon, and juvenile striped bass have higher tolerances than adult striped bass (EA 1978*a*; Coutant 1970).

The second factor, the temperature to which an organism has become physiologically adapted (acclimation temperature), affects aquatic organisms' upper and lower

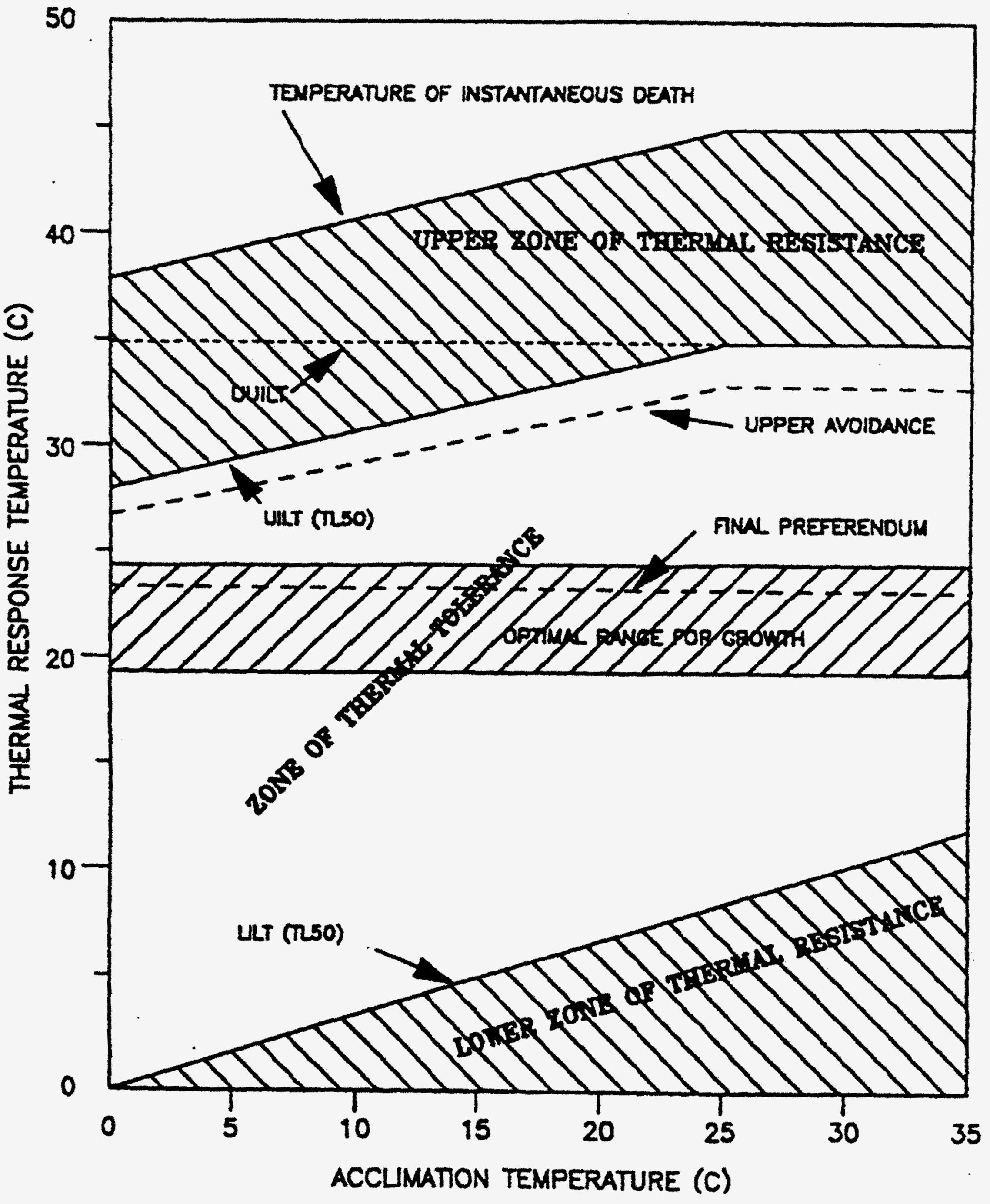

Figure VI-3. Interrelationship of various thermal response parameters and acclimation temperature.

temperature tolerance to long- and short-term periods of exposure (Brett 1956; Coutant 1972; Lauer et al. 1974). True acclimation to changed temperature requires several days to more than a week (Brett 1941; Fry 1971; Hochachka and Somero 1971). Organisms acclimated to warmer temperatures generally can tolerate higher maximum temperatures than if they were acclimated to lower temperatures. For example, the 5-minute TL50 for striped bass post yolk-sac larvae acclimated to 68°F is 91.4°F, while the 5-minute TL50 for the same species life stage acclimated to 78.8°F is 97.9°F.

The third factor crucial to tolerance of temperature change is duration of exposure (Coutant 1972). The tolerance of an organism to temperature changes is a direct function of exposure time. Organisms tolerate exposure to greater changes in temperature if the exposure is for a short period (Brett 1952). For example, striped bass acclimated to approximately 77°F survive an increase in temperature of 29°F (equal to an exposure temperature of 106°F) for only 10 seconds, but tolerate an increase in temperature of 18°F (equal to an exposure temperature of 95°F) for 60 minutes (EA 1979). This time-temperature aspect of tolerance of temperature change means that employing discharge designs that rapidly reduce maximum discharge temperature can minimize potential for heat shock.

iii. Temperature Avoidance

In the case of mobile species, organisms may adjust to their thermal environment behaviorally by movement along existing temperature gradients. When exposed to a temperature gradient, unconfined, free-swimming juvenile and adult fish and other mobile organisms avoid stressful high temperature by moving through the gradient to water having lower temperatures (Meldrim et al. 1974; Neill and Magnuson 1974; TI 1976a; EA 1978a). This is known as "temperature avoidance". Avoidance will occur as water temperature exceeds the species' preferred temperature by more than 2-5°F. This response precludes problems of heat stress from thermal discharge for juvenile and adult fishes and other mobile organisms in open water systems such as the Hudson River estuary (USEPA 1976). The effect of localized elevations in temperature that approach thermal tolerance limits for such species is therefore generally limited to exclusion from otherwise usable habitat. Such exclusion is itself generally only of concern if it threatens to block corridors of migration or eliminate access to habitat critical for the reproduction or survival of the population.

iv. Temperature Preference

By the same token, when exposed to a temperature gradient, juvenile and adult fish and other mobile organisms will tend to move to, and stay within, a preferred temperature range. The preferred temperature first selected by an organism depends on the initial acclimation temperature. Organisms continue to select progressively higher or lower temperatures until they reach their ultimate preferred temperature. This behavior provides a thermal environment that approximates the optimal available temperatures for many physiological functions, including growth (Neill and Magnuson 1974). A species' ultimate preferred temperature is usually near the upper end of its optimum range for growth (Brett 1971; Coutant 1975).

One consequence of thermal preference behavior is that fish in temperate and colder climates usually are attracted to heated water, such as may be caused by power plant discharges, during the fall, winter, and spring. When they are able to stay in the highest temperature portions of the thermal plume long enough to become acclimated to those temperatures, there is potential for cold shock (i.e., a sudden decrease in temperature beyond the organism's lower tolerance limit) in the event of a sudden plant shutdown. A second consequence is that fish will tend to move away from suboptimal temperature fields toward those that are more optimal for growth and performance of life functions.

v. Optimum Temperature Range for Reproduction and Development

Within the range of thermal tolerance there are temperature optima for metabolism controlling essential functions like growth and reproduction. Species are adapted to a range of temperatures in their environment over which they function at close to maximum physiological performance. As water temperatures increase above or below this range physiological performance degrades. The optimum temperature range for growth is different for cold, cool, and warm water species, and also varies among developmental life stages of particular species. For example, the optimum temperature range for growth of most salmonids is between 54.5 °F and 61°F (NAS/NAE 1973); for American shad it is between 64°F and 75°F (Leggett and Whitney 1972; EA 1978a; IA 1978a); and for small juvenile striped bass and blue crabs it is approximately 80-86.5°F (Kellogg and Gift 1983; Meldrim et al. 1974; Holland et al. 1971). The maximum value in a species' temperature range for optimal growth typically coincides with the organism's final temperature preference (Brett 1971; Coutant 1975) and is within 3-5°F of its maximum temperature tolerance for survival. Although growth rates may be altered by relatively short-term changes in water temperature, net growth is the product of thermal history over weeks to months, in addition to a variety of other factors such as habitat type and food availability (Reynolds 1977). As noted by the National Academy of Sciences and National Academy of Engineering (1972), "optimum temperatures (such as those producing fastest growth rates) are not generally necessary at all times to maintain thriving populations and are often exceeded in nature during summer months."

Similarly, spawning can be influenced by an array of factors varying among species, including lunar cycles, tidal elevation, photoperiod (i.e., duration of daylight), salinity, and water currents in addition to water temperature (Hoar 1969; Hardy 1978; Middaugh 1981; Conover and Ross 1982; Conover and Kynard 1984; Tewksbury and Conover 1987). Thus, field observations of typical spawning temperatures in some instances may be merely coincidental, while spawning may be controlled by other factors not necessarily accounted for by qualitative observation. The act of spawning may be relatively instantaneous for an individual organism and may coincide with a relatively narrow range of water temperatures. However, the conditioning that precedes the event and assures that mature individuals are at the appropriate stage of reproductive development when spawning temperatures occur can be a period of weeks or months (Hoar 1969; Hokanson 1977; Jones et al. 1976). Thus, reproductive condition in fish may represent a biological response to the range and average of environmental factors experienced during an extended period. Temperature is only one factor in a complex interrelationship of conditions conducive to spawning. These factors interact to assure that the time of spawning usually coincides with conditions (e.g., temperatures, food availability, salinity) conducive to development and survival of embryo and larval stages.

vi. Thermal Impact Criteria and Standards

The overall regulatory standard (that is, the management goal) for determining the significance of thermal discharge effects on marine ecosystems is defined in the Clean Water Act, as well as in 6 NYCRR Part 704. The discharge temperature and plume size must assure the protection and propagation of a balanced indigenous community (BIC) inhabiting the water body.[1] The overall protection objective described in the case history of thermal discharge regulation shows a clear recognition that "every thermal discharge will have some impact on the biological community of the receiving water."[2] Therefore, in determining compliance with the regulatory standard, "the issue is the magnitude of the impact and its significance in terms of the short-term and long-term stability and productivity of the biological community affected."[3]

To be "balanced", EPA has indicated that an aquatic community must not be "dominated by pollution-tolerant species whose dominance is attributable to polluted water conditions."[4] However, species diversity at each trophic level is not required[5] and some change to species composition and abundance are consistent with a "balanced

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[1] Clean Water Act Section 316(a), 33 U.S.C.Section 1326(a).

[2] Boston Edison Company (Pilgrim Station Units 1 and 2), NPDES Permit Determination No. MA0025135 (Decision of the Regional Administrator, 11 March 1977) at 17.

[3] Boston Edison Company (Pilgrim Station Units 1 and 2), NPDES Permit Determination No. MA0025135 (Decision of the Regional Administrator, 11 March 1977) at 17.

[4] 39 Fed Reg 11,435 (28 March 1974), See also 40 CFR 125.71(c), 44 Fed Reg 32,951-52 (7 June 1979)

[5] See 39 Fed Reg 36,178 (8 October 1974), explaining EPA's final 316(a) regulations were modified from the proposed regulations "to delete the suggestion that diversity must be present at all tropic levels."

community." EPA's thermal assessment guidance (USEPA 1977) lists the following as evidence of community imbalance:

- blocking or reversing short- or long- term successional trends of community development;
- a flourishing of heat-tolerant species and an ensuing replacement of other species characteristic of the indigenous community; and
- simplification of the community and the resulting loss of stability.[6]

USEPA thermal effects guidance further characterizes that "protection" means prevention of appreciable harm, and that "it is not intended that every change in flora and fauna should be considered appreciable harm, unless it impacts an endangered species or a potential critical habitat for an endangered species".[7] One definition of appreciable harm put forth by USEPA is that appreciable harm may occur if a thermal discharge causes such phenomena as the following:

> Substantial increase in abundance or distribution of any nuisance species or heat-tolerant community not representative of the highest community development achievable in receiving waters of comparable quality;
>
> Substantial decrease of formerly indigenous species, other than nuisance species;
>
> Changes in community structure to resemble a simpler successional stage than is natural for the locality and season in question;
>
> Unaesthetic appearance, odor, or taste of the waters;
>
> Elimination of an established or potential economic or recreational use of the waters;
>
> Reduction of the successful completion of life cycles of indigenous species, including those of migratory species; and
>
> Substantial reduction of community heterogeneity or trophic structure (USEPA 1977).
>
> New York State water quality regulations also set forth specific conservative criteria for thermal discharges [6 NYCRR Part 704], that if met, assure

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[6] EPA,316(a) Technical Guidance - Thermal Discharges (Draft 30 September 1974) at 18-19.
[7] USEPA, NRC, and FWS, 316(a) Technical Guidance Manual (Draft 11 December 1975) at 100, 106.

compliance with the regulatory standard. The criteria for estuarine discharges include a limit on the lateral extent of a 4°F temperature rise of two-thirds of the width of the river, and a limit on the cross-sectional area with a 4°F temperature rise to one-half of the river cross-section.

b *Exposure – Thermal Discharge Characteristics*

i. *Discharge Design and Limits*

All three stations have a submerged high velocity diffuser design for their discharges. The diffuser systems at Roseton Units 1 and 2 and Bowline Point Units 1 and 2 are located offshore and that for Indian Point Units 2 and 3 is located in a bulkhead at the edge of the river channel (see Section IV-B). This design is consistent with the USEPA recommendation that CWS systems at estuarine and coastal sites should optimize the dissipation of heat and minimize the area affected by excessive temperature (USEPA 1974). It is also consistent with USEPA's further emphasis that thermal discharges should be located in areas with good flushing characteristics and should minimize the addition of heat into intertidal (i.e., nearshore) zones.

The high exit velocity (up to approximately 10 ft/sec) of the diffusers results in relatively rapid dilution. The excess temperature of the discharge is reduced to about 50% of the initial excess temperature within about 50, 300, and 1000 ft of the discharge ports for Bowline Point Units 1 and 2, Roseton Units 1 and 2, and Indian Point Units 2 and 3, respectively. The short potential exposure time and rapidly declining temperature within the zone of initial mixing (ZIM) reduce the potential for mortality and sub-lethal effects on the reproduction and growth of organisms that drift through the plumes, and minimize the area affected by the higher plume temperatures. The potential for lethal effects of winter cold shock, in the event of a sudden station shutdown, are also reduced because the high exit velocities and turbulence, as well the dynamic tidal currents, prevent fish from staying in the warmest temperatures of the plume long enough to become acclimated to those temperatures. Beyond the initial zone of mixing, the bouyant thermal plume lifts from the bottom and becomes a surface-oriented phenomenon. As a result exposure of the benthic infauna and bottom-oriented macroinvertebrates and fish is limited at most to the immediate vicinity of the discharges.

ii. *Characterization of Discharge Temperature Distributions*

The effects of individual power plants on Hudson River temperature distribution have been extensively studied by the utilities. Field, mathematical model, and hydraulic studies have been performed at each power plant. More comprehensive descriptions of the river temperature distribution caused by each power plant can be found in the individual studies done for each plant (CHG&E 1977; Consolidated Edison and Power Authority of the State of New York 1978a; O&R 1977; LMS 1968, 1978c).

To characterize excess temperature distributions from the station discharges, it is necessary to compare river temperatures in the presence of thermal discharges to ambient temperatures that would be present without any thermal discharges. Since the Hudson River receives heat from the three stations being evaluated and from other permitted discharges, it is seldom if ever possible to measure the ambient temperature. A further difficulty in determining ambient temperatures occurs because the natural process by which heat is gained and lost produces a variable temperature pattern throughout the estuary (see Section V-B-4). Thus, the ambient condition must be defined for each location in the estuary at which heated water temperatures are to be evaluated. These considerations require that both models and empirical measurements be employed to characterize excess temperature distributions.

The ecological effects of power plant discharges depend in part on the degree and distribution of heat input to the environment. Of interest are water temperatures in the immediate vicinity of a power plant where the discharged heat occupies a clearly distinguishable plume (the near-field), and those farther away from the plant where the plume is no longer distinguishable from the river, but the thermal influence is still present (the far-field). Computer models and temperature data recorded in the Hudson River were used to perform these evaluations. Because different physical processes control the transfer and dissipation of heat in the near-field and far-field, two different computer models were used to evaluate the expected influence of thermal discharges from the Roseton Units 1 and 2, Indian Point Units 2 and 3, and Bowline Point Units 1 and 2 power plants. The thermal discharges from these plants were considered individually and in combination, and were evaluated in the context of the thermal effects discussed above and the existing New York State thermal water quality criteria.

The computer model selected to forecast the far-field conditions in the Hudson River was the Massachusetts Institute of Technology (MIT) dynamic network model. This model was selected because of its established credibility, prior application to the Hudson, and ability to simulate hydraulic and thermal processes at an appropriate level of spatial and temporal detail. The model accounts for time-variable hydraulic and meteorological conditions and heat sources of artificial origins, and produces riverwide temperature distributions along the 153 river miles between Troy and Manhattan.

The Cornell University Mixing Zone Model (CORMIX) was selected to estimate near-field conditions in the Hudson River. The model produces information on the three-dimensional configuration of the plume, assuming steady-state flow conditions for both the discharge and ambient environment. CORMIX represents the state of the art in computer modeling of aqueous discharge plumes and is the most widely accepted tool for evaluating these plumes. Full descriptions of the MIT and CORMIX models, including all model input data and data sources, are presented in Appendix VI-3-A.

The period studied was limited to the summer months (June through September), when river temperatures reach their annual maximum levels. Data for 1981 were used to calibrate and verify the far-field model, and to evaluate temperature distributions in the Hudson River under a variety of power plant operating conditions. The summer months of 1981 were selected for two reasons: (1) data for all of the thermal discharges were available for this year, and (2) statistical analysis of the 1981 summer conditions indicated that this year represents a relatively low-flow, high-temperature summer (Appendix VI-3-A), and therefore presents a conservative scenario for assessing compliance with the criteria. The near-field model was validated using river temperature data recorded at Bowline Point Units 1 and 2 in August of 1975 and Roseton Units 1 and 2 in August of 1976.

Two power plant operating scenarios were evaluated with the models to characterize the temperature distributions produced by the discharges and assess the degree to which the NYSDEC thermal criteria would be met:

1. Individual station effects - full capacity operation of Roseton Units 1 and 2, Indian Point Units 2 and 3, or Bowline Point Units 1 and 2; no other sources of artificial heat

2. Extreme operation conditions - Roseton Units 1 and 2, Indian Point Units 2 and 3, Bowline Point Units 1 and 2, and all other major sources of artificial heat operating at full capacity

In preparing a preliminary DEIS, modeling was performed using the MIT and CORMIX Version 2.0 under conditions of maximum ebb and flood currents. Those results have been supplemented herein with modeling performed with MIT and CORMIX Version 3.2 to examine hypothetical conditions represented by the lowest 10th percentile flood currents, mean low water depths in the vicinity of each Station, and concurrent operation of all generating stations at maximum permitted capacity (Appendix IV-3-B). To differentiate these conditions from the maximum flood and ebb conditions considered earlier, they are called "near-slackwater" conditions. The 10th percentile of flood currents was selected since these are close to the lowest velocities at which CORMIX can be expected to produce usable results, and because the modeling suggests that flood currents produce larger plumes than ebb currents.

Results obtained from these model runs included the riverwide temperature profile for each condition studied, the far-field temperature rises above ambient conditions for various operating scenarios, the surface width, the depth of the plume, the percentage surface width, and the percentage cross-sectional area bounded by the 4°F temperature rise. In addition, the decay in excess temperature with centerline distance was obtained from the "near-slackwater" model runs. All of these results are presented in detail in Appendix VI-3. A summary of important findings follows below.

Two-unit operation at full capacity of the Roseton Units 1 and 2 Generating Station itself resulted in an increase in monthly average cross-sectional temperature near Roseton Units 1 and 2 that ranged from 1.26°F during ebb tides in June to 1.77°F during flood tides in August (Table VI-4). The maximum average percent of the river's surface width with a temperature rise ≥4°F was 11%. This value occurred during flood tides in July and on both flood and ebb tide in August. The average percentage of the cross section with a temperature rise >4°F was 5% at both flood and ebb tide in all four months.

When the temperature rise contribution of all plants on the river was considered, with each plant operating at capacity and therefore discharging its maximum heat load, the monthly average cross-sectional temperature rise near Roseton Units 1 and 2 on running tides ranged from 1.64°F (June -flood tide) to 2.48°F (September - ebb tide). On near-slack tide the monthly average cross-sectional temperature ranged from 1.31°F (June) to 2.14°F (September). The percentage of the surface width bounded by the 4°F isotherm on running tides ranged from 9% (June - ebb tide) to 31% (September - flood tide). On near-slack tide the percentage of the surface width bounded by the 4°F isotherm ranged from 17% (June) to 51% (September). The range for the average cross-sectional area bounded by a 4°F increase is 5% (June) to 8% (September) on running tides and 5% to 16% on near slack tide.

Two-unit operation at full capacity of the Bowline Point Units 1 and 2Generating Station itself resulted in a monthly average temperature increase in the Bowline Point Units 1 and 2 vicinity of 0.59°F (September - flood tide) to 0.79°F (July flood tide) (Table VI-5). Only 3% of the river's surface width and 3 to 4% of its cross section were bounded by the 4°F temperature rise isotherm.

When the temperature rise contribution of all plants on the river was considered, with each plant operating at capacity and therefore discharging its maximum heat load, the monthly average cross-sectional temperature rise near Bowline Point Units 1 and 2 on running tides ranged from 2.64°F (June - ebb tide) to 3.78°F (August - flood tide). On near-slack tide the monthly average cross-sectional temperature ranged from 2.20°F (June) to 2.96°F (July). On running tides, the average percentage of the surface width bounded by the 4°F isotherm

TABLE VI-4

MODEL PREDICTIONS FOR MONTHLY AVERAGE SUMMER TEMPERATURE BEHAVIOR AT ROSETON

	JUNE		JULY		AUGUST		SEPTEMBER	
HEAT LOAD CONDITION	**FLOOD**	**EBB**	**FLOOD**	**EBB**	**FLOOD**	**EBB**	**FLOOD**	**EBB**
Roseton Only								
- Far-field model ΔT	1.28	1.26	1.69	1.68	1.77	1.75	1.44	1.44
- Plume width, ft, >4 F	252	246	394	385	426	426	246	246
- Plume depth, ft, >4 F	29	29	21	20	19	19	29	29
- Percentage river width >4 F	7	7	11	10	11	11	7	7
- Percentage river cross-section >4 F	5	5	5	5	5	5	5	5
Roseton, Indian Point & Bowline								
- Far-field model ΔT	1.32	1.31	1.79	1.78	1.92	1.90	2.00	1.99
- Plume width, ft, >4 F	252	246	512	446	607	590	636	656
- Plume depth, ft, >4 F	29	29	17	18	15	15	15	14
- Percentage river width >4 F	7	7	14	12	16	16	17	18
- Percentage river cross section >4 F	5	5	6	5	6	6	6	6
All Plants								
- Far-field model ΔT	1.64	1.65	2.29	2.30	2.41	2.41	2.47	2.48
- Plume width, ft, >4 F	350	364	949	944	1110	1059	1128	1102
- Plume depth, ft, >4 F	22	21	11	11	10	11	11	11
- Percentage river width >4 F	9	10	25	25	30	28	31	30
- Percentage river cross section >4 F	5	5	7	7	8	7	8	8

River dimensions at Roseton: Surface width = 3,700 ft Mean depth = 41 ft Cross sectional area = 152,000 sf

TABLE VI-5

MODEL PREDICTIONS FOR MONTHLY AVERAGE SUMMER TEMPERATURE BEHAVIOR AT BOWLINE POINT

HEAT LOAD CONDITION	JUNE		JULY		AUGUST		SEPTEMBER	
	FLOOD	EBB	FLOOD	EBB	FLOOD	EBB	FLOOD	EBB
Bowline Only								
- Far-field model ΔT	0.61	0.62	0.79	0.78	0.75	0.75	0.59	0.60
- Plume width, ft, >4 F	428	370	442	380	428	380	443	381
- Plume depth, ft, >4 F	23	23	23	23	23	23	23	23
- Percentage river width >4 F	3	3	3	3	3	3	3	3
- Percentage river cross section >4 F	4	3	4	3	4	3	4	3
Roseton, Indian Point & Bowline Point								
- Far-field model ΔT	2.31	2.21	3.03	2.87	3.14	3.02	2.47	2.48
- Plume width, ft, >4 F	935	648	2065	1484	2191	1662	1128	1102
- Plume depth, ft, >4 F	14	15	10	11	10	11	11	11
- Percentage river width >4 F	7	5	14	10	15	12	8	8
- Percentage river cross section >4 F	5	4	8	6	8	7	5	5
All Plants								
- Far-field model ΔT	2.75	2.64	3.74	3.55	3.78	3.62	3.32	3.24
- Plume width, ft, >4 F	1465	1135	3626	2484	3634	2669	2453	1863
- Plume depth, ft, >4 F	10	11	18	14	19	16	12	12
- Percentage river width >4 F	11	8	25	17	25	19	17	13
- Percentage river cross section >4 F	6	5	24	13	26	16	11	8

River dimensions at Bowline Point   Surface width = 14,300 ft   Mean depth = 19 ft   Cross sectional area = 270,000 sf ranged from 8% (June - ebb tide) to 25% (July and August - ebb tide). On near-slack tide the percentage of the surface width bounded by the 4°F isotherm ranged from 16% (June) to 44% (July). The range for the average cross-sectional area within the 4°F isotherm was 5% (June - ebb tide) to 26% (August - flood tide) on running tides and 5% to 22% on near slack tide.

Two-unit operation at full capacity of the Indian Point Units 2 and 3 Generating Station itself resulted in monthly average cross-sectional temperature increases ranging from 2.13°F on the ebb tide in June to 2.86°F on the ebb tide in August (Table VI-6). The average percentage of the river surface width bounded by the 4°F temperature rise isotherm ranged from 54% (August - ebb tide) to 100% (July and August - flood tide). Average cross-sectional percentages bounded by the plume ranged from 14% (June and September) to approximately 20% (July and August).

When the temperature rise contribution of all plants on the river was considered, with each plant operating at capacity and therefore discharging its maximum heat load, the monthly average cross-sectional temperature rise in the Indian Point Units 2 and 3 vicinity on running tides ranged from 3.24°F on ebb tide in June to 4.63°F on flood tide in August. Temperature rise exceeded 4°F on both tide stages in July and August. This condition, and the extremely variable geometry of the river near Indian Point Units 2 and 3, forced some modifications in the way the plume was defined. The modifications are described in Appendix VI-3. On near-slack tide the monthly average cross-sectional temperature ranged from 2.70°F (June) to 3.73°F (August). On running tides, the average percentage of the surface width bounded by the redefined plume ranges between 36% (September - ebb tide) and 100% (flood tide in all months). On near-slack tide the percentage of the surface width bounded by the 4°F isotherm was 99% to 100% in all months. The corresponding range for the average percentage of the cross-sectional area bounded by the redefined plume ranged from 27% (June - ebb tide) to 83% (August - flood tide) on running tides and was 24% in all months on near slack tide.

iii. Conclusions from the Assessment of Thermal Discharge Characteristics

The high velocity diffuser designs of the discharges at Indian Point Units 2 and 3, Roseton Units 1 and 2, and Bowline Point Units 1 and 2, in combination with the dynamic tidal nature of the receiving waterbody, minimize the potential for significant thermal impacts on a BIC. The hydrothermal field monitoring and modeling also demonstrate that the thermal plumes from Roseton Units 1 and 2 and Bowline Point Units 1 and 2 readily meet the criteria established in 6 NYCRR Part 704 for maximum surface width and cross-section of the 4°F temperature rise. Absent evidence to the contrary, the Roseton Units 1 and 2 and Bowline Point Units 1 and 2 discharges can be assumed to meet the protection

TABLE VI-6

MODEL PREDICTIONS FOR MONTHLY AVERAGE SUMMER TEMPERATURE BEHAVIOR AT INDIAN POINT

HEAT LOAD CONDITION	JUNE		JULY		AUGUST		SEPTEMBER	
	FLOOD	EBB	FLOOD	EBB	FLOOD	EBB	FLOOD	EBB
Indian Point Only								
- Far-field model ΔT	2.14	2.13	2.81	2.82	2.85	2.86	2.14	2.15
- Plume width, ft, >4 F	2689	2622	2713	3271	2713	2240	2837	2611
- Plume depth, ft, >4 F	9	9	12	10	12	16	8	9
- River width, ft	3311	4259	2713	5404	2713	4131	3136	4120
- River mean depth, ft	48	38	57	31	57	39	51	39
- Percentage river width >4 F	81	62	100	61	100	54	90	63
- Percentage river cross section >4 F	14	14	21	20	21	22	14	14
Roseton, Indian Point & Bowline								
- Far-field model ΔT	2.76	2.73	3.69	3.70	3.78	3.79	3.24	3.26
- Plume width, ft, >4 F	2660	3053	2330	4636	2126	4316	3136	3674
- Plume depth, ft, >4 F	12	10	33	19	41	19	14	13
- River width, ft	2661	5430	2330	10,283	2126	8219	3136	7213
- River mean depth, ft	58	31	61	19	66	19	48	25
- Percentage river width >4 F	100	56	100	45	100	43	100	51
- Percentage river cross section >4 F	20	19	53	45	62	43	29	28
All Plants								
- Far-field model ΔT	3.29	3.24	4.56[a]	4.55[a]	4.63[a]	4.62[a]	3.89	3.89
- Plume width, ft, >4 F	2914	3488	1926	4106	2030	3952	2060	4743
- Plume depth, ft, >4 F	16	13	51	15	59	16	56	9
- River width, ft	2914	7054	1926	8258	2031	8606	2060	13,120
- River mean depth, ft	51	25	72	22	71	21	69	13
- Percentage river width >4 F	100	49	100	50	100	46	100	36
- Percentage river cross section >4 F	32	27	71	33	83	34	81	71

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[a] For these cases, plume dimensions are bounded by 4.7 F in flood and 5.1 F in ebb. See Appendix VI-3.

standard by virtue of their compliance with the thermal water quality criteria, especially given that the criteria are established to be conservatively protective of the standard.

Characterization of the plume temperature distributions from the Indian Point Units 2 and 3 discharge using very conservative assumptions indicates that the 4°F lateral extent and cross-sectional criteria may sometimes be exceeded. However, these characterizations are nearly absolute upper bounds estimates. The plume dimensions that would normally occur would be much smaller than predicted by the modeling because:

- the plant operating conditions modeled (continuous operation of all plants at maximum permitted capacity) in practice seldom, if ever, occurs;
- tidal and river flow conditions modeled represent extreme conditions; and
- modeling assumed steady state conditions, while in reality plume configuration shifts dynamically with changes in tidal flows.

In any case, as the regulations themselves recognize, exceedance of the thermal criteria does not necessarily indicate that the protection standard is not met. Both federal and state regulations provide for a variance from discharge limits designed to meet the criteria, where such limits are more stringent than necessary to meet the standard.

As provided for in the regulations, the current discharge permits for all three stations contain limits for their discharges different from those in Part 704, but still sufficient to meet the standard. The current Indian Point Units 2 and 3 permit restricts the maximum discharge temperature to 110°F and provides that daily average discharge temperature will not exceed 93.2°F for an average 10 days between April 15 and June 30, and in any event for not more than 15 days any year. The current Bowline Point Units 1 and 2 SPDES permit mandates a daily maximum discharge temperature of 102°F. At Roseton Units 1 and 2 the existing SPDES permit allows a daily maximum discharge temperature of 99°F plus the temperature differential if intake water temperature exceeds 81°F.

c. Effects of Thermal Discharges on Aquatic Biota

i. Nature and Likelihood of Biothermal Effects

During the early 1960s, a rapid rate of increase in electrical demand was projected to continue indefinitely. Larger generating units with increased cooling water flows were being built to meet this increasing demand. Early concerns were that some of these were being built along streams that were too small to assimilate the thermal discharge without major ecological impacts. As a result waste heat was defined as a pollutant in the Federal Water Pollution Control Act of 1965. The major concerns that led to the inclusion of heat as a pollutant are reflected in federal water quality criteria and other documents issued for guidance to the States and other interested parties. These include guidance issued in 1968 by the National Technical Advisory Committee (NTAC), 1972 by the National Academy of Sciences (NAS), and 1974, 1975 and 1977 by the U. S. Environmental Protection Agency (EPA). Biotic categories addressed by this guidance are phytoplankton, zooplankton, rooted aquatic vegetation (habitat formers), macroinvertebrates/shellfish, fish, and other vertebrate wildlife. The major biothermal effects of concern were mortality from excess heat; mortality from cold shock; blockage of migration; and reduced growth or reproductive success.

In response to those concerns, offshore, submerged, high velocity discharges were designed and built at the Roseton Units 1 and 2, Indian Point Units 2 and 3, and Bowline Point Units 1 and 2 power plants to achieve low potential impact thermal plumes (NTAC 1972; EPA 1974; EPA 1977) by inducing turbulence, rapid dilution and reduction of the discharge temperatures, and by minimizing contact of the near-field plume with near-shore bottom habitats. Extensive laboratory studies, in-plant studies, field studies and assessments performed during the 1970s provided convincing evidence that operation of the Roseton Units 1 and 2, Indian Point Units 2 and 3 and Bowline Point Units 1 and 2 cooling water systems do not cause appreciable harm to the phytoplankton, zooplankton, macroinvertebrate/shellfish, aquatic rooted vegetation or other vertebrate wildlife. Concerns persisted about potential for long-term adverse impacts, primarily of entrainment and impingement on several species of fish. Since 1980 most of the utility-sponsored studies have focused on the fish biotic category.

ii. Mortality from Excess Temperature

A station's thermal discharge could potentially cause mortality of organisms if the temperature and duration of exposure exceeded the upper tolerance limit of the species. Mortality from chronic exposure to excess temperatures at the Roseton Units 1 and 2, Indian Point Units 2 and 3, and Bowline Point Units 1 and 2 stations is, in reality, negligible for several reasons. First, exposure of individuals to higher plume temperatures for more than a few minutes to a few hours is highly unlikely. This is because the location and orientation of the plumes is highly dynamic. They sweep back and forth with the tides, occupying any one orientation for a maximum of a few hours. Also, velocities within the ZIM are too high for organisms to occupy that portion of the plume more than momentarily. Even beyond the ZIM, organisms are unlikely to maintain one position for long due to the high tidal flow velocities that occur in the estuary. Finally, thermal mortality has rarely been documented for mobile life stages in the vicinity of any thermal plume because fish avoid potentially lethal temperatures (Appendix VI-3-A). This would be especially true at these power plants, because of their discharge designs. The rapid dilution of temperatures and open water location of these discharges minimizes the potential for thermal attraction to the plume and allows free movement of organisms. No instances of thermal mortality of juvenile and adult fish have been observed over the many years of operation of the stations.

Planktonic forms such as phytoplankton, zooplankton, and fish eggs and larvae may be entrained into the thermal plume as the discharge mixes with ambient water. Little, if any, mortality from thermal exposure would be expected at these plants because the rapid reduction of temperatures limits the duration of exposure to potentially lethal temperatures. Even the small number of organisms that might be entrained at the point of discharge would experience stressful temperatures for a period ranging from seconds to at most several minutes during transit through the ZIM. Laboratory data on a wide variety of macroinvertebrate and fish species indigenous to the Hudson River indicates that their tolerance to short-term temperature elevations exceeds maximum discharge temperatures under full operating load at these plants during most of the year, including the peak spring spawning period (Figure VI-4). Temperatures that may exceed short-term tolerance limits of these planktonic forms during peak summer temperatures are restricted to a small area within a few hundred feet of the discharge (Figure VI-4).

iii. Mortality from Cold Shock

As described above in subsection VI-A-2-i, when prevailing background water temperatures are cool during the late fall, winter, and early spring, plume temperatures generally would be preferred by fish species. Cold shock may occur if fish acclimated to elevated temperatures of the plume experience a rapid decrease in temperature, as in the event of a sudden station shutdown. Whether mortality actually occurs depends upon whether the organism is acclimated to elevated plume temperatures and whether it can tolerate the rate and magnitude of the temperature decrease.

The risk of mortality from temperature drops at the three stations is negligible for several reasons. First, acclimation of organisms to the higher plume temperatures is highly unlikely. This is because the location and orientation of the plumes is highly dynamic, sweeping back and forth with the tides, and therefore occupying any one position for a maximum of several hours. Also, velocities within the ZIM are too high for fish to occupy that portion of the plume more than momentarily (Appendix VI-3-A). Even beyond the ZIM, organisms are unlikely to maintain one position for long due to the high tidal flow velocities that occur in the estuary. Mortality attributable to cold shock has usually been associated with shoreline discharges, where low discharge velocity and confined areas (e.g. canals) of high discharge temperatures cause fish to congregate in winter. This does not occur at the three stations because of their high-velocity, open-water discharges and the high tidal energy of the Hudson River estuary. In fact the NAS has indicated that the risk of cold shock can be precluded by high-velocity, turbulent

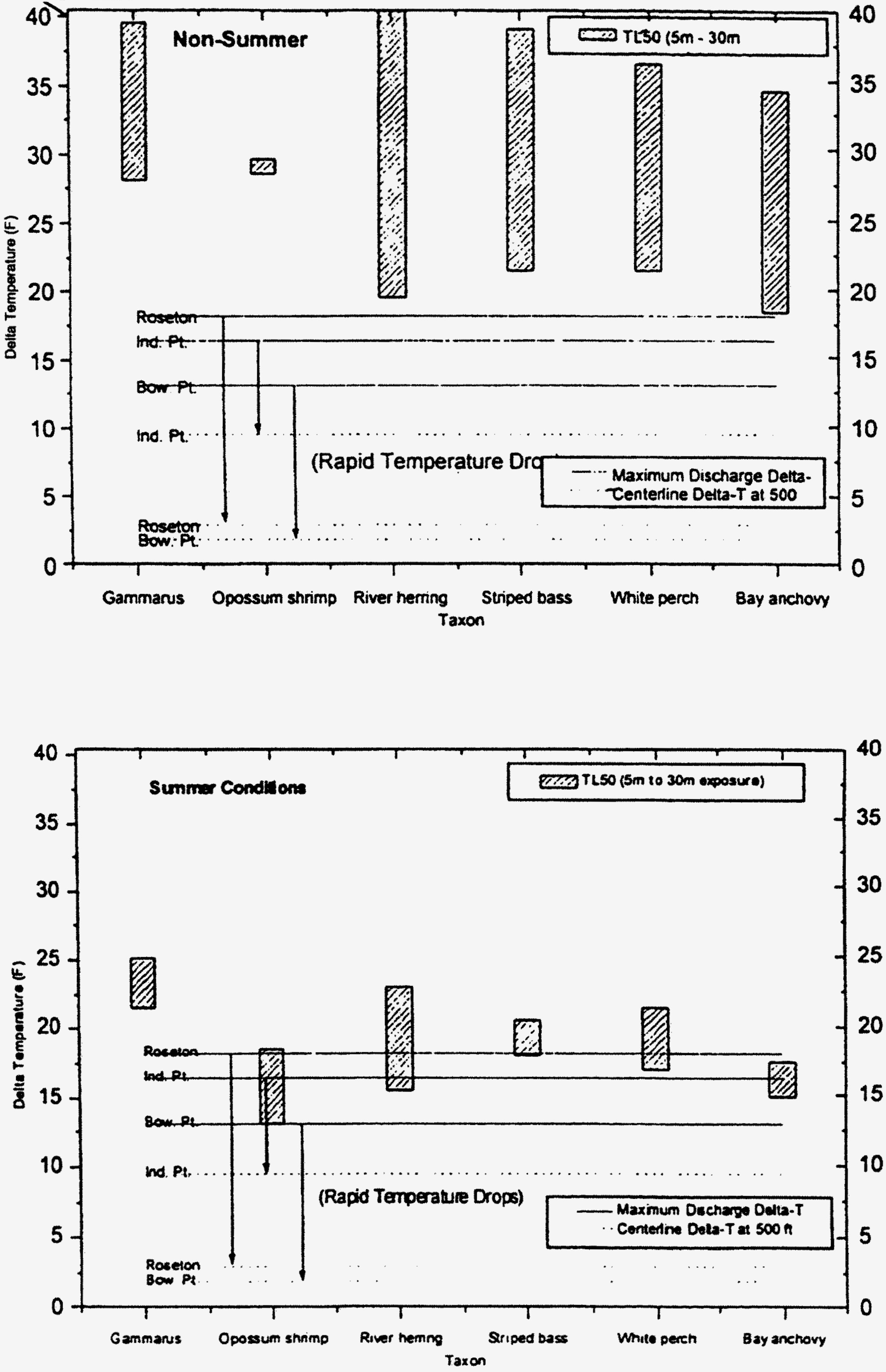

Figure VI-4. Range of short-term thermal tolerances of macroinvertebrates and fish larvae/early juveniles compared to delta-T at and shortly following discharge.

discharges that prevent residence to the higher temperatures of the plume for lengths of time sufficient to allow metabolic acclimation (NAS 1972). Finally all three stations consist of two separate units with the same discharge location, which greatly reduces the potential for the warm plume to disappear suddenly and create conditions conducive to cold shock. No instances of mortality from cold shock have been observed over the many years of operation of the stations.

iv. Blockage of Migration

Free-swimming juvenile and adult fish would avoid stressful high temperature in the plume by moving along temperature gradients to water having lower temperatures (Section VI.A.2.i). As discussed above, this response precludes mortality of juvenile and adult fish from exposure to excess temperatures in the stations' plumes. However, the avoidance response also may preclude diadromous species from migrating past the stations during their spawning or emigration runs. The solution is to maintain adequate zones of passage with temperatures below avoidance response temperatures of the relevant species. The NAS recommended leaving 1/3 of the cross-section free as a zone of passage (NAS 1972). New York State regulations (6 NYCRR Part 704) also set forth specific criteria for discharges that if met would assure protection and propagation of the BIC. The criteria for estuarine discharges include a limit on the lateral extent of a 4°F temperature rise to two-thirds of the width of the river, and a limit on the cross-sectional area with a 4°F temperature rise to one-half of the river cross section. These limits are highly conservative since laboratory data indicate that temperature elevations causing avoidance would likely exceed 10°F during the migrations of alewife, blueback herring, American shad, and striped bass (Table VI-7).

Even using the conservative 4°F criterion, the hydrothermal characterization of the plumes indicates that adequate zones of passage for migration are continuously maintained at Roseton Units 1 and 2 and Bowline Point Units 1 and 2. The modeling studies predict that the thermal criteria for lateral extent and cross-sectional area contained within a 4°F rise could be exceeded in the vicinity of Indian Point Units 2 and 3 during some months and tidal stages under full load operating conditions. However, as noted above, temperature elevations causing avoidance during the primary migratory periods would have to be considerably higher than 4°F. The surface orientation of the plume allows a zone of passage in the lower portions of the water column, the preferred habitat for many of the indigenous species. In addition, even if the higher plume temperatures exceed the predicted avoidance temperature for juveniles and adults of some species, complete exclusion from these areas of the plume would be unlikely. While plume areas at temperatures greater than the avoidance temperature may not be used for long-term habitation, these areas could still be utilized for migration. This is because fish can tolerate even those temperatures exceeding their upper incipient lethal temperatures for

TABLE VI-7

PREDICTED[1] EXCESS TEMPERATURES THAT WOULD BE AVOIDED BY MIGRATING FISH

	AVOIDANCE DELTA-T (°F)				
ACCLIMATION TEMPERATURE	**ALEWIFE (0+ TO ADULT)**	**BLUEBACK HERRING (0+)**	**Blueback herring (1+&older)**	**Striped bass (0+)**	**Striped bass (1+ to adult)**
40	17	29	17	36	19
45	16	27	17	33	19
50	15	25	18	30	19
55	15	22	18	26	19
60	14	20	19	23	19
65	13	17	19	20	19
70	12	15	20	17	18
75	11	12	20	14	18
80	10	10	21	10	18

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[1] Based on linear regression of laboratory measured avoidance temperature reported in the literature on acclimation temperature used in the tests.

brief periods (Section VI-A-2-i). No appreciable harm due to blockage of migration would therefore be expected from any of the stations.

v. *Reduced Growth or Reproductive Success*

Depending upon the species, thermal discharges could potentially either increase or decrease growth of the organisms exposed to the plume by shifting water temperatures toward or away from the species' optimum growth range. Reduction in growth could potentially cause harm to the populations by decreasing reproduction and survival.

Although temperatures in the higher temperature portions of the plume may exceed the predicted upper growth temperature for some species, reduced growth would be unlikely for at least two reasons. First, plume temperatures earlier in the growth season would be closer to optimum growth temperature than are ambient water temperatures during that season, thus enhancing growth. In addition, growth is dependent on factors other than temperature such as food availability, nutrition quality, and availability of shelter.

Second, organisms would have to be exposed to excessive temperatures for long periods of time to measurably affect growth. For example, laboratory growth tests on aquatic organisms are typically conducted for 7 to 28 days or longer in order to detect changes in growth. Planktonic forms, such as Gammarus and fish larvae, would only be briefly exposed to the higher plume temperatures as they drift with the discharge flow and tidal currents. Since the stations' thermal plumes are highly dynamic and shift location every few hours, it would be highly unlikely that the mobile juvenile and adult fish would remain continuously near the area of temperatures exceeding the upper end of the optimum growth range for a sufficient time to alter their ultimate growth. Further, preferred temperatures for a given species generally lie within the optimal temperature range for growth. Consequently, it is unlikely that fish with temperature avoidance capability would maintain a position at a specific temperature in excess of their preferred and optimal range for growth in a constantly changing and moving plume in for periods long enough to have an effect on growth. Within the estuary, optimal ambient conditions for growth and spawning for some species exist for only brief periods, and the thermal plume may provide these conditions sooner or extend them later into the annual ambient temperature cycle.

In summary, based on the biothermal literature, the design and location of the stations' CWS discharges, and studies of the resulting excess temperature distributions, the potential for substantial temperature effects on the biota is negligible at all three power plants. Observable effects, if any, would be expected to be limited to a relatively small area of high temperature in the vicinity of the discharge, and involve too small a proportion of the populations and available habitat to cause appreciable harm to the balanced indigenous community.

vi. *Retrospective Evidence on Protection and Propagation of the BIC*

The biological monitoring program carried out under the 1981 and 1987 permits has focused its efforts on the fish populations of the estuary. This focus on fish, agreed upon by DEC and the utilities, is appropriate because, as members of the middle and higher levels of the trophic structure, fish integrate effects that may occur on lower trophic levels. If the discharges were to materially reduce primary production or production by zooplankton, effects on fish would be expected.

In fact, numerous studies of power plant thermal discharges into estuaries (including the Hudson River – see Appendix V-1) and coastal marine waters during the 1960s and 1970s have also directly shown that adverse effects on aquatic communities are rare and only occur in a small area in the immediate vicinity of the discharge. Such effects are limited to periods of maximum discharge temperatures during the summer and during those hours when the circulating water was chlorinated to control biofouling of the condensers (Jensen 1974, 1978; EA 1978c; UWAG 1978a, 1978b; EA 1978c; Tetra Tech 1978; UWAG 1982). Thermal-effect measures used in these studies included maximum temperature tolerance of resident assemblages of phytoplankton and zooplankton species, as determined in laboratory studies, changes in community structure, abundance of nuisance species, standing crop (biomass), and photosynthetic rate. Power plant sites studied include freshwater systems, estuaries, and ocean sites (UWAG 1982).

The expectation that the thermal discharges from the Roseton Units 1 and 2, Indian Point Units 2 and 3, and Bowline Point Units 1 and 2 power plants would cause no appreciable harm to the balanced indigenous community is supported by the results of the utilities' biological monitoring studies. Assessments of the fish population trends (see Sections V-D-3 and VI-A-3-a) show no indication of substantial decrease in abundance or disruption of the life-cycles of indigenous species attributable to the thermal discharges.

There is no evidence of substantial increase in the abundance of any nuisance species attributable to the thermal discharges. Since 1991, the zebra mussel has invaded the freshwater areas of the Hudson River estuary (Section V-D-1), causing demonstrable reduction in the phytoplankton and zooplankton communities in freshwater areas of the Hudson. However, its presence is the result of dispersion throughout the waterways of the mid-west and northeast following its accidental introduction to the Great Lakes in the 1980s, and not a result of thermal factors.

Assessments of the fish community trends (Section V-D-3) show no indication of simplification of the community, reduction in heterogeneity or trophic structure, or interruption of the life-cycle functions of the estuary attributable to the thermal discharges. The community analyses indicate that:

- The estuary's fish community has remained species rich and dominated by the same 10-15 species over a period of 24 years during which the power plants have been in operation.
- Observed declines in fish species richness, i.e., changes in the number of freshwater species collected, may be related to habitat alteration in freshwater reaches of the river as a result of the dramatic expansion of water chestnut beds in the 1970s.
- The tidal freshwater reaches of the estuary continue to be dominated by diadromous species at the larval and young-of-year stages, confirming that adequate zones of passage past the stations' discharges have been maintained.
- Use of the estuary as reproductive habitat in the life-cycle of the indigenous populations has remained undiminished. Species richness and overall abundance of the larval fish community has increased over the 24-year monitoring period, possibly as a result of improvements in water quality in New York Harbor allowing increased migratory passage from the ocean to brackish and freshwater spawning areas in the estuary.

Use of the estuary as nursery habitat remains unharmed. Overall abundance of young-of-year and yearling fish has fluctuated, as expected in naturally dynamic systems like the Hudson River estuary. Recent increases in abundance of young-of-the-year in brackish water reaches of the estuary have occurred and may be related to improvements resulting from improved sewage treatment in the lower estuary. Declines in young-of-year abundance observed in the freshwater reaches are attributable to declines in a single species, blueback herring, which has declined throughout its range due to overfishing in open ocean waters.

In summary, based on retrospective analysis of data from the utilities' monitoring program, there is no evidence of appreciable harm from over two decades of operation of the Indian Point Units 2 and 3, Roseton Units 1 and 2, and Bowline Point Units 1 and 2 power plants. These results reinforce and confirm the expectation from the predictive biothermal assessment. That is, the thermal discharges from these three power plants provide for the protection and propagation of a balanced indigenous community in the Hudson River Estuary.

5. Water Quality Effects

a. Water Quality Standards

Classification and standards of quality and purity for surface waters in the State of New York are set forth in Article 2, Chapter X of the Rules and Regulations of the New York State Department of Environmental Conservation (DEC). Part 700 defines the terms used in Chapter X and the methods of evaluating water quality. Part 701 contains water quality classification. In particular, 6 NYCRR 701.6 defines the best usages of Class A water as a source of (potable) water supply, primary and secondary contact recreation, and fishing. Best usages of Class B (fresh surface waters) and Class SB (saline surface waters), defined in 6 NYCRR 701.7 and 701.11 are primary and secondary contact recreation and fishing; these waters are also suitable for fish propagation and survival. Finally, Class D water is defined in 6 NYCRR 701.9 as best used for fishing. The Hudson River is classified SB in the vicinity of Bowline Point Units 1 and 2 and Indian Point Units 2 and 3 (6 NYCRR Part 864). In the vicinity of Roseton Units 1 and 2 the Hudson River is classified A and a tributary in which discharges are made is classified D (6 NYCRR Part 858).

The derivation and use of standards and guidance values for water quality are set forth in 6 NYCRR Part 702. Specific quality standards and effluent standards are presented in Part 703. Criteria and effluent limitations applicable to Roseton Units 1 and 2, Indian Point Units 2 and 3, and Bowline Point Units 1 and 2 are presented in Section IV-B.

b. Permitted Chemical Discharges

As discussed in Section IV-B, the description of generating stations, the SPDES permits will include provision for discharges of non-cooling water effluents. Some of these waste streams contain chemical constituents that will be discharged in accordance with discharge limitations stated in the permit and monitored to assure compliance. The existing permits and permit renewal applications describe the chemical composition, effluent limits, and monitoring requirements for each waste stream.

SPDES permits issued by DEC contain effluent limitations that are set to assure maintenance of water quality and attainment of the uses specified in the water quality standards for the receiving body. The effluent limits are developed using mathematical models that simulate a specific substance in a specific segment of the water body. For toxic pollutants mass balance methods are used. This modeling technique assumes that none of the contaminants are lost or removed from the receiving water due to processes such as biological degradation, adsorption to particles, sedimentation, or volatilization. In other words, all of the contaminants that enter the receiving body stay in the water and contribute to the total loads in downstream segments. The actual metals limitation for a substance may be determined using slightly different methodologies depending upon conditions within the water body, but in all cases the permit limits are set to assure that standards are met.

If the sum of technology-based loads is greater than the allowable load, the allowable load is allocated among dischargers. The percent reduction required to meet allowable discharge loads can be calculated by dividing the allowable load by the sum of technology-based loads. The allocation is calculated by reducing the effluent-based limit for each permit by the same percentage that the total load must be reduced. In the Hudson, natural background concentrations of iron exceed the standard. No impact to aquatic life has been observed and attributed to iron, so the effluent limits are established at the background level.

6. Summary of Aquatic Impacts

Operation of Roseton Units 1 and 2, Indian Point Units 2 and 3, and Bowline Point Units 1 and 2 stations under the proposed action will continue to affect the Hudson River ecosystem as a result of entrainment and impingement of aquatic organisms and the addition of heat. The effects will include a reduction in the number of live organisms of some species and life stages in the river compared to the number that would be present with the plants not operating. The potential for these effects to have impacts on selected fish populations was also considered.

Fish are the focus of most aquatic impact studies. Fish are often secondary and higher level consumers in ecosystems. As such, they depend on the lower trophic levels (phytoplankton, zooplankton, small invertebrates) for food. If the lower trophic levels are disrupted, the effects will be transferred through the food web to the fish. The life cycle of many fish populations is on a time scale that makes fish appropriate indicators of perturbations. The physical and chemical environment in estuaries constantly changes, resulting in continual shifts in abundance and occurrence of species, particularly of microorganisms. These small plants and animals have the capacity to reproduce rapidly and exploit favorable changes within a matter of hours or days. This time scale makes assessment of impacts associated with particular sources (such as power plants) difficult, because population changes may be rapid. In comparison, fish populations are more stable. Although the birth and death rates of fish populations may change with the physical environment, these changes occur on a longer time scale than that applicable to microorganisms.

Many fish populations are highly mobile, and can reflect impact on a larger area than can non-mobile species such as rooted aquatic plants or invertebrates that live in the bottom sediments. While power plants sometimes have localized effects due to their thermal or chemical discharges, these are typically not of great concern unless the local effects impair use of critical habitat or disrupt migration patterns. Changes in the abundance of highly mobile fish populations reflect both the near-field and far-field impacts.

Some fish populations (and some populations of larger invertebrates, such as blue crabs) have direct commercial or recreational value to man. If effects on these populations can be quantified, direct estimates of their economic value can be calculated.

The potential impacts of the proposed operating plans on fish populations and communities of the Hudson River were examined. Selected species were examined in more detail using an age-structured population model. At the community level, relative abundance of groups of species was described and examined for changes over the last 24 years. This information on fish was considered along with that on other important ecosystem components and processes to determine whether impacts occurred to the Hudson River ecosystem.

a. Population Impacts

Biological populations increase through the birth of new organisms and decrease through deaths. Since these two processes are seldom, if ever, in exact equilibrium, the total number in a population changes continuously. Birth and death rates are generally determined by conditions in the environment so that under favorable circumstances births exceed deaths and the population increases; in unfavorable circumstances deaths exceed births and the population declines. However, there may also be intrinsic control mechanisms affecting these rates that tend to keep small populations from becoming extinct and large populations from severely overcrowding their environment.

Both the natural fluctuations and applicable intrinsic regulation were considered when population impacts were assessed. The two main approaches used for impact assessment, empirical observation and population modeling, included these considerations, but at different levels of detail.

The empirical observation approach used information on the historical pattern of population characteristics, such as abundance, sex ratios, or age structure, to estimate future patterns. This approach is useful in situations such as that on the Hudson River, where future conditions (i.e., the effects from all sources) are expected to be about the same as those in the past. Historical patterns of abundance provide valuable information on a population's ability to withstand effects in the future, and allow a qualitative assessment of the degree to which persistence of the population might be threatened. Continuing effects from other sources (e.g., fishing, pollution, and mortality at power plants other than those covered by the proposed operating plans) and natural regulatory processes are reflected in historical data and therefore need not be explicitly incorporated in the analysis.

Age-structured population models were used to quantify impact for striped bass, American shad, and Atlantic tomcod. For bay anchovy, a model developed at Oak Ridge National Laboratory was used to assess the effects of power plant mortality. Models can provide precise estimates of impact, but for the estimates to be accurate, numerous assumptions about the population are often required. It was impossible to test all the assumptions of these models. For certain major assumptions, alternatives were considered when impacts under alternative sets of future conditions were compared.

For all the modeled species, the predicted effects of power plant operation under the proposed action are that changes in population abundance would be negligible. Equilibrium levels of striped bass and American shad would decline slightly. For both species the decline would be for less than the decline predicted from the intended level of fishing mortality. For Atlantic tomcod, there is no predicted decline as a result of power plant mortality. For bay anchovy, the reduction in biomass would not be large enough to affect its predators.

b. Community Impacts

Intensive fisheries studies conducted throughout the Hudson River estuary since 1974 demonstrate that the fish community in this system remains healthy and robust, and consistent with that expected in a large, temperate estuary like the Hudson. At present, the Hudson contains a fish community which is species rich (i.e., a large number of species have been collected), with a mixture of marine, estuarine, freshwater and diadromous species. However despite the high species richness observed, the fish community in the estuary exhibits relatively low species diversity. This low species diversity results from the fact that this fish community is numerically dominated by a few species that are well adapted to the highly variable estuarine environment. The community of young fish is dominated by diadromous species, especially the herrings, in tidal freshwater areas, and by marine species, especially bay anchovy, in brackish water areas. For these species, the Hudson serves as an important spawning and nursery area. Collections of older individuals are numerically dominated by year-round resident estuarine species.

While changes in the composition and abundance of this fish community have been observed, all appear attributable to factors other than power plant operations. For example, slight decreases in the number of freshwater species in the upper estuary coincide with significant expansions of the water chestnut beds following cessation of herbicide treatments in the 1970s. These water chestnut beds now cover most of the available shallow water habitat in these areas. Further, increases in the number of marine species collected in brackish water areas of the estuary in recent years appear attributable to increases in the salinity over this same time period. In addition, increases in the abundance of young striped bass and decreases in the abundance of young blueback herring appear to be a result of fishery harvest and management practices throughout the species' ranges, much of which occurs outside the Hudson. Finally, increases in the abundance of some marine prey species, such as bay anchovy and Atlantic silversides, coincide with improvements in water quality in the New York Harbor area.

Overall, this assessment demonstrates that the operation of the existing power plants has not had any effect on the health and condition of the fish community in the Hudson River estuary. Further, given the long period of available data, there is no reason to expect that the proposed continued operation of these power plants will have any effect on the fish community in the Hudson in future years. In fact, this assessment provides evidence that specific environmental management activities, such as increased wastewater treatment and more protective fisheries management practices, can and do have demonstrable positive effects on populations of individual fish species and on the fish community as a whole within the Hudson River ecosystem.

c. *Ecosystem Impacts*

The focus of the utilities' monitoring program was on fish populations. However, other research has been conducted that provides information on the lower trophic levels and on the processes that are critical for functioning of the Hudson River ecosystem. This information was used to qualitatively assess the potential impact of the proposed operating plans on the ecosystem.

Temperate estuaries, such as the Hudson, are typified by highly variable and relatively unpredictable environmental conditions. Water temperatures vary over a range of approximately 60°F annually and 10°F within a day in some habitats. Salinity may range from 0 to more than 15 ppt seasonally, and rapid changes can occur with changes in freshwater inflow. Dissolved oxygen may also undergo both rapid within-day changes due to the shift from photosynthesis to respiration of the plant community and seasonal changes related to temperature effects on solubility and biological oxygen demand. Estuarine organisms have adapted to this ever-changing environment and have developed means to cope with the stresses imposed by it.

The physical effects of the power plants are concentrated primarily in the middle part of the estuary, where environmental conditions are most variable. The only measurable physical effect of power plant operations is a small increase in water temperature in the vicinity of each plant's discharge. Outside of this zone the physical effects of station operation are essentially undetectable. Consequently, there is no reason to expect that the operation of these power plants has had, or will have, any demonstrable effect on any of the physical and chemical factors that drive ecosystem processes within the estuary.

The Hudson River ecosystem is typical of that found in temperate estuaries in that it relies heavily on imported organic material (produced in upstream areas or originating terrestrially) as its source of energy in the form of organic carbon. Primary production within a large part of the estuary (conversion of inorganic carbon to organic carbon through photosynthesis) is limited to a thin layer of water near the surface because high turbidity stops light from penetrating. Operation of the power stations does nothing to change the inflow of carbon, and should have little effect on the already limited level of production by phytoplankton. Although passage through the cooling systems may reduce production of entrained phytoplankton, the slightly elevated temperatures in areas adjacent to the plants probably stimulates production by others. Overall, changes in primary production are not likely to be of consequence since the seasonal temperature cycle is not very different from the natural condition. As power plants do not have major effects on either primary production or energy inputs, studies of these processes are seldom required for power plant monitoring programs.

Secondary production (carbon incorporated into organisms that eat plant material) is seasonally variable, as is typical for a temperate zone ecosystem. Biomass of zooplankton, which often is the initial food source for larval fish, is typified by short pulses of high production in the spring and summer. Different species have different temperature and salinity preferences, which tends to spread total production through time and space. The decomposers (those organisms that eat primarily dead plant material that settles to the bottom) have a more even temporal production pattern. Nearly all of the organisms in this trophic level have a rapid turnover rate, which means that they increase population size very quickly under favorable conditions. Typically, power plants do not have major effects on these types of organisms, and studies of their abundance and production rates are seldom required for power plant monitoring programs.

Effects on higher trophic levels (those animals that consume plant eaters or other carnivores) are also relatively minor, as discussed above (impacts on fish populations and communities); however, those analyses did not explicitly consider trophic interactions among species. Estuaries are typified by relatively unspecialized food webs that tend to keep changes in any single food category from causing widespread disruption of the entire trophic structure. This means that most organisms have several food sources, and changes in one or two sources would not severely disrupt their energy intake. Feeding on other sources would be increased to make up for a decrease in one source.

Overall, the physical effects of these stations on the ecosystem are within the scope of natural variation, and occur primarily where natural conditions are most variable. Due to the reliance of the ecosystem on imported organic carbon rather than on production within the river proper, the base of the food chain is relatively immune to the effects of the plants. Consumer organisms are typically either small and reproduce quickly or reside in habitats that are little affected by the stations. High-level consumers (i.e., fish populations) usually employ a generalist feeding strategy and are therefore insensitive to changes in the abundance of any one prey species. A healthy ecosystem exists in the Hudson River after nearly a quarter of a century of operation of these plants, and there is no evidence of any impact of plant operations on either the trophic structure of the ecosystem or on transfers of energy and matter among the trophic levels. Further, it is not expected that the proposed continued operation of these plants will have any adverse effects on the Hudson's ecosystem in future years.

C. Other Impacts

1. Wildlife Impacts

There has been no observed effect of existing power plant operations on wildlife in the Hudson River corridor, although it should be noted that no systematic effort was made to document such impacts. Temperatures in the thermal plume are within the tolerance range of indigenous wildlife. Although impingement sampling has focused on fish and invertebrates at each of the Hudson River power plants, there is no anecdotal evidence or commentary on field sheets indicating significant wildlife impingement. Conversations with field supervisors responsible for conducting impingement surveys indicate that wildlife found on the intake screens appear to have been dead prior to being carried into plant bar racks or onto screens. One exception to this observation is the occasional presence of turtles in the impingement collections. Although no data exist to quantify these observations, impingement of turtles appears to be a rare occurrence. In any event, it seems likely that turtles, with their protective carapaces, will survive impingement and be returned to the river in the fish-sluicing device.

Review of New York Natural Heritage Program files indicated that no unique threatened or endangered wildlife sightings have occurred in the immediate project vicinity of the Roseton Units 1 and 2, Indian Point Units 2 and 3, and Bowline Point Units 1 and 2 Generating Stations (correspondence from B. Buffington, DEC, 28 January 1993, Appendix IV-2). The files did note the historical presence of an eastern woodrat midden in the vicinity of Bowline Point Units 1 and 2. This species is believed extirpated from New York State, although DEC recently attempted repopulation efforts in the Mohonk Mountain area.

Haverstraw Bay is noted as a waterfowl concentration area. Although the Natural Heritage files note the presence of only one protected bird species, the fish crow, a large number of migratory waterfowl are known to use the Hudson River corridor as a flyway. Breeding bird lists for each plant site are included in Appendix V-2.

In recent years bald eagles have overwintered in the Hudson River area, particularly around Peekskill and Constitution Island. In 1992 the river served as a nesting habitat for one pair of eagles but the exact location of this nest is kept confidential by DEC. Continued operation of the power plants is not expected to impact the eagles. Although eagles have not been reported on the sites of any of the three generating stations, they are now commonly seen along the shores of estuary.

Overwintering eagles tend to concentrate in areas where preferred food fish are abundant and easily obtained. Studies elsewhere (Bowerman and Giesy 1991) document eagles feeding below hydroelectric facilities on fish stunned or disoriented after passage through turbines. This feeding strategy appears to be used by New York eagles overwintering in the Mongaup River Valley. Individuals from this population have been observed sitting on the edge of ice below hydroelectric facilities and catching fish. This feeding strategy has not been documented on the Hudson River for steam electric generating stations, although eagles have been seen riding ice floes in front of the Roseton Units 1 and 2 generating station. The eagle population has expanded since operation of the power plants; this is clearly related to expansion of the population throughout the United States as a result of decreases in pesticide levels. The common presence of eagles in the mid Hudson area (Hudson River Almanac Volume IV) suggests that power plants are not inhibiting this habitat use. To the extent that the thermal plumes help maintain open-water areas during the winter, feeding by these and other fish-eating birds may be facilitated.

2. Air Effects

The baseline air emissions expected from operation of these facilities and other facilities in NY were predicted using PROMOD for 1998 and 1999 (studies were conducted in 1996 in response to questions from NYSDEC on the preliminary DEIS). The average annual statewide emissions of NO_x, SO_2, CO, CO_2, and particulates based on the PROMOD analysis are:

Emission Type	Thousand Tons/year
NO_x	64
SO_2	175
CO	21
CO_2	42,283
Particulates	62

VII. Mitigation

VII. MITIGATION ASSOCIATED WITH THE PROPOSED ACTION

A. INTRODUCTION

Mitigation associated with the proposed action includes a reduction in both the number of fish entrained through the cooling water systems of the Bowline Point Units 1 & 2, Indian Point Units 2 & 3, and Roseton Units 1 & 2 power plants and the number of fish impinged on the intake screens of the plants. The mitigation will be provided by a combination of cooling water flow management strategies and the use of intake technologies. Additionally, the feasibility of deploying new intake technologies to further reduce impingement at Roseton Units 1 & 2 will be studied.

B. ENTRAINMENT

1. Background

Entrainment will be mitigated by reduction of the volumes of cooling water used by the Bowline Point Units 1 & 2, Indian Point Units 2 & 3, and Roseton Units 1 & 2 power plants relative to a baseline, defined as operation with the minimum flows required for efficient operation at full power throughout the year. Verification that entrainment has been mitigated to the extent identified in the Proposed Action will be performed using the fish protection index described in Appendix Section IV-1. That index was used to establish the minimum number of fish protection points (FPPs), based on five taxa of fish (striped bass, white perch, Atlantic tomcod, bay anchovy, and river herring), to be achieved on average annually during the period 2001 through 2010. The minimum number of FPPs to be achieved on average annually across all plants is 112.87. The expected equivalent contribution by each plant to that number is 22.10 by Bowline Point Units 1 & 2, 73.18 jointly by Indian Point Units 2 & 3, and 17.59 by Roseton Units 1 & 2.

The minimum number of FPPs is based on the flow reductions that could be achieved using both the outages and flows stipulated by the 1981 and 1987 SPDES permits over the 10-year period beginning in May 1981. The maximum flows stipulated in the SPDES permits for Bowline Point Units 1 & 1 and Roseton Units 1 & 2 were the same as the flows required to efficiently operate these plants at full power. However, the maximum flows stipulated in the 1981 and 1987 SPDES permit for Indian Point Units 2 & 3were below those required for efficient operation at full power. Therefore, the minimum number of FPPs for Indian

Point Units 2 & 3 includes fish protection associated with the lower-than-efficient flows stipulated in its 1981 and 1987 SPDES permits (36.83) as well as fish protection associated with outages (36.35).

Reductions in cooling water use may be achieved by any combination of flow management strategies including single-unit operation, load-based flows, and seasonal flow schedules. The actual combination of strategies that will be used to meet the minimum number of FPPs at each plant will be determined by the operator of that plant and cannot be forecast with certainty. Therefore, four hypothetical operating scenarios were developed to illustrate how the minimum number of FPPs could be met. These scenarios are useful for examining the range of reductions in entrainment conditional mortality rates (CMR) that could occur for seven taxa of fish (striped bass, white perch, Atlantic tomcod, bay anchovy, river herring, American shad, and spottail shiner) relative to the baseline scenario. Even though it is unlikely that these specific hypothetical scenarios will occur, they illustrate how the minimum number of FPPs can be met under different flow management scenarios. In all of the scenarios, the maximum flows allowed in the 1981 and 1987 SPDES permits were followed.

The "Early" scenario depicts the entrainment CMRs that would result when flow reductions at each station, whether from single-unit operation or load-based flows, would begin during the first week of the year when entrainment historically occurs (week 8) and would continue until the requisite FPPs were accumulated at each plant.

The "Design" scenario depicts entrainment conditional mortality rates (CMR) that would result from the patterns of single-unit operation used to establish the minimum number of FPPs in Appendix Section IV-1. This scenario restricts single-unit operation to the periods specified in the 1981 and 1987 SPDES permits, i.e., May 15 to July 31 for Bowline Point Units 1 & 2 May 10 to August 10 for Indian Point Units 2 & 3, and May 15 to June 30 for Roseton Units 1 & 2.

The "Late" scenario depicts entrainment conditional mortality rates (CMR) that would result from flow reductions, whether due to single-unit operation or load-based flows, at each station that would begin as late in the year as possible and would still provide the requisite FPPs at each plant.

The "Minimum" scenario depicts entrainment conditional mortality rates (CMR) that would result from single-unit operation at each station or other flow reductions that would occur only at the time when the maximum number of FPPs were available. This scenario would define the minimum amount of time necessary to provide the requisite FPPs at each plant.

2. Mitigation

The FPPs for the four hypothetical scenarios are the same at Bowline Point Units 1 & 2 (22.1) and Indian Point Units 2 & 3 (36.35). At Roseton Units 1 & 2, the FPPs are the same for the "Early", "Late", and "Minimum" scenarios (17.58) and slightly higher for the "Design" scenario (21.95). However, reductions in the entrainment CMR differ among taxa. The difference is greatest for tomcod and bay anchovy. The total entrainment CMR for tomcod under the "Early" scenario (0.175) (Table VI-4) is 28% less than the baseline (Table VII-1), whereas the total entrainment CMR under the "Late" scenario (0.229) is 6% less than the baseline. The total entrainment CMR for bay anchovy under the "Early" scenario (0.196) is 1% less than the baseline whereas the total entrainment CMR under the "Late" scenario (0.148) is 26% less than the baseline. For both tomcod and bay anchovy, the reductions in total entrainment CMR under the "Design" scenario and "Minimum" scenario lie between those under the "Early" and "Late" scenarios. However, the "Design" scenario and "Minimum" scenario provide greater reductions in total entrainment CMR for striped bass and white perch. For river herring, the "Design" and "Late" scenarios provide the greatest reduction in total entrainment CMR.

C. IMPINGEMENT

Impingement will be mitigated by the same measures used to reduce entrainment and by the continued deployment and operation of the intake technologies described in Section IV. These actions should result in impingement CMRs (for the Bowline Point Units 1 & 2, Indian Point Units 2 & 3, and Roseton Units 1 & 2 plants combined) below 1% for striped bass, white perch, Atlantic tomcod, bay anchovy, river herring, American shad, and spottail shiner (Table VI-6).

1. Roseton Units 1 & 2

At Roseton Units 1 & 2, the conventional traveling screens and the dual-flow screens have been modified to reduce the number of times fish encounter and then swim away from the screens before they are removed from the intake. These screens will be continuously rotated to increase the survival of fish they intercept. Fish removed from the screens will be returned to the Hudson River.

Central Hudson is currently assessing the feasibility of deploying a high-frequency underwater acoustic system at Roseton Units 1 & 2 for reducing impingement of fish in the herring family. Studies funded by the Hudson River utilities demonstrated that high-frequency sound could effectively reduce impingement of alewives at the James A. Fitzpatrick Nuclear Power Plant on Lake Ontario. Central Hudson is planning a full-scale test of a high-frequency fish deterrent system at Roseton Units 1 & 2 in 2000. Fish in the

TABLE VII-1

PERCENT REDUCTION IN THE ENTRAINMENT CONDITIONAL MORTALITY RATE (CMR) FOR SEVEN TAXA OF FISH UNDER FOUR HYPOTHETICAL OPERATING SCENARIOS AT THE BOWLINE, INDIAN POINT, AND ROSETON POWER PLANTS ASSUMING MAXIMUM FLOWS STIPULATED IN THE 1981 AND 1987 SPDES PERMITS ARE FOLLOWED

	PERCENT REDUCTION IN ENTRAINMENT CMR						
SCENARIO	**WHITE PERCH**	**STRIPED BASS**	**RIVER HERRING**	**BAY ANCHOVY**	**ATLANTIC TOMCOD**	**AMERICAN SHAD**	**SPOTTAIL SHINER**
Early	8	6	7	1	28	8	2
Design	14	13	16	14	10	24	17
Late	8	7	16	26	6	13	36
Minimum	14	17	11	6	13	9	2

herring family typically represent approximately 30-35% of those impinged at Roseton Units 1 & 2. If the acoustic deterrent system tested at Roseton is effective, Central Hudson will continue to deploy such a system during periods of herring impingement.

2. Indian Point Units 2 & 3

At Indian Point Units 2 & 3, the modified Ristroph screens will be continuously rotated and fish removed from the screens will be returned to the Hudson River via specially designed sluices and pipes. When these screens were installed at Indian Point Unit 3 in 1991 and at Indian Point Unit 2 in 1992, the DEC considered them to be best technology available, or likely to become available in the foreseeable future, for reducing impingement at these plants.

3. Bowline Point Units 1 & 2

At Bowline Units 1 & 2, a barrier net will be seasonally deployed to prevent fish from reaching the traveling screens. Some fish will get behind the barrier net. Therefore, the traveling screens will be continuously rotated to increase the survival of fish they intercept. Fish removed from the screens will be returned to the Hudson River.