APPENDIX VI

Appendix VI-1-A

Entrainment Process and Sampling

APPENDIX VI-1-A

ENTRAINMENT PROCESS AND SAMPLING

A.. Description of the Process

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 a multitude of condenser tubes used to cool the turbine exhaust steam. The raw 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 and depicted in Figure 1.

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 themselves. Organisms just small enough to go through the screens may incur abrasions or compression as they are pulled through the mesh. Further damage may occur during passage from the traveling screens to the pumps.

Passage through the pump is where the most 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 quite 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.

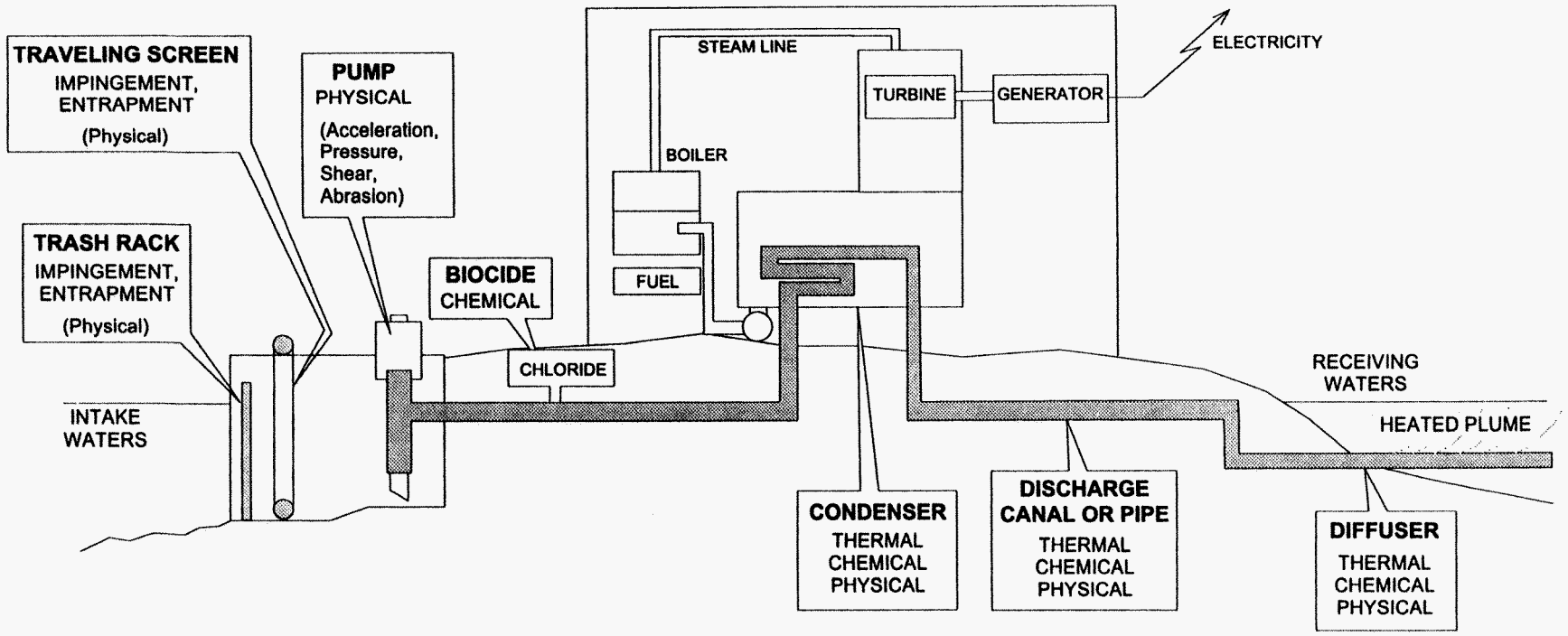


Figure 1. Schematic diagram of a typical steam electric generating station with once-through cooling water.

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 from less than a minute to more than 30 minutes, depending on the type and length of the discharge structure. Figure 2 describes, in general terms, the temperature rise experienced by entrained organisms.

Chemical

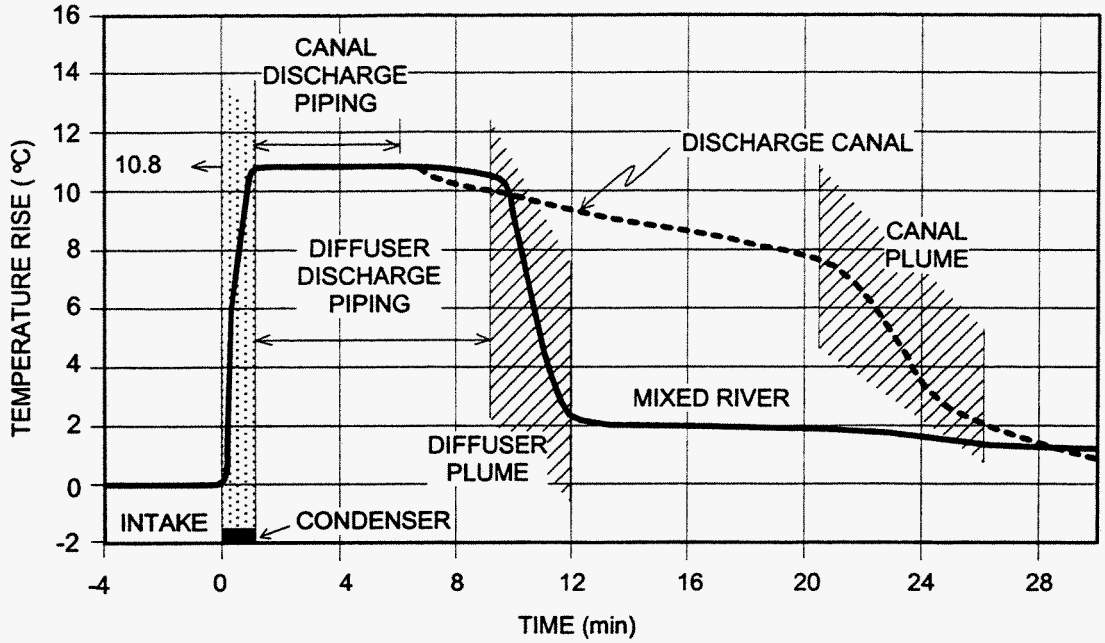
To prevent fouling during certain times of the year, some power plants inject intermittent pulses of biocide into the coolant. Some organisms may be directly exposed to chlorine.

All Stresses Combined

Organisms that survive entrainment may be exposed to thermal and biocidal stresses for seconds to hours after discharge, depending upon whether a diffuser, multiport jet, weir, or canal forms the outfall. In addition, if a diffuser is present, the organisms may be exposed to shear stresses as they are discharged through the diffuser and into the river with the cooling water. However, the shear stresses generated at the diffuser and when the dilution water from the river is mixed with the discharge plume are considerably less than those encountered by the organisms during passage through the plant and well below the lethal range.

The number of ichthyoplankton entrained depends on factors such as location in relation to the plant intakes (e.g., vertical distribution in the water column); physiology and condition of the organisms; and power plant factors such as intake design, zone of water withdrawal, velocities at the screen face, screen mesh size, pumping rates, and operation schedules. Early life stages such as eggs and yolk-sac larvae behave like passive particles, i.e., they will be carried with the river velocities and those flows entering the plant intake. As ichthyoplankton mature into post-yolk-sac and juveniles, they develop increasing swimming ability and their susceptibility to entrainment may be dictated more by behavior and other factors than by flows at the intakes. It is often assumed that they behave as passive particles and are entrained at rates directly proportional to the intake flow. This approach results in the linear relationship (shown in Figure 3) between the number of organisms entrained and the plant's flow rate. Annual entrainment abundance estimates are often calculated based on this direct proportion and total plant flows.

The approximate relationship between numbers entrained and flow rate does not accurately depict the relationship between the flow rate and the number of organisms cropped by entrainment. The latter relationship is complicated by the fact that the temperature change across the condensers, ΔT, increases when plant flow rate is reduced below the design condition (Figure 4). The increased ΔT may cause the cooling water temperature to exceed the organisms' lethal limit. Beyond this point, additional decreases in the plant flow rate



After Coutant (1970b)

Figure 2. Hypothetical time-courses of temperature changes experienced by organisms entrained in condenser cooling water and subsequently discharged.

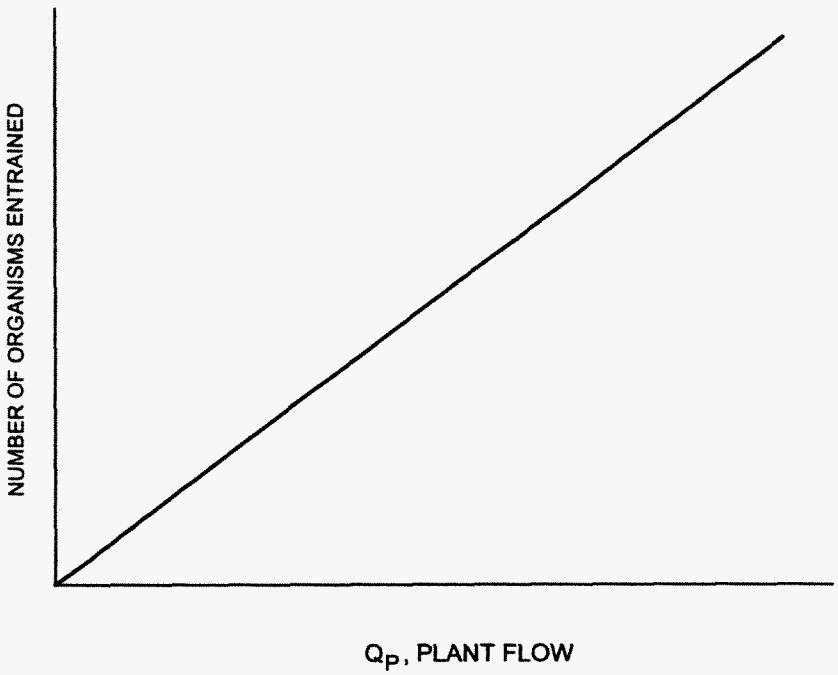


Figure 3. Relationship between number of organisms entrained and plant flow rate (Q_P).

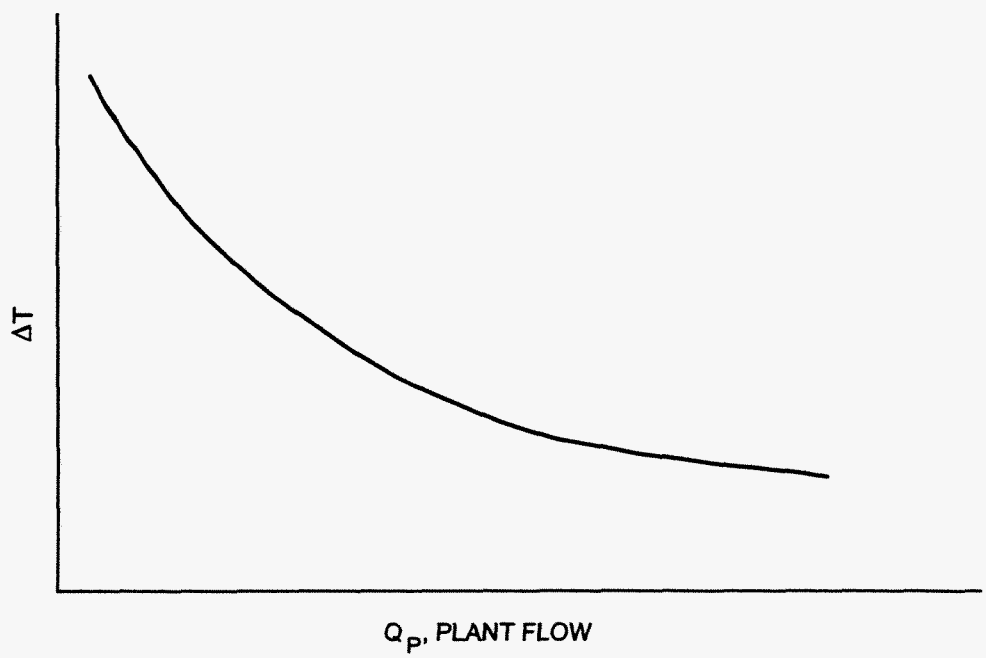


Figure 4. Relationship between temperature increase across the condenser (Δ_T) and plant flow rate (Q_P).

will result in further increases in the thermal mortality rate until it reaches 100% (Figure 5).

The influence of an increase in thermal mortality rate on the mortality rate due to all stresses combined depends on the organisms' tolerance of physical and chemical stresses in the absence of thermal stresses. If mortality due to physical and chemical stresses is 100%, the thermal mortality rate has no influence on the total rate, and decreases in plant flow translate directly into reductions in the numbers of organisms lost due to entrainment. However, if a large fraction of the entrained organisms survive the physical and chemical stresses, the combined mortality rate will increase when ΔTs reach the range over which thermal mortality occurs. For fragile organisms, i.e., that small fraction that survives physical and chemical stresses, the combined mortality rate also increases with ΔT but at a less dramatic rate.

For fragile organisms, when plant flows are increased enough that ΔTs decrease and thermal mortality diminishes, the number lost due to entrainment may decline or remain nearly constant over a range of plant flows. After this range of flows, the number lost increases with flow but at a lower rate determined by the magnitude of the mortality rate due to nonthermal stresses. A similar pattern evolves for hardy organisms, i.e., those with a relatively low mortality rate in response to nonthermal stresses. After the transitional range of plant flows, the number lost resumes its pattern of increase but at a lower rate.

B.. Data to Estimate Entrainment Effects

The Long River Programs summarized in Section V-D are described in the annual reports listed in Appendix V-1. Studies concerned with the impacts of entrainment have been conducted periodically at the generating stations since 1972. The following sections summarize the studies conducted at each plant.

Roseton

Sampling to estimate the numbers of organisms entrained has been conducted at the Roseton Generating Station from 1974 to 1987. These studies focused on the seasonal and diel abundance patterns associated with various fish species and life stages. Early entrainment studies at Roseton also included macrozooplankton. Water quality, plant operating conditions, and environmental conditions (i.e., tidal stage) were recorded with each sample.

In addition to the routine entrainment abundance monitoring, a variety of other entrainment studies have been conducted at Roseton Generating Station. These studies have included estimates of survival and evaluation of mitigation measures and sampling gear and design.

Entrainment survival studies began at Roseton in 1975 and continued through 1980. Initial studies included phytoplankton, zooplankton, and ichthyoplankton survival estimates. Later studies focused on estimates of initial and latent survival of striped bass, white perch, Atlantic tomcod, and herring.

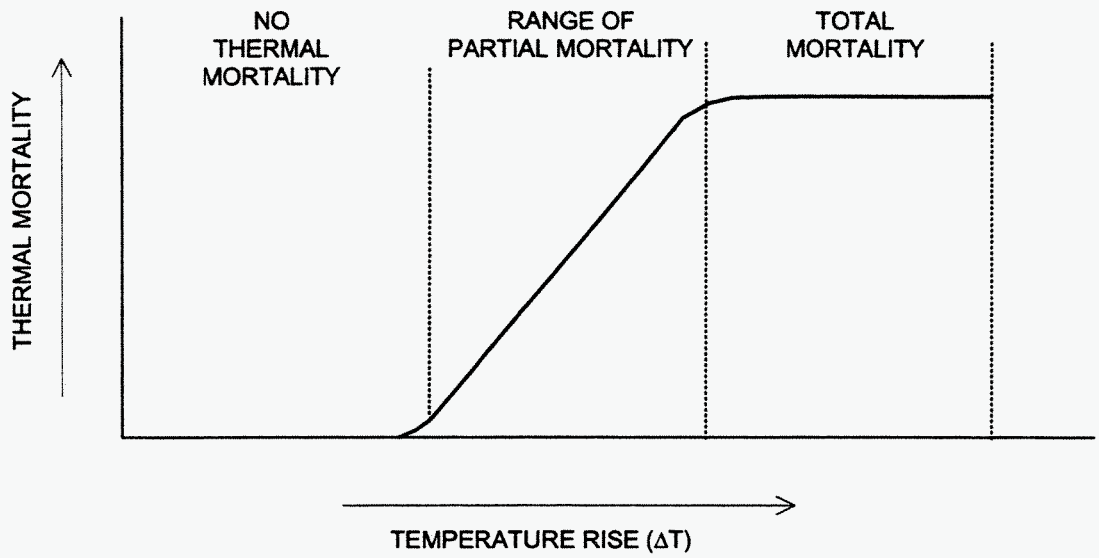


Figure 5. Variation of number of entrained organisms killed by thermal stress as a function of temperature rise.

Indian Point

Entrainment sampling began at Indian Point Generating Station in 1972 and, with the exception of 1982, was continued until 1987. Annual reports describing the entrainment studies conducted at Indian Point are listed in Appendix V-1. Entrainment abundance studies were designed to quantify and identify the species and life stages entrained at each unit. In the 1970s, entrainment sampling concentrated on selected species of macrozooplankton and striped bass ichthyoplankton at both the intake and discharge structures. During the 1980s, entrainment sampling at Indian Point focused on ichthyoplankton entrainment. Annual entrainment programs have evaluated seasonal, diel, and tidal abundance patterns as well as length frequency distributions of selected species.

Special studies concerning entrainment mitigation, survival, and differences in sampling gear and design have also been conducted at Indian Point. Survival studies have considered initial and latent survival as well as the differences between thermal and mechanical mortality. Survival studies conducted in 1988 examined mechanical mortality after the installation of the dual and variable speed pumps at Units 2 and 3, respectively (EA 1989). Studies have focused on selected species: striped bass, white perch, herrings, bay anchovy, and Atlantic tomcod.

Bowline Point

Entrainment sampling at Bowline Point Generating Station began in 1973 and continued until 1987. Appendix V-1 lists the annual reports of each study. Initial studies included phytoplankton and zooplankton sampling to define temporal variations in species and life-stage composition. Subsequent studies focused on entrainment effects on striped bass, white perch, Atlantic tomcod, and bay anchovy.

Data collected included abundance according to species and life stage, and length frequencies for selected species. Special studies concerning the survival of fish larvae and juveniles were also conducted on a regular basis at Bowline Point between 1975 and 1979. These studies examined the thermal and mechanical components of entrainment mortality and the length frequency distributions associated with species survival.

C.. Qualitative Description of Entrainment Effects

Entrainment sampling has been conducted at the Roseton, Indian Point, and Bowline power plants for 14, 14, and 15 years, respectively. The number of taxa identified in these sampling efforts at these stations is 52, 34, and 37, respectively. However, for most of these species the numbers caught were small. Tables 1, 2, and 3 indicate that 95% of the catch at the three stations was composed of six species (bay anchovy, blueback herring and alewife, striped bass, white perch, and American shad). Based on the relative importance of species to the ecosystem, their current or potential value as recreational or commercial resources, and their appearance in entrainment samples, certain species were selected by DEC for analysis here.

TABLE 1

COMPOSITION OF ENTRAINMENT ABUNDANCE SAMPLES AT ROSETON GENERATING STATION, 1981-1987

TAXON	EGGS %	YOLK-SAC LARVAE %	POST YOLK-SAC LARVAE %	JUVENILE %	UNIDENTIFIED LIFESTAGE %	TOTAL (a) %
Clupeidae	28.78	9.10	70.38	16.31	53.59	48.61
White perch	69.20	14.26	9.94	53.70	1.80	33.49
Striped bass	0.76	36.96	13.70	5.21	0.50	9.27
Cyprinidae	0.81	17.04	1.58	0.37	3.99	2.43
Tessellated darter	0.04	18.99	1.25	5.04	0.22	1.89
Morone spp.	—	0.10	1.13	0.49	20.68	1.76
Unidentified	0.29	0.12	0.07	—	16.74	1.15
American shad	0.01	0.81	1.00	2.16	1.18	0.61
Bay anchovy	0.02	<0.01	0.51	3.58	0.02	0.27
Yellow perch	<0.01	1.24	0.26	—	0.14	0.21
Atlantic tomcod	<0.01	1.25	0.01	2.81	1.10	0.16
Rainbow smelt	<0.01	0.01	0.09	0.77	—	0.05
Hogchoker	0.06	—	0.02	1.30	—	0.04
Centrarchidae	<0.01	0.07	0.04	0.04	—	0.02
American eel	—	—	—	2.93	—	0.01
Blueback herring	—	—	—	2.12	0.01	0.01
Fundulus spp.	0.01	0.02	0.01	0.45	—	0.01
Banded killifish	<0.01	<0.01	0.01	0.16	—	0.01
Atlantic menhaden	—	—	0.01	0.12	—	<0.01
Spottail shiner	—	—	<0.01	1.10	—	<0.01
Percidae	—	0.01	<0.01	—	0.03	<0.01
Fourspine stickleback	—	<0.01	—	0.49	—	<0.01
White sucker	—	0.01	<0.01	—	—	<0.01
Brown bullhead	—	—	<0.01	0.41	—	<0.01
Silverside	<0.01	—	<0.01	—	—	<0.01
Pomoxis spp.	—	<0.01	<0.01	—	—	<0.01
White catfish	—	—	<0.01	0.08	—	<0.01
Alewife	—	—	—	0.12	—	<0.01
Summer flounder	—	—	—	0.08	—	<0.01
Redbreast sunfish	—	<0.01	<0.01	—	—	<0.01
Threespine stickleback	—	—	—	0.08	—	<0.01
Eudolus spp.	<0.01	—	—	—	—	<0.01
Trout-perch	—	—	<0.01	—	—	<0.01
Largemouth bass	—	—	<0.01	—	—	<0.01
Creek chubsucker	—	—	—	0.04	—	<0.01
Atlantic needlefish	—	<0.01	—	—	—	<0.01
Northern pipefish	—	—	—	0.04	—	<0.01

Note: Clupeidae includes both herring and alewife. Some individuals identified only to family or genus.
(a)Includes all life stages and individuals.

TABLE 2

COMPOSITION OF ENTRAINMENT ABUNDANCE SAMPLES AT BOWLINE POINT GENERATING STATION, 1981-1987

TAXON	EGGS %	YOLK-SAC LARVAE %	POST YOLK-SAC LARVAE %	JUVENILE %	UNIDENTIFIED LIFESTAGE %	TOTAL (a) %
Bay anchovy	60.65	1.50	87.92	49.23	0.23	85.02
Clupeidae	.68	31.31	6.93	3.20	—	6.72
Striped bass	0.06	37.66	2.66	24.22	—	2.95
White perch	32.22	3.45	1.10	4.70	—	2.53
Morone spp.	1.46	015	0.28	0.16	44.94	0.53
Unidentified	3.91	25.24	0.81	10.27	53.26	1.84
American shad	0.88	—	0.07	0.10	—	0.10
Centrarchidae	—	0.11	0.01	—	1.53	0.02
Hogchoker	—	0.19	0.01	—	—	0.02
Silverside	—	0.04	0.02	0.03	—	0.02
Northern pipefish	—	—	<0.01	0.73	—	<0.01
Cyprinidae	0.01	0.04	<0.01	—	—	<0.01
Weakfish	—	—	<0.01	0.07	—	<0.01
Atlantic tomcod	—	—	<0.01	.045	—	<0.01
Percidae	—	—	<0.01	—	—	<0.01
American eel	—	—	—	0.33	—	<0.01
Eastern mudminnow	—	0.02	<0.01	0.24	—	<0.01
Fundulus spp.	—	0.28	0.01	0.09	—	0.01
Gizzard shad	—	—	<0.01	—	—	<0.01
Rainbow smelt	—	—	0.01	—	—	0.01
Rough silverside	—	—	<0.01	0.02	—	<0.01
Inland silverside	—	—	0.03	0.02	—	0.03
Atlantic silverside	—	—	0.01	0.07	—	<0.01
Tessellated darter	—	—	<0.01	—	—	0.01
Yellow perch	—	—	<0.01	—	—	<0.01
Bluefish	—	—	—	0.10	—	<0.01
Scianidae	—	—	<0.01	—	—	<0.01
Naked goby	—	—	<0.01	1.58	—	<0.01
Gobiidae	—	—	0.12	3.48	0.03	0.02
Blueback herring	—	—	—	0.03	—	0.14
Alewife	—	—	—	0.03	—	<0.01
Atlantic needlefish	—	—	—	0.02	—	<0.01
Fourspine stickleback	—	—	—	0.09	—	<0.01
Threespine stickleback	—	—	—	0.07	—	<0.01
Windowpane	—	—	—	0.02	—	<0.01
Winter flounder	—	—	—	0.02	—	<0.01

Note: Clupeidae includes both herring and alewife. Some individuals identified only to family or genus.
(a)Includes all life stages and individuals.
All species and life stages were not identified for all years.

TABLE 3

COMPOSITION OF ENTRAINMENT ABUNDANCE SAMPLES AT INDIAN POINT GENERATING STATION, 1983-1987

TAXON	EGGS %	YOLK-SAC LARVAE %	POST YOLK-SAC LARVAE %	JUVENILE %	UNIDENTIFIED LIFESTAGE %	TOTAL (a) %
Bay anchovy	98.59	5.54	62.00	14.33	4.65	65.14
Clupeidae	0.09	75.74	16.15	1.64	0.04	13.80
Striped bass	0.12	7.79	11.09	4.07	0.33	8.29
White perch	0.83	2.00	7.64	3.86	0.03	5.77
Unidentified	0.30	0.04	0.03	0.06	76.14	2.74
Morone spp.	<0.01	0.11	0.95	0.01	17.63	1.30
American shad	0.01	0.18	0.65	0.29	<0.01	0.48
Weakfish	<0.01	—	0.32	25.83	0.01	0.60
Rainbow smelt	—	0.01	0.21	5.94	0.03	0.24
Atlantic tomcod	—	—	0.02	36.04	0.01	0.54
Gobiidae	—	<0.01	0.16	0.79	—	0.13
Tessellated darter	—	4.64	0.11	0.06	0.01	0.21
Cyprinidae	0.03	3.02	0.14	—	0.17	0.20
Hogchoker	0.01	0.12	0.22	0.22	<0.01	0.16
Yellow perch	—	0.37	0.10	—	0.03	0.08
Common carp	<0.01	0.06	0.04	—	—	0.03
Atherinidae	<0.01	0.07	0.03	—	0.06	0.03
Atlantic menhaden	—	—	0.03	0.34	<0.01	0.16
American eel	—	—	—	2.11	—	0.03
Northern pipefish	—	—	<0.01	3.82	0.01	0.06
Percidae	—	0.10	0.02	—	0.81	0.04
Inland silverside	<0.01	0.03	0.02	—	—	0.01
Centrarchidae	0.01	0.08	0.02	—	<0.01	0.02
Sciaenidae	<0.01	—	0.02	0.33	<0.01	0.02
Fundulus spp.	0.01	0.03	0.01	—	—	0.01
Goldfish	—	—	0.01	—	<0.01	0.01
Winter flounder	—	—	0.01	0.02	—	<0.01
Banded killifish	<0.01	0.03	<0.01	0.01	—	<0.01
Rough silverside	—	0.01	<0.01	0.01	0.01	<0.01
Mummichog	<0.01	<0.01	<0.01	—	—	<0.01
Atlantic silverside	—	0.01	<0.01	—	—	<0.01
Summer flounder	—	—	<0.01	—	—	<0.01
Catostomidae	0.01	—	—	—	—	<0.01
White sucker	<0.01	—	<0.01	—	—	<0.01
Fourspine stickleback	—	<0.01	<0.01	—	—	<0.01
Windowpane	—	—	<0.01	0.02	—	<0.01
Atlantic needlefish	—	—	<0.01	—	—	<0.01
Spot	—	—	<0.01	0.04	—	<0.01
Threespine stickleback	—	—	—	0.02	—	
White catfish	—	—	<0.01	0.01	—	<0.01

Table 3 continued

TAXON	EGGS %	YOLK-SAC LARVAE %	POST YOLK-SAC LARVAE %	JUVENILE %	UNIDENTIFIED LIFESTAGE %	TOTAL (a) %
Seaboard goby	—	—	—	0.02	—	<0.01
Labridae	<0.01	—	—	—	—	<0.01
Searobin	—	—	<0.01	—	—	<0.01
Bluefish	—	—	—	0.02	—	<0.01
Halfbeak	—	—	<0.01	—	—	<0.01
Butterfish	—	—	<0.01	0.04	—	<0.01
Smallmouth flounder	—	—	<0.01	0.01	—	<0.01
Conger eel	—	—	<0.01	0.01	—	<0.01
Spottail shiner	—	—	—	0.03	—	<0.01
Northern puffer	—	—	—	0.01	—	<0.01
Brown bullhead	—	—	—	0.01	—	<0.01
Smallmouth flounder	—	—	—	0.02	—	<0.01

Figures 6, 7, 8 and 9 show the time of occurrence and relative magnitude of entrainment losses for these selected species at Roseton, Indian Point, and Bowline Point.

D. Quantitative Description of Entrainment Effects

Entrainment conditional mortality rate is the probability of fish dying from passage through the cooling water system of a power plant. It is expressed as the fractional reduction in the number of fish in the Hudson River at the end of the first year of life. If there are no density-dependent mechanisms operating, the conditional mortality rate will carry through proportionally to later life stages. If, on the other hand, the survival rate increases for individuals remaining in that cohort, the reduction in the size of the cohort at some later life stage will be less than the estimated conditional mortality rate. Thus, the impact of entrainment on a population depends on the nature (density-dependent/ density-independent) and timing (relative to the conditional mortality) of natural mortality factors.

Two different approaches are available for estimating conditional mortality rates. The first, the Empirical Transport Model (ETM), uses river sampling to determine the portion of the river population entrained at a given power plant. The ETM formulation is based on the spatial and temporal distributions of the organisms; it does not require estimates of the absolute number of organisms in the river or the numbers entrained. Hence, it does not require sampling within the plant to estimate the numbers entrained, but it does require estimates of the ratio or fraction of organisms in the river that are likely to be entrained (i.e., are exposed) and the fraction of the organisms that does not survive plant passage.

The other approach to estimating conditional mortality due to entrainment uses direct estimates of the numbers entrained coupled with estimates of the standing crop of organisms in the river and the fraction of entrained organisms killed by plant passage to estimate the conditional entrainment mortality rate (CEMR). The number of organisms entrained is based on sampling of the cooling water in the discharge canal or pipe. As discussed above, mortality due to exposure to elevated temperatures is typically considered separately from that due to mechanical, pressure, and chemical stresses. A full description of the two modeling approaches, along with the equations used to compute the thermal component of plant mortality are presented in Appendix VI-1-B.

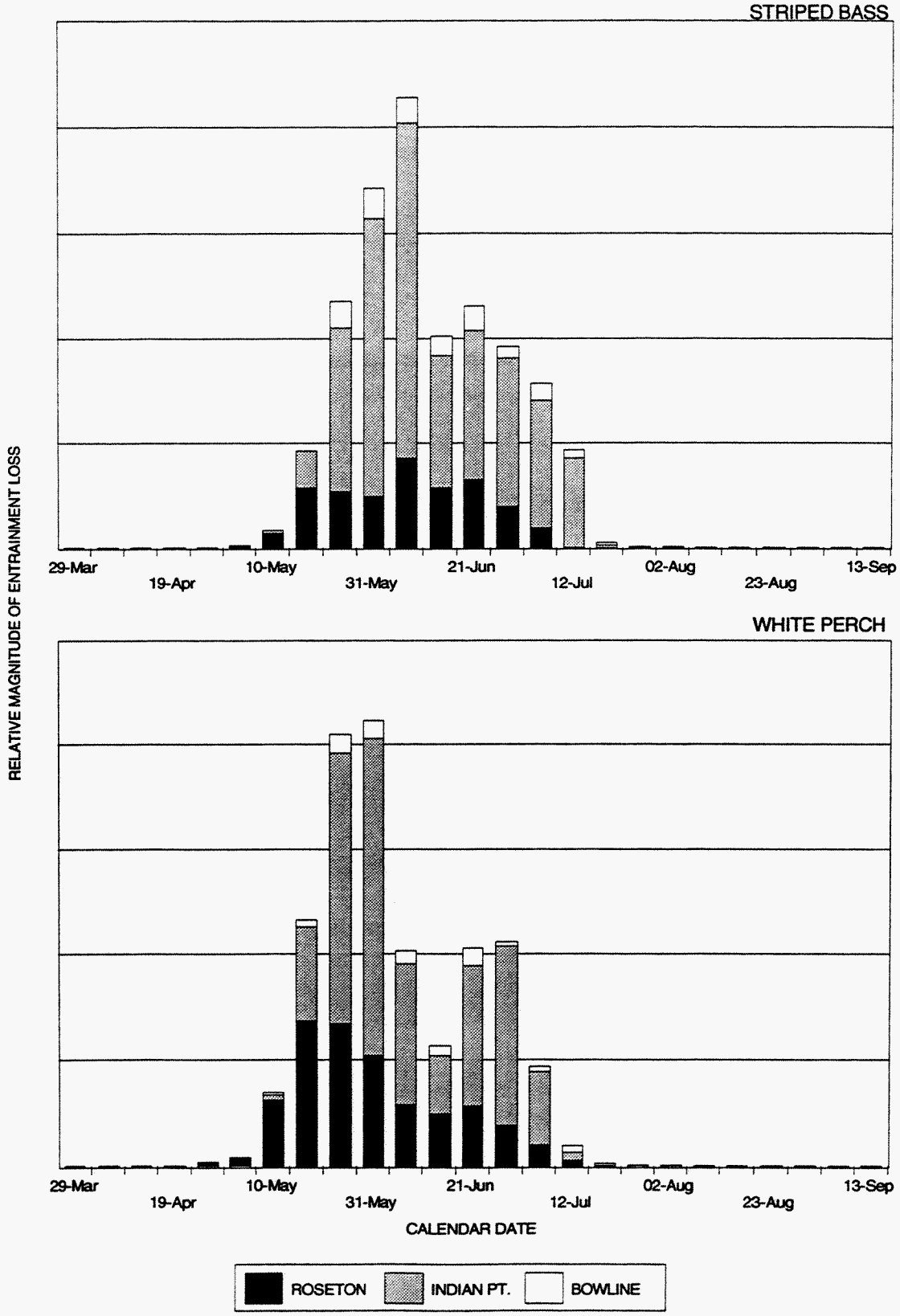


Figure 6. Time of occurrence and relative magnitude of entrainment losses of select species at Bowline Point, Roseton, and Indian Point as related to water withdrawal (1981-1987).

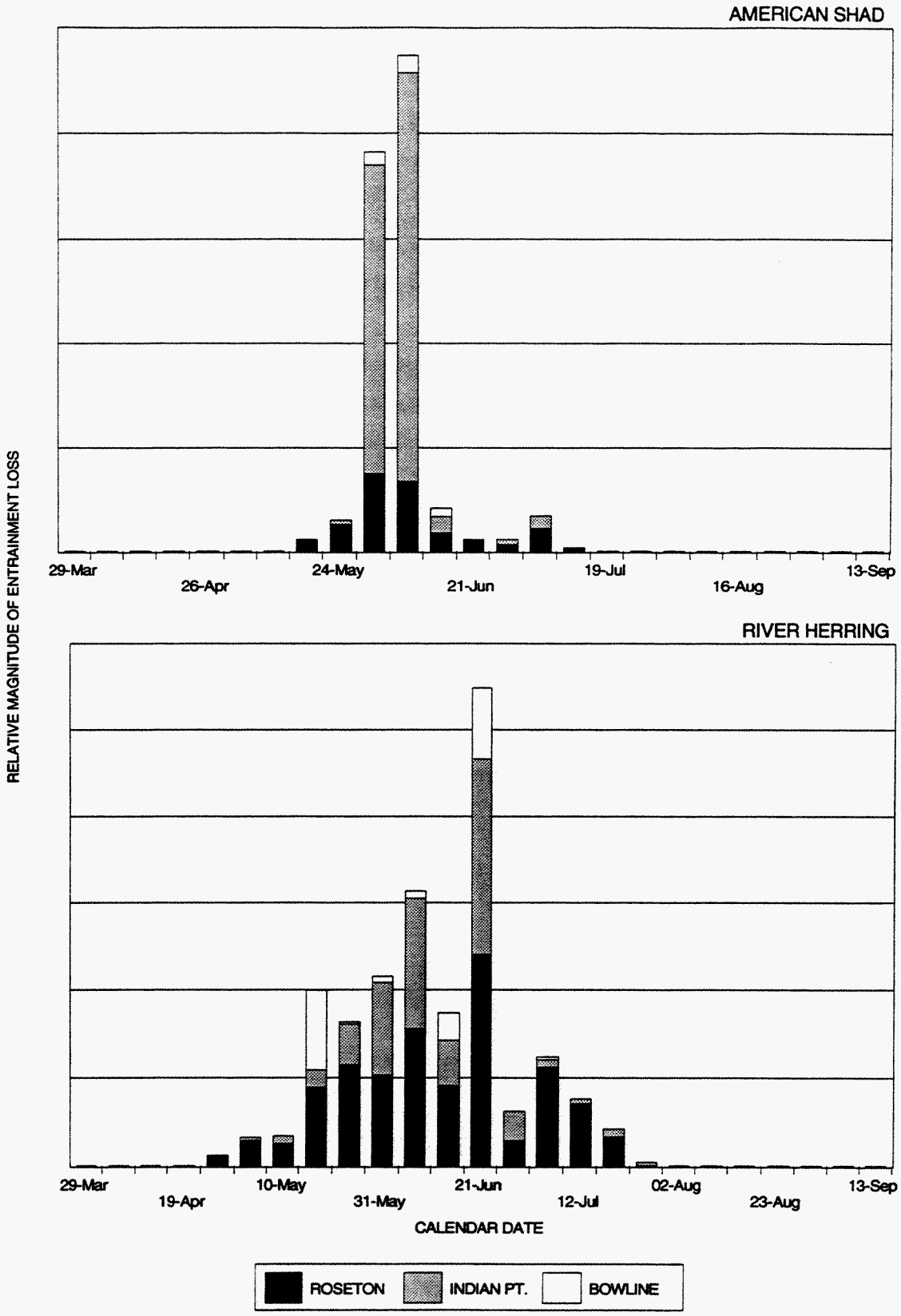


Figure 7. Time of occurrence and relative magnitude of entrainment losses of select species at Bowline Point, Roseton, and Indian Point as related to water withdrawal (1981-1987).

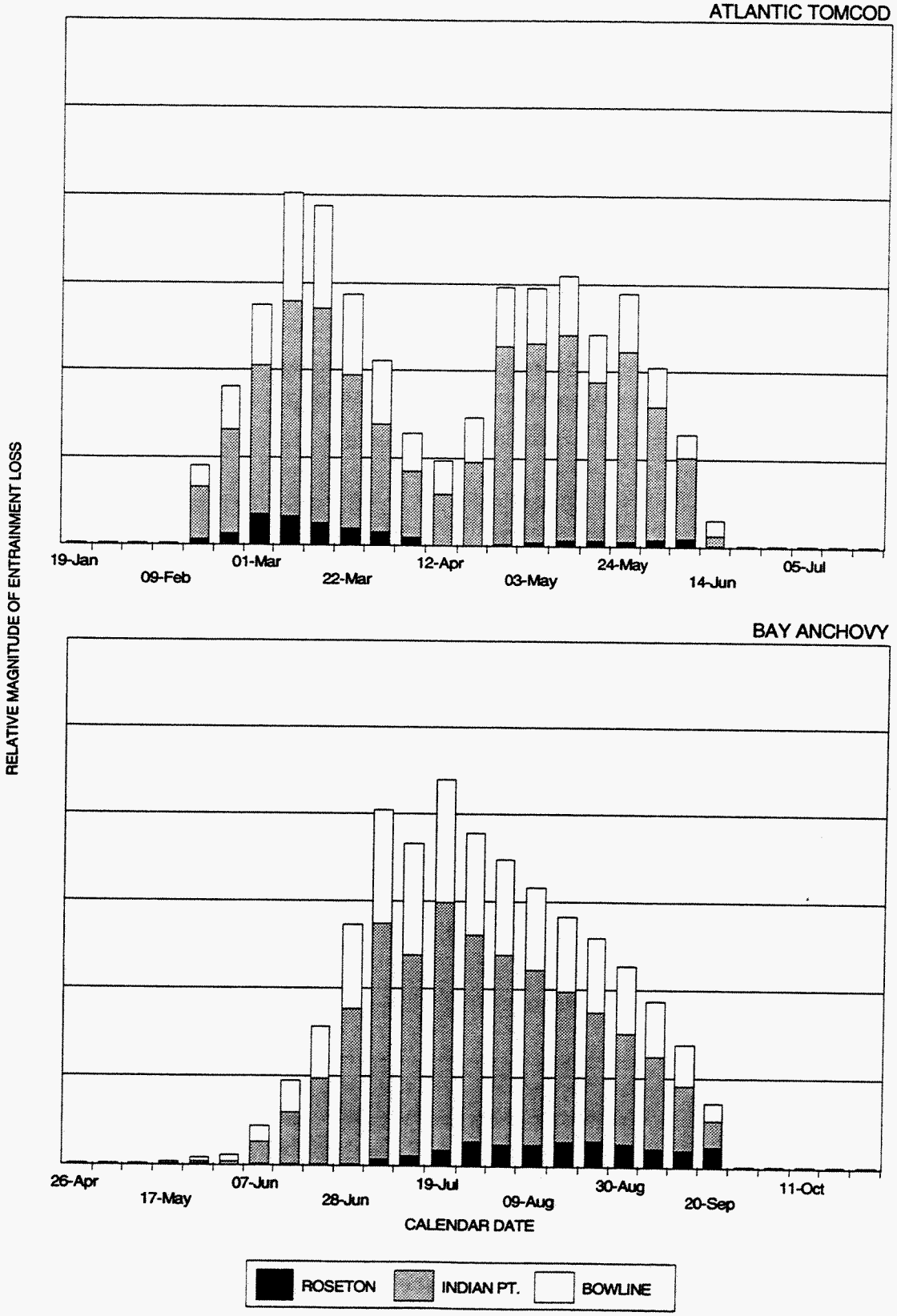


Figure 8. Time of occurrence and relative magnitude of entrainment losses of select species at Bowline Point, Roseton, and Indian Point as related to water withdrawal (1981-1987).

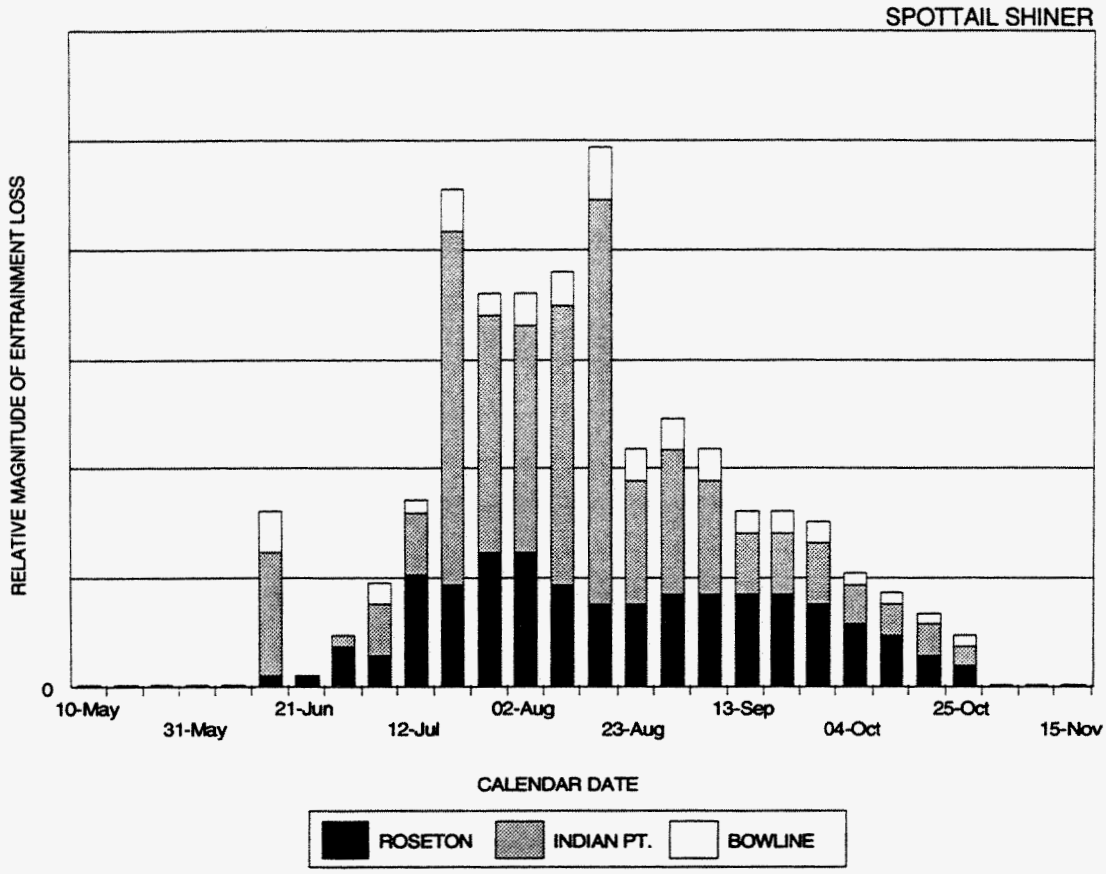


Figure 9. Time of occurrence and relative magnitude of entrainment losses of select species at Bowline Point, Roseton, and Indian Point as related to water withdrawal (1981-1987).

Appendix VI-I-B

Methods Used To Estimate Entrainment Effects

Introduction

Background

The Draft Environmental Impact Statement (DEIS) for the operation of Bowline Point, Indian Point and Roseton power plants includes the estimation of the fractional reduction in young-of-year fish populations due to entrainment and the distribution of effects through time. Sampling programs that began in the mid-1970s as part of the Hudson River Monitoring Program (HRMP), provide measurements on both the abundance of fish populations at various times and in various life stages in the Hudson River estuary and the numbers of fish entrained and killed by the plants. Modeling is used to estimate conditional entrainment mortality rates and to assess the potential effectiveness of alternative mitigation scenarios such as planned outages. For the DEIS, estimates of the conditional entrainment mortality rates (CMR), the fractions of young-of-year populations that would die from entrainment-related causes if no other causes of mortality operated, were made for American shad (*Alosa sapidissima*), Atlantic tomcod (*Microgadus tomcod*), bay anchovy (*Anchoa mitchilli*), striped bass (*Morone saxatilis*), white perch (*Morone americana*), spottail shiner (*Notropis hudsonius*), and "river herring" over the period 1974 through 1995. The river herring designation includes both alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) due to difficulties in distinguishing the larvae of these two species.

The CMRs for the seven fish employed two estimation methods—the Empirical Transport Model (ETM) and the Conditional Entrainment Mortality Rate (CEMR) model. Each method has specific data requirements that can limit its application to particular years, taxa and power plants. The ETM was originally developed for use with data on river-wide distribution patterns of ichthyoplankton. Numbers entrained are estimated from larval densities and power plant flows. The Type I ETM model was developed for use with field data that identify fish life stages but not ages.

Boreman et al. (1978, 1981) and Boreman and Goodyear (1988) describe model development, assumptions, and previous applications. The ETM (Boreman and Goodyear, 1988) is based on the assumptions that

> (1) the data used to establish the spatial and temporal distributions of organisms are accurate, (2) organisms redistribute instantaneously among regions of the water body between life stages, but do not move among regions within each life stage, (3) power plant effects on organisms do not alter their overall pattern of distribution within the water body, (4) organism distribution parameters are estimated from field measurements of the entire standing crop of each entrainable life stage, and (5) natural mortality of a given life stage is uniform within the modeled system .

The ETM method can be applied to all years of the Longitudinal River Survey (LRS) that allow estimates of river-wide distribution patterns of ichthyoplankton.

The CEMR model was developed later as part of the Outage Evaluation Program, a multi-year program begun in 1982 that was sponsored by the Hudson River Utilities and conducted in cooperation with the New York State Department of Environmental Conservation. The CEMR method was developed to take advantage of direct samples of the entrained ichthyoplankton that were available from programs conducted at the three power plants in 1981 and from 1983 through 1987—the only years the CEMR method could be applied to, to estimate conditional entrainment mortality rates.

Because the CEMR method relies on the most direct source of data for estimating mortality (direct counts of entrained organisms), it is the preferred method for estimating conditional mortality rates—the ETM method is used for years when entrainment data are not available. To produce a consistent time-series of conditional mortality rates based on direct entrainment counts when available and ETM estimates otherwise, the ETM was modified to have an algebraic structure similar to the CEMR model and calibrated against the CEMR model. The calibration was performed using data from 1981 through 1987 (which support both CEMR and ETM estimates) for American shad, river herring, striped bass, white perch, and bay anchovy at four plants (Bowline Point, Indian Point, Roseton and Danskammer). In addition, a calibration was performed for river herring and white perch at the Albany Steam Station using entrainment data from 1983.

Characterization for Historical Conditions

For the purpose of characterizing historical power plant effects, year-specific estimates of CMR (note that CMR refers to the rate and CEMR refers to the model) are needed because what happened in each year is of interest. Each year-specific estimate should be as accurate as possible given the type and amount of data collected for that year—using CEMR (which is based on direct counts of entrained ichthyoplankton) for 1981 through 1987 when entrainment abundance data were collected, and ETM for the remaining years. Because the CEMR method relies on the most direct source of data for estimating mortality (direct counts of entrained organisms), it is the preferred for estimating conditional mortality.

As discussed previously, the ETM was modified and calibrated against the CEMR model to produce a consistent time-series of CMR estimates (including both CEMR-based and ETM-based estimates). The modified ETM model represents the weekly conditional survival fraction as a product of daily conditional survival fractions, just as the CEMR model does. This is a departure from the original ETM, which represents the weekly conditional survival fraction in terms of an exponential decay function with a weekly time step.

To further increase the degree of consistency between the CEMR-based and modified ETM-based CMR estimates, the modified ETM was also calibrated to the CEMR model. The purpose of the calibration was to identify W-ratio values (the quotient of average intake density of a taxon over the average regional density) which could not be directly estimated from field data, for the ETM that make the ETM-based estimates, on average, equal to the corresponding CEMR-based estimates of CMR.

Unsampled Areas

Along with the availability of direct counts of entrained ichthyoplankton, the portion of the Hudson River that is subject to sampling in each year also affects CMR estimates for the historical period. The LRS is the source of data for river-wide abundance estimates used in CEMR and for river-wide distribution pattern estimates used in ETM. It is a major element of the HRMP, which also includes the Fall Shoals Survey (FSS) and Beach Seine Survey (BSS). The HRMP uses a stratified random sampling design to allocate samples to locations in the Hudson River. For the HRMP, the Hudson River is divided into 13 regions (numbered 0 to 12 from the mouth to Albany) and 5 habitat strata (channel, bottom, shoal, shore and beach). The LRS and FSS sample three of these habitat strata (channel, bottom and shoal), whereas the BSS samples two (shore and beach).

In addition to the defined regions and habitat strata, Region 12 was split into two sub-regions, the area from River Mile (RM) 125 to RM 140 and the area from RM 140 to RM 152, because the northern portion was not sampled by the LRS in all years of the program. All together, the 14 regions/subregions and 5 strata of the HRMP define 70 statistical strata, covering the entire area of interest from the Battery to the Troy Lock.

Although the majority of the volume of the Hudson River has been subject to sampling by the LRS, not all statistical strata have been sampled in all years. Twenty-seven (27) of the 70 statistical strata were sampled in all years. Thirty-seven (37) of the statistical strata, including all beach areas, shore zones and some shoals, have not been sampled by the LRS, although the volume associated with some of these strata is small in comparison to the volume of sampled strata. Six (6) of the statistical strata, including Region 0 and the northern portion of Region 12, have been sampled in recent years but were not sampled in earlier years. Table X-1 summarizes the unsampled strata for the LRS.

The presence of unsampled areas in the historical database can introduce biases into estimates of abundances and distribution patterns used in estimates of CMR. For example, excluding the northern- and/or southern-most portions of the River from distribution pattern estimates (e.g., as used in ETM) could cause estimates of the fraction of the population inhabiting the middle regions of the River to be biased high if fish inhabited that area of the River. If this occurred, the ETM would produce over-estimates of CMR. Similarly, excluding any area inhabited by a fish taxon and life stage of interest would cause CEMR to over-estimate CMR.

An approach to reducing this type of bias is to use data from sampled areas in each year to predict the densities in adjacent unsampled areas. The resulting data set would be complete for each year—using either an actual density estimate or a predicted density for each of the 70 statistical strata. This method could be viewed as an extension of the method used to predict densities in unsampled shoal, shore zone, and beach areas.

In 1986 and 1987, the Utilities conducted special studies in traditionally unsampled shoals, shore zone, and beach areas in the Poughkeepsie, Catskills, and Tappan Zee regions. Data from these studies were used to develop adjustment factors used to predict densities in unsampled areas based on densities in adjacent sampled areas (Coastal 1991a and b). Analyses similar to those conducted with data from the 1986 and 1987 unsampled areas studies were

applied to data collected in areas that were unsampled in some, but not all, years. In 1987, the LRS was expanded to sample the northern portion of Region 12, which was not sampled in previous years. In 1988, the LRS was expanded further to include sampling of Region 0, which was not sampled in earlier years. Data from these later years have been used to develop prediction equations that could be applied to data from the earlier years. For example, data collected after 1986 in the northern portion of Region 12 (coupled with data collected in the southern portion of Region 12 in those years) provide a basis for predicting densities in the northern portion of Region 12 (based on observed densities in the southern portion of Region 12) in years when the northern portion was not sampled. For each year, the entire volume of Region 12 is then used in estimating river-wide abundances for CEMR, and distribution patterns for ETM. These adjusted estimates are used for analyses based on Regions 0 through 12 and for analyses based on Regions 1 through 12 only.

Annual data sets of ichthyoplankton densities that were standardized using this type of approach are now used as input to abundance indices and for assessments of conditional mortality rates using either ETM or CEMR. The standardized annual data sets used for these analyses provide a high level of consistency between ETM and CEMR.

Changing Environmental Conditions

The approach discussed above to account for fish inhabiting unsampled areas assumes that the relationship between densities in the unsampled area and the adjacent sampled area is stationary over time. For example, ichthyoplankton densities in Region 1 could be used to predict densities in Region 0 for years prior to 1988 (based on the relationship between densities in Regions 1 and 0 during the years 1988 through 1995). This approach would produce a consistent time-series of CMR estimates (for the entire historical period) if the relationship between densities in Region 1 and Region 0 did not change from the earlier years of the historical period (1974 through 1987) to the later years (1988 through 1995). However, as discussed below, water quality data collected by the HRMP suggest that a change in environmental conditions occurred in the late 1980s that may have affected the relationship between densities in Region 0 and Region 1.

Due to this uncertainty about environmental change, two sets of CMR estimates are computed for the years prior to 1988. One set includes predicted Region 0 densities (to reduce bias associated with omitting a portion of the river wide fish population from CMR calculations), and one set includes only Regions 1 through 12 (to avoid possible biases due to any change that may have occurred in the relationship between Region 1 and Region 0 densities).

Assessment of Future Effects of Power Plant Operations

For the purposes of assessing the likely future effects of power plants under alternative plant operating scenarios, CMR estimates that reflect representative future conditions (i.e., conditions like ichthyoplankton distribution patterns that would affect entrainment) are desirable. Although it is not possible to accurately predict future distribution patterns of ichthyoplankton, and the approach presented here is to select historical years that span a range of conditions that might be expected in the future.

It can be argued that recent conditions (e.g., 1991 through 1995) better reflect future conditions than do past conditions (e.g., 1981 through 1987, or pre-1981). This argument is supported by improvements in water quality in the lower Hudson River that occurred in 1991, and may have affected distribution patterns of some species and life stages. These water quality improvements appear to be due to upgraded wastewater treatment facilities in the lower Hudson River. The North River wastewater treatment plant (WWTP) achieved full secondary treatment in 1991.

Due to changing environmental conditions in the Hudson River and the inclusion of Region 0 in LRS sampling since 1991, CMR estimates from these later years are used to assess the likely future effects of alternative plant operating scenarios.

Approach for Estimating CMR

Tables X-2a and b summarize the methods for estimating CMR for all years of the historical period. Estimates for all years were used to characterize the effects of power plants during the historical period (1974 through 1995). One set of CMR estimates included 13 regions. The other set included 12 regions (Regions 1 through 12) for the period 1974 to 1987. For both of these sets of CMR estimates, the ETM model was re-calibrated to the CEMR model using both 12-region and 13-region analyses.

CMR estimates for 1991 through 1995 were used to assess the likely effects of future plant operations. These CMR estimates are based on actual field data for all 13 regions.

Structure of this Report

The remaining sections of this report describe the models, the modifications that were made to the algebraic structure of ETM, the calibration of the modified ETM, the derivation of additional constituent parameters, descriptions of the sources of data for ETM and CEMR, and modeling results. Except where otherwise noted, the equations are specific to power plant, year, and taxon.

Modeling Methods: Comparison of ETM and CEMR

Empirical Transport Model (ETM)

In ETM, the total entrainment mortality (m_T) is calculated as

$$m_T = 1 - \sum_{s=1}^{S} R_s \left[\prod_{j=0}^{J} \left[\prod_{l=1}^{L} \left[\sum_{k=1}^{K} D_{s+j,kl} \quad e^{-(E_{s+j,kl} \; C_{s+j,sl} \; t)} \right] \right] \right] \tag{1}$$

where m_T = total conditional entrainment mortality rate; and

s = week 1, 2, 3, ..., S of the spawning period (subscript s will also denote cohorts born in those weeks);

j = age 0, 1, 2, ..., J of entrainable individuals in weeks;

l = life stage 1, 2, 3, ..., L;

k = river region 1, 2, 3, ..., K;

R_s = proportion of spawning that occurred in week s, so that $\sum_{s=1}^{S} R_s = 1$;

$D_{s+j,kl}$ = average proportion of river-wide abundance of life stage l individuals during week $s+j$ that are in region k, with $\sum_{k=1}^{K} D_{s+j,kl} = 1$ for each week, cohort and life-stage;

$E_{s+j,kl}$ = instantaneous entrainment mortality rate constant for life stage l individuals during week $s+j$ in region k (units of per day);

$C_{s+j,sl}$ = proportion of week $s+j$ that individuals of cohort s spend in life stage l; and

t = duration in days of week $s+j$ (i.e., $t = 7$).

This formulation differs slightly from the formulation presented by Boreman and Goodyear (1988) because it allows for cohort-specific life-stage durations (C_{wsl}) and week-specific distribution patterns (D_{wl}) with $w = s+j$.

The instantaneous entrainment mortality rate constant is defined as

$$E_{s+j,kl} = P_{s+j,k} \quad f_{s+j,kl} \quad W_{s+j,kl} / V_k \tag{2}$$

where $P_{s+j,k}$ = rate of water withdrawal from region k in week $s+j$ (units of $m^3\ d^{-1}$);

$f_{s+j,kl}$ = fraction of life-stage l individuals in region k during week $s+j$ entering the intake that eventually are killed by plant passage;

$W_{s+j,kl}$ = ratio of the average intake density to average regional density of life-stage l individuals during week $s+j$ in region k; and

V_k = volume of region k (units of m^3).

In the application of this model to Hudson River data, the region-specific subscripts (k) on the terms $f_{s+j,kl}$ and $W_{s+j,kl}$ are dropped because the data do not support region-specific estimates of these parameters. Also, average values for $W_{s+j,kl}$, rather than week-specific values, are used, and so the week-specific subscript ($s+j$) is dropped.

This formulation of the ETM also can be written in term terms of calendar week (w) instead of age (j) as

$$m_T = 1 - \sum_{s=1}^{S} R_s \left[\prod_{w=s}^{s+J} \left[\prod_{l=1}^{L} \left[\sum_{k=1}^{K} D_{wkl} \; e^{-(E_{wkl} \, C_{wsl} \, t)} \right] \right] \right], \tag{3}$$

with $w = s + j$.

Conditional Entrainment Mortality Rate Model (CEMR)

The CEMR model was patterned after the ETM, but was developed to use direct estimates of the number of ichthyoplankton entrained available from discharge sampling at the power plants. The CEMR model is a discrete-time model with a daily time step and does not account for any variability in cohort abundance within a day. The parameters s, S and J have the same meaning as in ETM except that they are defined in terms of days rather than weeks. For each day, two underlying parameters are defined: the river wide abundance of the cohort, and the number of individuals in the cohort that die from entrainment. The general formulation of the CEMR model is

$$m_T = 1 - \sum_{s=1}^{S} R_s \left[\prod_{d=s}^{s+J} \left[\prod_{l=1}^{L} \left(1 - \frac{X_{ds}}{N_{ds}} \right)^{\delta_{dsl}} \right] \right] \tag{4}$$

where N_{ds} = the river-wide abundance of cohort s on day d;

X_{ds} = the number of individuals in cohort s that are killed by entrainment during day d; and

δ_{dsl} = the proportion of day d that individuals of cohort s spend in life-stage l ($\sum_l \delta_{dsl} = 1$ for each day of entrainment vulnerability for cohort s).

The daily conditional mortality rate due to entrainment for cohort s (CMR_{ds}) is the fractional reduction in the abundance of the cohort due to the presence of entrainment (note that CEMR refers to the CEMR model, CMR denotes an estimate of the conditional mortality rate). The daily conditional mortality rate is defined as $CMR_{ds} = X_{ds} / N_{ds}$, and the daily conditional survival rate (CSR_{ds}) is (1 - CMR_{ds}). These expressions are based on the assumption that the number of individuals that are killed by entrainment in any day does not affect the number that die from natural mortality. The number that die from natural causes in a day, however, can affect the number that die from entrainment without violating this assumption.

Due to data limitations, an additional assumption and an adjustment factor are required in order to estimate CMR_{ds}. Cohort-specific data on river-wide abundance and on the number killed by entrainment are not available. Therefore, data that are life-stage specific (but aggregated over all cohorts that are in the same life stage) are used as a surrogate for cohort-specific data. The assumption is made that the daily conditional mortality rate for individuals in cohort s and life-stage l on day d is the same as the daily conditional mortality rate for the entire population of life-stage l individuals on day d. The daily conditional mortality rate for life-stage l individuals on day d is defined as

$$CMR_{dl} = \sum_{s}^{S} X_{dsl} \Big/ \sum_{s}^{S} N_{dsl} \tag{5}$$

where N_{dsl} = the river-wide abundance of cohort s individuals that are in life-stage l on day d; and

X_{dsl} = the number of individuals in cohort s that are in life-stage l and are killed by entrainment during day d.

The number of individuals killed (X_{dsl}) is defined as the product of two terms,

$$X_{dsl} = NE_{dl} f_{dl} \tag{6}$$

where NE_{dl} = the number of individuals in life-stage l that are entrained on day d; and

f_{dl} = the fraction of life-stage l individuals entering the intake on day d that eventually are killed by plant passage.

Therefore, CSR_{ds} is defined for estimation as

$$CSR_{ds} = \prod_{l}^{L} \left(CSR_{dl} \right)^{\delta_{dsl}} \tag{7}$$

where $$CSR_{dl} = 1 - \left(\frac{NE_{dl} \quad f_{dl}}{N_{dl}} \right).$$

The ratio of the number entrained to the river-wide abundance is estimated using field data collected by two different gear types: ichthyoplankton trawls in the river and pump samplers in the power plant discharge canals. Therefore, an adjustment factor is needed to correct for the difference in gear efficiencies. The adjustment factor is termed the relative probability of capture (RPC_{dl}), and it includes the quotient of ichthyoplankton trawl gear efficiency (q_{1dl}) over pump gear efficiency (q_{2dl}) for larvae of life-stage l on day d. As discussed below, RPC_{dl} also implicitly includes a term for changes in density due to destruction of larvae (preventing identification to taxa of interest) during collection by either gear and by transit through the plant.

When the RPC_{dl} factor is explicitly included in the formula for the daily conditional survival rate, the rate can be rewritten as

$$CSR_{dl} = 1 - \left(\frac{NE'_{dl} \quad f_{dl}}{N'_{dl}} \quad RPC_{dl} \right) \tag{8}$$

where N'_{dl} = $N_{dl}\, q_{1dl}$, the measured river-wide abundance of life-stage l individuals on day d not adjusted for ichthyoplankton trawl gear efficiency;

NE'_{dl} = $NE_{dl}\, q_{2dl}$, the measured number of life-stage l individuals entrained on day d not adjusted for pump gear efficiency; and

RPC_{dl} = q_{1dl} / q_{2dl}, the ratio of the gear efficiencies for larvae of life-stage l on day d.

Relative probability of capture estimates are taxon, life-stage, and length specific. Therefore, for each day d, RPC_{dl} is assigned a value, RPC_{lc}, where RPC_{lc} is the relative probability of capture for life-stage l individuals in length class c and the mean of life-stage l individuals on day d is within length-class c.

With these two modifications to address data limitations, the full CEMR model as applied in the DEIS is

$$m_T = 1 - \sum_{s=1}^{S} R_s \left[\prod_{d=s}^{s+J} \left[\prod_{l=1}^{L} \left(1 - \frac{NE'_{dl}\, f_{dl}}{N'_{dl}} \; RPC_{dl} \right)^{\delta_{dsl}} \right] \right]. \tag{9}$$

The RPC_{lc} factors for striped bass and white perch yolk-sac larvae (YSL) and post yolk-sac larvae (PYSL) are taken from an earlier field study at Indian Point (Coastal, 1991a). The RPC factors for PYSL bay anchovy were computed using data from a 1988 RPC study at Indian Point and the methods described in Coastal (1991a). In the field studies, it was not possible to separate the effects of relative gear efficiencies and changes in observable ichthyoplankton density due to larval destruction within the gears or cooling system. Therefore the estimated RPC_{lc} factor adjusts for the combination of these effects. When applying the RPC_{lc} factor values in the calculation of the CEMR model estimates, distinguishing between these effects is not necessary because the larval counts are affected by, and need to be adjusted for, all of the effects present when the RPC_{lc} values are estimated.

For the remaining life stages of bay anchovy, striped bass and white perch, and for all stages of American shad and river herring, an RPC_{dl} value of 1.0 is used. No estimates are available for the eggs or juveniles of American shad, striped bass, or white perch, nor for any stages of river herring, Atlantic tomcod, or spottail shiner. American shad estimates for yolk-sac larvae and post yolk-sac larvae are available from the field study, but because the relationship between the RPC_{lc} estimates and the length of the larvae could not be explained in terms of factors thought to affect relative probability of capture (e.g., gear avoidance and extrusion), an RPC_{dl} value of 1.0 is used in the present CEMR calculations for all lengths of these stages of American shad larvae. For each taxon, life-stage and length, the value for RPC_{dl}, derived for Indian Point, is applied for all plants.

Model Comparison

Although the CEMR model is based on a discrete one-day time step, the daily conditional mortality rate can be interpreted in terms of a continuous-time model (within each day) with competing sources of mortality. The continuous-time model is based on the assumption that

during any day both natural and entrainment mortality act on the individuals at risk. The reduction in the number of individuals at any time during the day reduces the number that can be entrained subsequently during the day. The ETM is also based on this type of continuous-time model for mortality. Under this assumption, the number of individuals entrained (X^*_{ds}) can be represented as

$$X^*_{ds} = N_{d,hr=0,s} \frac{E_{ds}}{E_{ds} + M_{ds}} \left[1 - e^{-(E_{ds} + M_{ds})} \right] \tag{10}$$

where $N_{d,hr=0,s}$ = the river-wide abundance of cohort s at the beginning of day d;

E_{ds} = the mean instantaneous entrainment mortality rate (per day) for individuals of cohort s on day d; and

M_{ds} = the mean instantaneous natural mortality rate (per day) for individuals of cohort s on day d.

Equation (10) is the Baranov catch equation (Ricker, 1975) for single age groups as applied to entrainment mortality.

The daily river-wide abundance as used in CEMR can be interpreted as being the average river-wide abundance over day d (N^*_{ds}) and represented as

$$\begin{aligned} N^*_{ds} &= N_{d,hr=0,s} \int_0^1 e^{-(E_{ds} + M_{ds})t} \, dt \\ &= N_{d,hr=0} \, (E_{ds} + M_{ds})^{-1} \left[1 - e^{-(E_{ds} + M_{ds})} \right]. \end{aligned} \tag{11}$$

In this case, the daily conditional mortality rate as computed for CEMR could be interpreted as $CMR^*_{ds} = X^*_{ds} / N^*_{ds} = E_{ds}$ and would be equal to the instantaneous entrainment mortality rate rather than the fraction of the abundance lost to entrainment over a discrete time interval. If the assumptions of this continuous-time model are satisfied, the conditional survival rate (as a fraction) would be computed as $CSR^*_{ds} = \exp\left(-X^*_{ds} / N^*_{ds}\right)$ rather than $CSR_{ds} = 1 - X_{ds} / N_{ds}$.

These two formulations produce very similar values when the daily conditional mortality rate is small, although the discrete-time formulation of the daily conditional survival rate (in CEMR) always produces lower values of conditional survival than the corresponding continuous-time formulation (in ETM), and hence produces higher conditional mortality rates. For example, with a daily conditional mortality rate of 0.01, the daily conditional survival rate for the discrete-time model is 1 - 0.01000 = 0.99000 compared to exp (-0.01000) = 0.99005 for the continuous-time model (Figure X-1). If a cohort were exposed to a daily conditional survival rate of 0.01 for 60 days, the overall conditional survival rate would be $(0.99000)^{60} = 0.547$ for the discrete-time model and $(0.99005)^{60} = 0.549$ for the continuous-time model (Figure X-2). Average daily conditional mortality rate estimates (X_{ds} / N_{ds}) computed separately for each taxon (American shad, river herring, striped bass, and white perch), life stage (egg, yolk-sac larvae, post yolk-sac larvae, and juvenile), and power plant (Bowline Point, Indian Point and Roseton) over all days of entrainment vulnerability for 1981 and for 1983 through 1987 are less than 0.01 with one exception. The average estimate for striped bass post yolk-sac larvae at

Indian Point was 0.022. For values from close to 0 up to 0.022, the discrete-time and continuous-time models produce nearly equal conditional survival rate estimates (Figures X-1 and X-2).

General Model of Conditional Entrainment Mortality Rate

The Type I ETM and CEMR model can be viewed as special cases of a general model. For comparison, the ETM convention of weekly cohorts is adopted. The annual conditional mortality rate is represented as a weighted average of cohort-specific conditional mortality rates ($m_{T,s}$). Accordingly, the weighting factor for the weighted average is R_s, the proportion of the total spawn that occurred in week s, so that

$$m_T = \sum_{s=1}^{S} R_s \; m_{Ts} \cdot \tag{12}$$

Each cohort-specific conditional mortality rate is equal to one minus a product of weekly conditional survival rates:

$$m_{Ts} = 1 - \prod_{w=s}^{s+J} CSR_{sw} \cdot \tag{13}$$

Each weekly conditional survival rate depends on the fraction of the week spent in each life-stage, as represented by the general formula

$$CSR_{sw} = \prod_{l=1}^{L} \left(\overline{CSR}_{d \in w,l} \right)^{\sum_{d \in w} \delta_{dsl}} \tag{14}$$

where $\overline{CSR}_{d \in w,l}$ = the average daily conditional survival rate for life-stage l individuals in week w;

$d \in w$ = day d within week w; and

$\sum_{d \varepsilon w} \delta_{dsl}$ = $7\, C_{wsl}$ (from equation 1).

The general model for overall conditional mortality rate can then be represented as

$$m_T = 1 - \sum_{s=1}^{S} R_s \left[\prod_{w=s}^{s+J} \left[\prod_{l=1}^{L} \left(\overline{CSR}_{d \in w,l} \right)^{\sum_{d \in w} \delta_{dsl}} \right] \right]. \tag{15}$$

The ETM and CEMR models differ in the way that the weekly conditional survival rate is estimated. In ETM (equation 3), the weekly conditional survival rate for individuals from cohort s for the portion of the week spent in life-stage l is defined as a weighted average of region-specific, weekly conditional survival rates:

$$\left(\overline{CSR}_{d \in w,l} \right)^{\sum_{d \in w} \delta_{dsl}} = \sum_{k=1}^{K} D_{wkl} \left[\left(e^{-E_{wkl}} \right)^{\sum_{d \in w} \delta_{dsl}} \right]. \tag{16}$$

In the CEMR model (equation 4), the weekly conditional survival rate for individuals from cohort s, for the portion of the week spent in life-stage l, is defined in terms of the product of daily conditional survival rates:

$$\left(\overline{CSR}_{d \in wl} \right)^{\sum_{d \in w} \delta_{dsl}} = \prod_{d=d \in w} \left(1 - \frac{X_{dl}}{N_{dl}} \right)^{\delta_{dsl}}. \tag{17}$$

Equations (16) and (17) estimate the same parameter of the general model (equation 15) in different ways. In the ETM, weekly conditional survival rates are estimated from data on the river-wide distribution pattern of fish larvae. In CEMR, they are estimated from direct samples of entrained larvae. The difference in equations (16) and (17), therefore, captures the major difference between the ETM and the CEMR approaches to estimating CMR.

Modified ETM

In order to produce conditional mortality rate estimates based on ETM that are consistent with CEMR-based estimates, the algebraic structure of ETM is modified to be more like the algebraic structure of the CEMR model. The modification was made to the definition of the weekly conditional survival rate. The modified definition of the weekly conditional survival rate for individuals from cohort s, for the portion of the week spent in life-stage l is

$$\left(\overline{CSR}_{d \in wl} \right)^{\sum_{d \in w} \delta_{dsl}} = \prod_{d \in w} \left[1 - \left(\sum_{k} D_{wkl} \frac{P_{wk} \; f_{wl} \; W_{wl}}{V_k} \right) \right]^{\delta_{dsl}} \tag{18}$$

and the resulting modified ETM is

$$m_T = 1 - \sum_{s=1}^{S} R_s \left[\prod_{w=s}^{s+J} \left[\prod_{l=1}^{L} \left[\prod_{d \in w} \left[1 - \left(\sum_{k=1}^{K} D_{wkl} \frac{P_{wk} \; f_{wl} \; W_{wl}}{V_k} \right) \right]^{\delta_{dsl}} \right] \right] \right]$$

$$= 1 - \sum_{s=1}^{S} R_s \left[\prod_{w=s}^{s+J} \left[\prod_{l=1}^{L} \left(1 - \sum_{k=1}^{K} D_{wkl} \frac{P_{wk} \; f_{wl} \; W_{wl}}{V_k} \right)^{\sum_{d \in w} \delta_{dsl}} \right] \right]. \tag{19}$$

The modified ETM retains the major features of ETM. The fraction entrained is still defined in terms of a weighted average of region-specific ratios of (1) the volume of cooling water withdrawn from a region to (2) the volume of the region. The weighting factor for each region is the proportion of the river-wide abundance that is in the region. Like the CEMR model,

the modified ETM does not adjust the daily fraction entrained for continuous reduction of abundance due to entrainment within the day. The modified ETM and the CEMR models are similar in both algebraic structure and component parameters (Table X-3).

Calibration of Modified ETM

The modified ETM is calibrated using intermediate calculations from the CEMR model and available data from 1981 through 1987 (no data were available for Danskammer in 1981 nor for Indian Point in 1982). The calibration is accomplished by estimating $W_{wk.l}$ (W-ratio) from the conditional survival rates as defined for the two models. Precise estimates of the W-ratio have always been problematic, therefore this term is chosen for calibration.

Based on the approximate equality of the conditional survival rate terms ($\overline{CSR}_{d\in w,l}$) used in the two models (equations 17 and 18),

$$1-\left(\frac{\overline{X}_{d\in w,l}}{\overline{N}_{d\in w,l}}\right)\cong 1-\left(\sum_{k=1}^{K} D_{wkl}\,\frac{P_{wk}\quad f_{wl}\;W_{wl}}{V_k}\right) \tag{20}$$

from which

$$W_{wl}\cong\left(\frac{\overline{X}_{d\in w,l}}{\overline{N}_{d\in w,l}}\right)\left(\sum_{k=1}^{K} D_{wkl}\,\frac{P_{wk}\quad f_{wl}}{V_k}\right)^{-1}. \tag{21}$$

Since the W-ratios are not affected by the through-plant mortality rate, equation (21) was simplified by setting the through-plant mortality rate (f_{wl}) equal to 1 in both the CEMR and ETM formulations of $\overline{CSR}_{d\in w,l}$. Plant-specific, weekly W-ratios were then estimated as

$$\hat{W}_{wl}=\left(\frac{\sum_{d\in w}\hat{N}E'_{dl}}{\sum_{d\in w}\hat{N}'_{dl}}\;\hat{R}PC_{dl}\right)\left(\sum_{k=1}^{K}\hat{D}_{wkl}\,\frac{P_{wk}}{V_k}\right)^{-1} \tag{22}$$

where hats denote estimates.

W-ratios averaged over all years were computed in two steps. First, average W-ratios were computed by year (y) as weighted averages of the arc-tangent transformed week-specific estimates with weights being relative measures of exposure to entrainment:

$$\hat{W}_{yl}=\arctan\left[\left[\sum_{w}\tan(\hat{W}_{ywl})\;\left(\sum_{s=1}^{S}\hat{R}_s\hat{C}_{wsl}\right)\right]\left[\sum_{w}\left(\sum_{s=1}^{S}\hat{R}_s\hat{C}_{wsl}\right)\right]^{-1}\right]. \tag{23}$$

Then overall average W-ratios ($\hat{W}_l$) were computed as simple averages of the year-specific averages:

$$\hat{W}_l=\frac{1}{n_y}\sum_{y}\hat{W}_{yl}, \tag{24}$$

where n_y is the number of years with year-specific averages.

Parameters and Data

Parameters Addressed

This section addresses methods and data used to estimate model parameters listed in Table X-3. Table X-4 presents definitions, and identifies the equations using the Table X-3 parameters. The parameters and data can be roughly divided into two groups--those that are based on facilities and data collected on plant operation and those that are based on data collected on fish populations.

Plant Operation Parameters and Data

For both the CEMR model and the ETM models the plant operations data sets originally constructed for the June 1993 DEIS were used for years covered by that version of the DEIS (1974 to 1991). For the year's 1992 through 1995 data were acquired from a variety of sources. The plant operation data sets are described on a per-facility basis later in this in section.

The CEMR model requires daily flow rates, intake and discharge temperatures, and transit time (exposure duration) for each power plant. The ETM, like the CEMR model, requires flow rates (weekly rather than daily), intake and discharge temperatures, and exposure duration from each facility. The same plant operation data sets were used for the CEMR and ETM estimates for the Bowline Point, Danskammer, Indian Point and Roseton power plants for the years with entrainment sampling.

Fish Population Parameters and Data

For each species addressed, ETM requires estimates of relative regional abundance by life stage, relative cohort size, life stage duration, combined thermal and mechanical mortality rates, and relative density in withdrawn water relative to the overall region. CEMR requires estimates of the densities of entrained organisms by life stage, mechanical and thermal mortality rates, life stage durations, and daily river-wide abundances.

V_k.— Table X-6 presents the volumes of the river segments as obtained from the utilities' year class reports.

L and J.—The life stage at any age (l, with a maximum of L) and the maximum age at which a fish species could be entrained (J) were obtained or estimated using published data on life stage duration and growth.

The duration in days of each life stage was based on (1) values from Boreman et al. (1982), (2) equations predicting duration as a function of water temperature, or (3) a review of the literature to estimate the age at which juveniles became too large to entrain (Table X-7).

Life stage duration was predicted from water temperature (HRU, 1988d) for the egg and YSL life stages for American shad and striped bass and for the egg stage of white perch. For American shad, an exponential model was fit to data from Table 20 in Boreman (1983). The resulting equations are

$$L_E = \exp(4.118164) \times \exp(-0.127013 \times T_E) \text{ and}$$

$$L_Y = \exp(3.006309) \times \exp(-0.088367 \times T_Y)$$

where

L_E and L_Y = duration in days of the egg (E) and YSL (Y) life stages; and

T_E and T_Y = river-wide water temperature, averaged over regions and strata weighted by the estimated abundance of egg (E) or YSL (Y).

If temperatures were outside the range of the experimental data (< 12EC for egg and YSL, > 27EC for egg, and > 17EC for YSL), then T_E or T_Y was set equal to the nearest experimental value.

For striped bass, the following equations from Boreman (1983) were used:

$L_E = 10.77 \times \exp(-0.0934 \times T_E)$ and

$L_Y = 14.95 - (0.453 \times T_Y)$.

For white perch YSL, the following equation from Boreman (1981) was used:

$L_E = \exp(2.635925) \times \exp(-0.105852 \times T_E)$.

If temperatures were outside the range of the experimental data (< 11.1EC or > 25EC), then T_E was set equal to the nearest experimental value.

For Atlantic tomcod and bay anchovy, all life stage durations were taken from Boreman et al. (1982). For spottail shiner, only the maximum age of entrainable juveniles was needed. This was estimated as the difference between age at maximum entrainable size and age at metamorphosis from PYSL to juvenile.

The age of spottail shiner at metamorphosis from PYSL to juvenile was not available in the literature. The largest larval size reported was 14.25 mm (Scott and Crossman, 1973), and the smallest juvenile reported in several years of sampling at a mid-western lake (McCann, 1959) was 13 mm. Length at metamorphosis was therefore assumed to be 14 mm. Length-at-age data were available only for emerald shiner—a linear regression on the emerald shiner data predicted age at 14 mm to be 22.6 days (p # 0.004).

Spottail shiners were not measured during entrainment sampling, so a conservative estimate of 60 mm (the maximum over all species for which length data were available) was used as the estimate of the maximum entrainable length. Spottail shiner juveniles reached 60 mm in length 3 to 4 months (90-120 days) after spawning (McCann, 1959), and the average of 105 days was assumed to be the age of juvenile spottail shiners at 60 mm of length.

Assuming age at metamorphosis to be 22 days, and age at maximum entrainable length to be 105 days, the life stage duration of entrainable juveniles is 83 days. The slowest reported growth rate in the literature for spottail shiner juveniles was 0.63 mm/day (McCann, 1959), which give an estimate of 73 days to grow from 14 to 60 mm. Using an estimated life stage duration of 83 days should be a conservative estimate that should somewhat overestimate the length of exposure to entrainment mortality and thus the total effect on the population.

S and R_S—The week of the spawning period is represented by s, and the maximum number of weeks in the spawning period is represented by S. Because weekly cohorts are defined by the week in which they were spawned, weekly cohorts are also represented by s and S. The temporal distribution of spawning across the spawning period determines relative cohort size, which is expressed by R_S, the proportion of spawning that occurred in week s.

For American shad, bay anchovy, river herring, striped bass, and white perch, the relative size of each daily egg cohort was calculated as described for the CEMR model and then summed over days within each week to convert to a weekly time step.

For Atlantic tomcod, cohort size was based on YSL rather than eggs. The LRS did not begin sampling early enough in the year to provide an empirical estimate of YSL abundance in 1981-1987. The two years with the earliest LRS sampling were 1976 and 1977. For each of these years, relative weekly Atlantic tomcod YSL cohort size was estimated as described earlier for egg cohorts, then averaged over years. The total period of YSL presence in the river was from week 8 to week 16 (where week 1 begins with the first Monday of the year), but the last three weeks accounted for less than 0.1% of all YSL. Given that the last significant numbers of YSL occurred in week 13 and assuming a 4-week life stage duration for YSL (Boreman et al., 1982), the last cohort would have matured from egg to YSL in week 10. Relatively few YSL were collected in the first week when data were available (6% of the total, compared to 21.5% in the next week), but it was possible that YSL first appeared prior to the first week of LRS sampling (week 8). Assuming that this is the case, on average four weekly cohorts of Atlantic tomcod occur, beginning in week 7 (approximately February 15). In the absence of information on relative cohort size, equal size was assigned to the four cohorts ($R_c = 0.25$ for all cohorts).

For spottail shiner, no adequate data were available on eggs or larvae that could be used to estimate cohort number and size. Spawning in Lake Erie has been reported as occurring in late June or early July, with ripe females reported on May 15 (Scott and Crossman, 1973). A total of 6 weekly cohorts were assumed to occur beginning in the first week of June, with each cohort being of equal size ($R_c = 0.167$).

δ_{dsl}—This parameter is the proportion of day d that individuals of cohort s spend in life stage l. Life stage duration estimates (Table X-7) were used to estimate the proportion of each day spent in each life stage for each daily cohort (δ_{dsl}). For the weekly time step in the ETM model,

$$\delta_{ds_w l} = \frac{\sum_{s_d \in s_w} \sum_{d \in w} \delta_{ds_d l}}{\eta_w} \tag{25}$$

where

$\delta_{ds_w l}$ = the proportion of week w that weekly cohort c_w spends in life stage l;

$\delta_{ds_d l}$ = the proportion of day d that daily cohort c_d spends in life stage l;

η_w = the total number of daily cohort-days in week w;

$s_d \in w$ are all daily cohorts present in week w, and $d \in w$ are all days in week w.

N_{dsl} and RPC_{dl}—Table X-4 defines N_{dsl} and RPC_{dl}. For any species, the river-wide abundance of cohort s individuals that are in life-stage l on day d (N_{dsl}) is determined from data on the density of individuals in the river, estimates of the relative probability of capture of gear (RPC_{dl}), estimates of weekly survival rates, and information on life stage duration. The derivation of these quantities is described below.

River-wide Abundance (N_{dsl})—River-wide abundance was estimated using data from the river sampling program chosen as being most appropriate for each species and life stage. Data were used from the LRS (HRU, 1988c, 1989a), BSS (HRU, 1988c, 1989a) and FSS (HRU, 1988c, 1989a). For the entrainable juveniles a combination of programs was often used (Table X-8). In general, river-wide estimates were based on estimates for portions of the river defined by region (12 regions covering river miles 12 to 152, or 13 regions covering river miles 0 to 152) and strata (defined by water depth).

For most species, river-wide abundance estimates for the egg, YSL, and PYSL life stages were made using the LRS program (Table X-8). The following volume-weighted average of abundance estimates by region and strata was used:

$$N_{ld} = \frac{\sum_k \sum_h N_{ldkh} \times V_{kh}}{\sum_k \sum_h V_{kh}} \tag{26}$$

where

$N_{ld} =$ the river-wide abundance of life stage l on day d;

$N_{ldkh} =$ the abundance of life stage l on day d in region k and strata h; and

$V_{kh} =$ the water volume of stratum h in region k,

and

$$N_{ldkh} = V_{kh} \times \vartheta_{ldkh}$$

where

$\vartheta_{ldkh} =$ the density of life stage l on day d in region k and stratum h;

and

$$\vartheta_{ldkh} = \frac{\sum_i B_{dkhji}}{\sum_i V_{dkhi}}$$

where

B_{ldkhi} = the number caught in sample i on day d in region k and stratum h of organisms in life stage l; and

V_{dkhi} = the volume of sample i on day d in region k and stratum h.

Daily density estimates were calculated from LRS data sets for each date sampled by the LRS. Missing dates were then filled in using linear interpolation within each region and stratum. Densities in unsampled strata within each region were then estimated as

$$\vartheta_{ldkh} = \vartheta_{ldkh^*} \times k_{lh}$$

where

k_{lh} = a coefficient used to estimate density in stratum h based on density in stratum h^*.

In regions 1 through 4 and 6, density in the shore strata (6 to10 feet deep) and beach strata (1 to 5 feet deep) were estimated from the density of the shoal strata (10 to 20 feet deep). In regions 5 and 7 to 12, density in the shore, shoal, and beach strata were estimated from the density of the bottom strata (> 20 feet deep, within 10 feet of the bottom). Table X-9 presents coefficients by species, life stage, and stratum.

Prediction equations were developed for predicting ichthyoplankton densities in Region 0 based on observed densities in Region 1. Separate analyses were conducted for each taxon, life stage and stratum. The prediction equations had the following mathematical form:

$$\ln(D_{0,w}) = \alpha + \beta \ln(D_{1,w})$$

where $D_{0,w}$ = density in Region 0 in week w; and

$D_{1,w}$ = density in Region 1 in week w.

The coefficients, α and β, were estimated using linear regression and data from all years and weeks in which both Region 0 and Region 1 were sampled. A prediction equation was kept only if the regression was statistically significant with a probability level less than 0.05. Table X-10a lists the estimated coefficients for the significant prediction equations.

The same method was used to develop equations for predicting densities in the northern portion of Region 12 based on the observed densities in the southern portion of Region 12. Table X-10b presents the estimated coefficients for the significant prediction equations from these analyses.

For both the Region 0 and Region 12 analyses, an assessment was conducted to determine whether covariates (i.e., conductivity, dissolved oxygen or temperature) would improve the predictions. For both sets of analyses, the inclusion of covariates did not significantly improve the predictions. Therefore, covariates were not included in the prediction equations.

Once regional densities had been estimated, the water volume for the entire region was used when needed as either a weighting factor or multiplier to obtain river-wide abundance.

For American shad, bay anchovy, striped bass, and white perch a PYSL-based projection was used as the initial estimate of juvenile river-wide abundance (Table X-8). For river herring the juvenile abundances based upon the LRS program were used as the first estimate. The river-wide abundances of juvenile Atlantic tomcod and spottail shiner were not estimated, because the CEMR model is not used for these species. The estimation of the distribution of these two species among regions, required by the ETM model, is discussed in a later section.

The gear used in the LRS was not designed to fully sample the juveniles of American shad, bay anchovy, striped bass, white perch, or the river herring. The nets are too small and towed too slowly for these larger larvae, and gear avoidance is likely leading to underestimates of the number of these individuals in the river. However, the LRS was judged to do an adequate job of sampling the juvenile stage of these species for the purpose of estimating the proportion of juveniles in the various regions of the river for the ETM model, and as the beginning step in estimating the river-wide abundance of river herring juveniles for the CEMR model. The FSS and BSS programs start too late and use field-sampling methods designed for collecting juveniles predominantly larger than the entrainable size of interest. Therefore, neither of these programs could be used directly to estimate entrainable juvenile abundance. For American shad, bay anchovy, striped bass, and white perch the abundance of juveniles is initially made using the PYSL-based projection, and then revised using data from the FSS. For river herring the revision using the FSS data is applied to the estimates of juvenile abundance arising directly from the LRS.

The PYSL-based projection results in an estimate of juvenile abundance based upon the estimated sizes of the PYSL cohorts and the PYSL survival rate:

$$PROJN_{Jw} = (\sigma_P)^{l_P} \sum_s N_{Ps} \times \sigma_P^{\,w-(s+l_P)} \quad (27)$$

where

$PROJN_{Jw}$ = the projected daily abundance of juvenile fish in week w (day represented as a fraction of week);

σ_P = the estimated weekly survival rate of PYSL for the year if a sufficient number of cohorts were present (if not the mean of all other years estimated weekly PYSL rates was used);

l_P = the duration of the PYSL life stage; and

N_{Ps} = the estimated initial river-wide abundance of PYSL cohort s.

The initial river-wide abundance of PYSL cohort s (N_{Ps}) and the PYSL survival rate for the current year (σ_P) were estimated using the model

$$N_{Pw} = \sum_s N_{Ps} \times \sigma_P^{w-s} \times X_{sw} \quad (28)$$

where

N_{Pw} = the observed weekly PYSL river-wide abundance in week w;

N_{Ps} = the estimated river-wide abundance of PYSL cohort s in its first week;

σ_P = the estimated weekly survival rate of PYSL for the year; and

X_{sw} = 1 if cohort s is present during week w.

The solution to this model was found using non-linear regression. The first week when the cumulative abundance of the PYSL life stage exceeded 5% of the annual total was designated as the week of the first cohort. The last cohort was identified by counting back l_P weeks (the PYSL duration) from the last week when the PYSL stage was found in the river. The total number of cohorts for the year is then found by counting from the first cohort to the last cohort. If the LRS sampling program sampled two or more cohorts during the year then both the initial river-wide abundance of PYSL cohort s (N_{Ps}) and the PYSL survival rate for the current year (σ_P) were estimated. If there was only one cohort, or if the initial regression model for the species and year did not yield a reasonable solution for σ_P (e.g., estimated = 1), then the average of all of the σ_P values from years with solutions was placed into the model, and this modified model was then solved to find estimates of the initial river-wide abundance of PYSL cohorts (N_{Ps}'s).

The PYSL-based projection is a conservative estimate of the abundance of the juveniles, because the lower PYSL survival rate is used as a surrogate for the higher survival rate of the juvenile stage of the species.

The FSS data were then used to revise the initial estimates of juvenile abundance. The FSS revision is based upon a simple premise—the river-wide estimate of the number of older juveniles from the FSS must be less than or equal to the river-wide abundance of the juveniles of that species earlier in the year. Therefore, for a given week, if the FSS data resulted in a higher abundance than the initial estimate, then the FSS estimate was used for that week and earlier weeks of lower juvenile abundance. As stated earlier, the initial estimates for American shad, bay anchovy, striped bass, and white perch were made based upon the PYSL projection, while the initial estimates for river herring were made based directly upon the juvenile counts in the LRS data.

Relative Probability of Capture (RPC)—Table X-11a summarizes the RPC values for striped bass and white perch from the Coastal (1991a) study, while Table X-11b presents the RPC factors for bay anchovy.

D_{wkl}—Table X-4 defines D_{wkl}. For any species, the average proportion of river-wide abundance of life stage l individuals that are in region k (D_{wkl}) is determined from two quantities—(1) the river-wide abundance of life stage l at any time; and (2) the proportion of the river-wide population of that life stage at that time that is in each region k. The derivation of river-wide abundance is discussed in the previous section. Calculation of the distribution by region is described below.

The relative abundance by region is represented as:

$$U_{lwk} = \frac{N_{lwk}}{\sum_k N_{lwk}} \tag{36}$$

where

U_{lwk} = the proportion of the river-wide population of life stage l in week w that is in region k; and

N_{lwk} = the abundance of life stage l in week w in region k.

For each species, U_{lwk} was estimated for each week that data were collected by the sampling program appropriate to life stage l. For American shad, river herring, striped bass, and white perch, the regional abundance estimates were calculated for the egg, YSL, PYSL, and entrainable juvenile stages as described in the River-wide Abundance section. For Atlantic tomcod the abundances of YSL, PYSL, and entrainable juvenile stages were calculated using the same methods, however the regional abundances were used only as an intermediate step in the calculation of the regional distribution pattern. For spottail shiner only the distribution of the entrainable juvenile stage was estimated, and this was done using the BSS data:

$$N_{Ywk} = \frac{\sum_i B_{Ywki}}{n_{wk}} \times V_k \tag{37}$$

where

N_{Ywk} = the relative abundance of juveniles in week w in region k;

B_{Ywki} = the total catch of juveniles in haul i in week w, region k;

n_{wk} = the total number of beach seine hauls in week w, region k; and

V_k = the area of the water within the shore stratum in region k.

Within a given region during a year, there are no missing U_{lwk} values for dates falling between the first and last days of sampling of that region for the applicable program (BSS for SS juveniles, LRS for all others). This is because the regional densities, upon which the regional distributions are based (via the regional abundance estimates), were "filled-in" across dates using linear interpolation. However, in some years regions were totally left out of the sampling or were not sampled early or late in the program. In these cases, U_{lwk} values may be missing for all or some regions during a given week.

For any week with a missing U_{lwk} value a substitute value was used. The substitutions were based upon, as detailed below, the values contained in a data set of the "average" regional distributions for each week. The averages contained in this data set were calculated using all available years of sampling from the applicable program. For a given week (1 to 52), data from all years with all regions sampled during that week were used to calculate an overall mean U_{lwk} value for that week. To ensure these weekly values still summed to 1 for the river as a

whole, these averages were standardized by summing within the week and dividing each regional U_{lwk} value by the river-wide sum.

If the substitution data set had non-missing U_{lwk} values for a week in which all of the year-specific regional values for U_{lwk} were missing, then the entire set (all 12 or 13 regions) of U_{lwk} values for that week from the substitution data set was used. If only some of the regions had missing values, then the non-missing U_{lwk} values were first re-scaled so that their sum matched the sum of the same regions within the substitution data set, then the year-specific missing values were directly replaced with the values from the substitution data set. For example, assume in a given year that regions 1 through 3 were not sampled during a week late in the LRS sampling program. The U_{lwk} values for regions 1, 2, and 3 would be missing, but the initial U_{lwk} values for the remaining regions (4-12) would be non-missing, and would be a better estimate of the distribution of the larvae among regions 4 to 12 than the corresponding values from the substitution data set. Further assume that the total proportion for regions 4 to 12 in the substitution data set is 0.8 (of the total of 1.0 river-wide). Using this method, each of the U_{lwk} values for regions 4 to 8 would be divided by 0.8 so that their sum would be 0.8 as it is in the substitution data set. Since the current year's non-missing values have been re-scaled; the values for regions 1 to 3 from the substitution data set could then be directly substituted.

W_l

The ratio of the average plant intake density of a given life stage to the average regional density (W_l) adjusts for non-uniform distribution of fish in the river. For American shad, bay anchovy, river herring, striped bass, and white perch at Bowline Point, Indian Point, Roseton and Danskammer, W_l values for 12 and 13 regions were estimated based on a calibration of the ETM and CEMR models (Tables X-12a, and X-12b). For river herring and white perch at the Albany Steam Station, a calibration was performed based on data from the Albany Steam State Pollution Discharge Elimination System (SPDES) (LMS, 1984d). For all other species and plants, W_l was assumed to be 1.0 for all life stages.

P_{wk}

The rate of water withdrawal from any region *k* in any week was calculated from the rates of water withdrawal by the following facilities.

Albany Steam Station—Daily flow values for 1981 through 1985 were keypunched from Discharge Monitoring Worksheets. Monthly average flows in 1986 and 1987 were obtained from the computer file provided by NYSDEC (1993). A SAS computer file was created containing daily flow in m^3/day for 1981-1987, assigning the monthly average value to each day of the month in 1986 and 1987.

Bowline Point.—Flow data at Bowline Point for March through September were provided by the utilities for each year from 1981-1987 (HRU, 1990b). For 1981-1985, plant flow rate by unit was computed for each hour during the day from the plant operating condition (pump and condenser configuration). Table X-13 summarizes the flow resulting from each

condition. For 1986 and 1987, flow rate data were only available by unit on an average daily basis.

For January-February and October-December, average monthly flow rates were keypunched from tables in annual impingement reports (LMS, 1982b, 1983b, 1984b, 1985b, 1986a, 1987a, and 1988b). The flow rate on each day of the month was assumed to be equal to the average daily flow rate for the month.

Danskammer.—The average monthly combined-unit flow rate at Danskammer for 1982-1987 was keypunched from tables in annual Roseton/Danskammer impingement reports (LMS, 1983a, 1984a, 1987c, 1988d, EA, 1985b, and 1986). No entrainment sampling took place in 1981, and so no flow data were required for that year. The flow rate on each day of the month was assumed to be equal to the daily average for the month. Per-unit flow was estimated by assuming that the total flow was distributed among units in proportion to their maximum flow capacity:

$$P_i = \frac{P_{Pi}}{\sum_i P_{Pi}} \times P_C \tag{38}$$

where

$P_i =$ flow rate (m^3/sec) at unit I;

$P_{Pi} =$ full-capacity flow rate at unit i, where $P_{P1} = P_{P2} = 2.55$ m^3/sec, $P_{P3} = 4.92$ m3/sec, $F_{F,4} = 9.00$ m^3/sec; and

$P_C =$ the combined-unit flow rate.

Indian Point.—Daily flow data at Indian Point for all of 1981 and for May to mid-August for 1986-1987 were provided by the utilities (HRU, 1990d). Average daily flow rates by unit for 1983-1985 were taken from tables in entrainment reports (EA, 1984 and 1985a, NAI, 1987). Missing data were filled in using monthly average flow for the combined units, with a few still-missing values keypunched from entrainment reports (NAI, 1987, 1988). The flow rate on each day of the month was assumed to be equal to the daily average for the month.

Lovett Generating Station.—Average monthly combined-unit flows (1981-1982) or daily per-unit flows (1983-1987) at Lovett were keypunched from tables in annual impingement reports (LMS, 1982c, 1983c, 1984c, 1985c, 1986b, 1987b, 1988c). The flow rate on each day of the month was assumed to be equal to the daily average for the month. Flows by unit in 1981 and 1982 were estimated by assuming that the total flow was distributed among units in proportion to their maximum flow capacity (unit 3 = 15.9% of the total, unit 4 = 39.2%, and unit 5 = 44.9%).

Roseton.—Flow data at Roseton for March through September were provided by the utilities for each year from 1981-1987 (HRU, 1990f). For 1981-1985, plant flow rate by unit was computed for each hour during the day from the plant operating condition (pump and condenser configuration). Table X-14 shows the flow resulting from each condition. For 1986 and 1987, flow rate data were only available by unit on an average daily basis.

For January-February and October-December, average monthly flow rates for combined units were keypunched from tables in annual impingement reports (LMS, 1982a, 1983a, 1984a, 1987c, 1988d, EA, 1985b, and 1986). The flow rate on each day of the month was assumed to be equal to the daily average for the month.

Empire State Plaza.—Average daily flow rates by month from April 1986 through December 1987 were available in a computer file (NYSDEC, 1993). For a few additional months (June-August 1981 and May-September 1985), Discharge Monitoring worksheets provided monthly average flow rates. No flow data were available for other months in the 1981-1987 window. For months when data were available, a computer file was created that contained daily flow rates in m^3/day, where the daily average for the month was assigned to each day of that month.

Westchester RESCO.—Neither daily nor monthly flow data from 1981-1987 were available for Westchester RESCO. Analyses were therefore run assuming the maximum permitted discharge rate of 38,000 gallons per minute (Table X-5). Daily flow rates (in m^3/day) were assumed to be equal to the maximum rates.

Facility-Specific Proportion of Water Withdrawn

For each facility that withdrew more than 50 mgd of Hudson River water (Table X-5), ETM required the facility's proportion of total water withdrawal that originated in each region of the river. Table X-15 summarizes these values.

f_{dl}

This parameter expresses the fraction of life stage l individuals that enter an intake on day d and eventually are killed by plant passage. The fractions of individuals killed were calculated from the instantaneous through-plant mortality rate. That rate has two components, the thermal mortality rate and the mechanical mortality rate. Mechanical mortality rates were estimated from empirical entrainment survival studies. Thermal mortality rates were estimated from discharge temperature and duration of exposure (transit time).

Through-plant mortality rates used in the ETM model were calculated for each facility as:

$$m_{lw} = 1 - (1 - m_{Tlw}) \times (1 - m_{Mlw}) \tag{39}$$

where

m_{lw} = the through-plant mortality rate of an entrained organism in life stage l in week w;

m_{Tlw} = the thermal mortality rate for life stage l in week w; and

m_{Mlw} = the mechanical mortality rate for life stage l in week w.

For American shad, Atlantic tomcod, river herring, spottail shiner, striped bass and white perch, daily rates were estimated as described above and then averaged over days within weeks, weighted by daily flow rates. For bay anchovy, 100% through-plant mortality was assumed.

Mechanical Mortality

Mechanical mortality rates for each species and life stage were estimated based on empirical entrainment survival studies. The data used were compiled from studies using either pumped or flume collection gear at Indian Point (pump gear in 1978 and 1979, flume gear in 1979, 1980, and 1988; EA, 1979, 1981b, 1982, 1987), Roseton (pump gear in 1977, 1978 and 1980, flume gear in 1980; EA, 1980, 1983), and Bowline Point (pump gear in 1979 and 1979, flume gear in 1979; EA, 1981a). Fish collected at intake and discharge sampling locations were classified as live or dead, with "stunned" fish counted as dead.

For each combination of plant, gear, year, species and life stage, data were used only if the survival rate for samples collected in the intake was greater than 0, and only if the total number collected in the discharge was large enough that at least one surviving fish would be expected based on intake survival rates. The mechanical mortality rate due to entrainment was estimated as the ratio of survival in discharge samples to survival in intake samples to correct for mortality due to the sampling procedure itself. The method is

$$m_M = 1 - \frac{\sigma_D}{\sigma_I} \tag{40}$$

where

$\sigma_I =$ the survival rate in intake samples (total living / total collected); and

$\sigma_D =$ the survival rate in discharge samples.

Mechanical mortality rates were weighted by the inverse of their variance before averaging over gear and year:

$$wt = \frac{1}{\left(\frac{\sigma_D}{\sigma_I}\right)^2 \times \left(\frac{\frac{1}{B_I} \times \sigma_I \times (1-\sigma_I)}{\sigma_I^2} + \frac{\frac{1}{B_D} \times \sigma_D \times (1-\sigma_D)}{\sigma_D^2} \right)} \tag{41}$$

where

$wt =$ the weight used in averaging over gear and year;

$B_I =$ the total number of organisms collected in intake samples; and

$B_D =$ the total number of organisms collected in discharge samples.

Due to frequent zero survival rates for river herring (leading to undefined variance), the weight used for herring was based on sample sizes only:

$$wt = \frac{1}{\left(\frac{1}{N_I} + \frac{1}{N_D}\right)}. \tag{42}$$

Data were pooled over all plants due to the absence of sufficient data to provide accurate plant-specific estimates. Adequate empirical data were available to provide estimates for:

- Atlantic tomcod YSL, PYSL, and juvenile;
- herring PYSL;
- minnow PYSL;
- striped bass YSL, PYSL, and juvenile; and
- white perch PYSL and juvenile.

Herring (American shad, blueback herring, and alewife) were treated as one species. Adequate data were not available for spottail shiner, but it was assumed that spottail shiner mechanical mortality rates were equal to those estimated for "minnows". For herring and spottail shiners, the PYSL mortality rate was assumed to be valid for YSL and juvenile. Similarly, for white perch, the PYSL rate was assumed to be valid for YSL. For all species, egg mortality was assumed to be 1.0. Table X-16 presents mechanical mortality estimates.

Thermal Mortality

Thermal mortality was estimated using a double hinged line model based on exposure temperature (discharge temperature and duration of exposure for each unit, each plant). A double hinged line model specifies a function such that the function takes on a constant value (0 in this case) when the value of an independent variable is less than a lower boundary and a different constant value (1 in this case) when the value of the same independent variable is greater than an upper boundary as follows:

$$m_T = \begin{cases} 0 \text{ if } T_D < X_1 \\ 1 \text{ if } T_D > X_2 \\ m_T^* \text{ otherwise} \end{cases} \tag{43}$$

and

$$m_T^* = \left[\frac{1}{X_2 - X_1}\right](T_D - X_1) \tag{44}$$

where

M_T^* = the thermal mortality rate for a given species and life stage;

T_D = the discharge temperature (EC);

X_1 = the lower temperature boundary (EC) for the double hinged line model; and

X_2 = the upper temperature boundary (EC) for the double hinged line model.

For striped bass, boundary values were estimated using nonlinear regression from experimental data (Kellogg et al., 1984, HRU, 1992b) as

$$X_1 = a1 + (b1 \times T_A) + (c1 \times \log_{10}(t_i)) \text{ and}$$

$$X_2 = a2 + (b2 \times T_A) + (c2 \times \log_{10}(t_i))$$

where

$T_A =$ intake temperature; and

$t_i =$ transit time through unit *i*.

Table X-17 summarizes the coefficients (*a1-c1*, *a2-c2*) for each life stage. The striped bass equations were used for white perch with the exception of the YSL life stage, where thermal mortality was estimated using an equation from LMS (1988a):

$$M_T = 0.9915 - [(0.07205 \times T_D \times \log_{10}(t_i)) + (0.01451 \times T_D \times T_A) + (3.293 \times \log_{10}(t_i)) - (0.5921 \times T_A)]$$

Table X-18 presents boundary values for Atlantic tomcod, American shad, river herring, and spottail shiner. For Atlantic tomcod YSL and PYSL, X_1 was set equal to the average TL95 thermal tolerance limits at 10 minutes of exposure, as reported in Table 5.2-5 in EA (1978). X_2 was set equal to the average TL5 limit reported in the same source. The boundary values for the juvenile life stage were set equal to those for PYSL.

For American shad and river herring YSL and PYSL, X_1 was set equal to the average TL95 thermal tolerance limits for alewife at 10 minutes of exposure, as reported in Table 5.2-5 in EA (1978). X_2 was set equal to the average TL5 limit reported in the same source. The boundary values for the juvenile life stage were set equal to those for PYSL.

For spottail shiner, X_1 was set equal to the TL95 thermal tolerance limits for the early juvenile life stage reported in EA (1978), and X_2 was set equal to the TL5 limit reported in the same source.

Discharge Temperature

Albany Steam Station.—Daily water temperatures recorded at Poughkeepsie Waterworks were used to estimate intake temperatures at Albany Steam Station (HRU, 1991b). The water works is about 65 miles downstream of the steam station. Linear interpolation was used to estimate temperatures on days when no measurements were taken. Monthly average discharge temperature data were keypunched from Discharge Monitoring Worksheets for January-March and October-December 1981; January-April, August-September, and November 1982; May and August-December 1983; January-March 1984; May and August-December 1986; and January-December 1987. In all other months, daily discharge temperature was estimated from intake (Poughkeepsie Waterworks) temperatures. The following statistically significant linear regression was used to predict discharge temperature from Poughkeepsie Waterworks temperatures in 1987, the only year with a complete set of Discharge Monitoring Worksheets available:

$$T_d = 6.72447 + 0.868815 \times T_w$$

where

$T_d =$ discharge temperature (EC) at Albany Steam Generating Station, and

$T_w =$ water temperature (EC) recorded at Poughkeepsie Waterworks.

Bowline Point.—Temperature data at Bowline Point during entrainment sampling (May-August) were provided by the utilities for each year from 1981-1987 (HRU, 1990b). For 1981-1985, intake and discharge temperatures were provided for each unit on an hourly basis. For 1986-1987, average intake and discharge temperature were provided for each unit on a daily basis.

On dates when temperature data were not available on computerized utility files, intake temperatures at the Indian Point Generating Station, located 6 miles upstream of Bowline Point, were used to estimate intake temperatures at Bowline Point (HRU, 1991a).

The average rise in temperature at Units 1 and 2 was estimated for each of the following three operating conditions (EA, 1985c) by averaging over dates when the plant was operating at that flow level:

3 pumps full (384,000 gpm)

2 pumps full with condenser open (316,000 gpm), and

2 pumps throttled (257,000 gpm).

For each hour of the day, the average rise in temperature was calculated for each of the above conditions at each unit. When necessary, discharge temperature was estimated as intake temperature plus this rise, using either on hourly estimates or the average rise over all hours of the day.

Danskammer.—Intake temperatures at Danskammer were assumed to be equal to those at Roseton (less than 1 mile downstream) on dates when temperature data at Roseton were available (see previous section). On all other dates, intake temperature was assumed to be equal to river temperature measured at the Poughkeepsie Waterworks about 6 miles upstream of Danskammer (HRU, 1991b). Linear interpolation was used to estimate temperatures at Poughkeepsie on dates when no measurements were taken.

The temperature increases at Danskammer generating units were estimated using the following equations from Boreman et al. (1982):

$$\Delta_3 = (9.345 \times G_3 + 125.8) / P_3 \text{ or}$$

$$\Delta_4 = (18.810 \times G_4 + 177.7) / P_4$$

where

Δ_3 or Δ_4 = the rise in temperature (EF) at Unit 3 or Unit 4; and

G_3 or G_4 = the generating load at Unit 3 or Unit 4 as a percent of dependable maximum net generation.

Generating load, taken from Table VII-8 in Boreman et al. (1982), varied by month (Table X-19). No estimate was available prior to April or after August. For these months, the value for the closest month (April or August) with available data was used. No equations were available for estimating rise in temperature at Units 1 or 2. Both these units were assumed to have a constant rise of 18EF (10EC), using the maximum value from Table 1.2-1 in EA (1977). Discharge temperature was calculated as the sum of the estimated rise in temperature (converted to degrees Centigrade) and the intake temperature.

Indian Point.—Temperature data at Indian Point during entrainment sampling (May-August) were provided by the utilities for 1981 and 1983-1987 (HRU, 1990d). For 1981 and 1983-1985, intake and discharge temperatures were provided for each unit at Indian Point on an hourly basis. For 1986-1987, average intake and discharge temperatures were provided for each unit on a daily basis.

On a few dates in 1981 when temperature data were not available on utility files (for any facility), river temperatures measured at Poughkeepsie Waterworks (over 30 miles upstream) were used as an estimate of intake temperature (HRU, 1991b). Discharge temperature was calculated based on the average rise in temperature as a function of flow rate:

$$\Delta_i = \frac{P_P \times \Delta_{Pi}}{P_i}$$

where

Δ_i = the rise in temperature (EC) at unit *I*;

P_i = the flow rate (m^3/sec) at unit *i*, with P_P being the full flow (maximum capacity) rate of unit *I*; and

Δ_{Pi} = the full flow design change in temperature at unit i, with Δ_{P2} = 8.85 EC and Δ_{P3} = 9.6 EC.

For each day when discharge temperature data were not available, the rise in temperature at each unit was calculated and added to the intake temperature to provide an estimate of discharge temperature.

Lovett Generating Station.—For 1983-1987, daily per-unit intake and discharge temperature data were keypunched from tables in annual impingement reports (LMS, 1982c, 1983c, 1984c, 1985c, 1986b, 1987b, 1988c). For 1981-1982, intake temperatures were assumed to be equal to those at Indian Point (about 1 mile upstream). A linear regression was run for each unit predicting discharge temperature from intake temperature using Lovett data for 1983-1987. The regressions were all significant (p values < 0.001), and the following regression equations were used to estimate discharge temperature:

$$T_{D,3} = 6.253319 + (1.020405 \times T_I) \text{ or}$$

$$T_{D,4} = 8.252059 + (1.017982 \times T_I) \text{ or}$$

$$T_{D,5} = 7.631272 + (1.010216 \times T_I)$$

where

$T_{D,i}$ = discharge temperature (EC) at Unit i (i=3, 4, or 5); and

T_I = intake temperature (EC) recorded at Indian Point.

The combined-unit discharge temperature was calculated as the average over all units weighted by unit flow.

Roseton.—Temperature data at Roseton during entrainment sampling (May-August) were provided by the utilities for each year from 1981-1987 (HRU, 1990f). For 1981-1985, intake and discharge temperatures were provided for each unit on an hourly basis. For 1986-1987, average intake and discharge temperatures were provided for each unit on a daily basis.

On dates when temperature data were not available on utility files, river temperatures at Poughkeepsie Waterworks (about 6 miles upstream of Roseton) were used as estimates of intake temperature (HRU, 1991b). Discharge temperature was calculated based on the average rise in temperature as a function of flow rate. The average rise in temperature at Units 1 and 2 was estimated for each of the following three operating conditions (LMS, 1986c) by averaging over dates when data were available:

2 units, 2 pumps operating (418,000 gpm)

2 units, 3 pumps operating (561,000 gpm), and

2 units, 4 pumps operating (641,000 gpm).

For each hour of the day, the average rise in temperature was calculated for each condition at each unit. When necessary, discharge temperature was estimated as intake temperature plus this rise, using either hourly estimates or the average rise over all hours of the day.

Empire State Plaza.—No information on transit time as a function of flow rate was available for Empire State Plaza. Analyses were therefore based on a 100% mortality rate, and no intake or discharge temperature data were required.

Westchester RESCO.—No information on transit time as a function of flow rate was available for Westchester RESCO. Analyses were therefore based on a 100% mortality rate, and no intake or discharge temperature data were required.

Transit Time

Albany Steam Station.—Based on estimates of a 450-foot discharge canal length and an average velocity in the canal of 4.5 feet/second (Young, 1993), the transit time at Albany Steam was calculated to be 1.67 minutes (100 seconds).

Bowline Point.—Transit time at Bowline Point was assumed to be inversely proportional to flow rate. A proportionality constant was computed based on the transit time values reported in EA (1981a) and the corresponding flow under each condition:

$$t = 129.6 / P$$

where

$t =$ transit time in minutes; and

$P =$ flow rate in m^3/second.

Danskammer.—Unit-specific transit times at Danskammer were estimated as a function of flow rate using the following equations from Boreman et al. (1982):

$$t_3 = 145.013 \times P_3^{-0.996} \text{ or}$$

$$t_4 = 73.317 \times P_4^{-0.999}$$

where

t_3 or $t_4 =$ transit time (minutes) at Unit 3 or 4; and

P_3 or $P_4 =$ flow rate (1000 gallons per minute) at Unit 3 or 4.

No equations were available for estimating transit time at Units 1 or 2. Both these units were assumed to have a constant transit time of 6.9 minutes, using the maximum exposure duration from Table 1.2-1 in EA (1977).

Unit 4 at Danskammer was off line from 27 September 1986 to 1 March 1987, and Unit 3 was off line from 13 March 1987 to 23 September 1987. The combined-unit flows used in analyses accurately reflected these outages. However, in estimating thermal mortality, flow was assumed to be occurring in all four units. This led to overestimates of thermal mortality. The 1986-1987 outage at Unit 4 occurred at a time of year when thermal mortality was already zero, so estimates for 1986 were not affected. In 1987, a moderate (15% difference on average) overestimate of thermal mortality occurred for American shad and river herring. Since mechanical mortality was high for these species, the effect on total mortality estimates was less than 3%. Striped bass and white perch thermal mortality rates were relatively low (25-35% on average, vs. 76% for herring), and the degree of overestimation was also relatively low (1.5-7.2% for the life stages affected). Bay anchovy were assumed to experience 100% mortality, and even with the overestimate total entrainment at Danskammer for Atlantic tomcod and spottail shiner was less than 0.1%. In summary, in 1987 entrainment effects at Danskammer were slightly overestimated for American shad, river herring, striped bass, and white perch.

Indian Point.—Transit time at each unit of Indian Point was calculated as a function of flow rate using the following equations presented in EA (1984):

$$t_2 = 1 / (-0.0008275907 + 0.000108864 \times P_2 + 0.00003650407 \times P_3), \text{ and}$$

$$t_3 = 1 / (-0.003645829 + 0.0001525479 \times P_3 + 0.0001306958 \times P_2)$$

where

t_2 or t_3 = transit time in minutes at unit 2 or unit 3;

P_2 or P_3 = the flow rate (1000 gpm) at unit 2 or unit 3.

Lovett Generating Station.—Unit-specific transit time at Lovett was estimated as a function of flow rate, using the following equations from Boreman et al. (1982):

$t_4 = 93.87 / P_4$ or

$t_5 = 252.0 / P_5$

where

t_4 or t_5 = transit time (minutes) at Unit 4 or 5; and

P_4 or P_5 = flow rate (1000s of gallons per minute) at Unit 4 or 5.

No equation was available for estimating transit time at Unit 3. The equation for Unit 5 (using Unit 3 flows) appeared to approximate the values expected for Unit 3 (Saksen, 1993), so Unit 3 transit times were estimated using the proportionality constant for Unit 5. The combined-unit transit time was calculated as the average over all units weighted by unit flow.

Roseton.—Transit time at Roseton was assumed to be inversely proportional to flow rate. A proportionality constant was computed based on the transit time values reported in LMS (1985a) and the corresponding flow under each condition:

$t_1 = 132.7 / P$ or

$t_2 = 141.7 / P$

where

t_1 or t_2 = transit time in minutes when one (1) or two (2) units are operating, and

P = flow rate (combined over both units) in m^3/second.

Empire State Plaza.—No information on transit time as a function of flow rate was available for Empire State Plaza. Analyses were therefore based on a 100% mortality rate, and no intake or discharge temperature data were required.

Westchester RESCO.—No information on transit time as a function of flow rate was available for Westchester RESCO. Analyses were therefore based on a 100% mortality rate, and no intake or discharge temperature data were required.

NE_{dl}

NE_{dl} represents the number of individuals in life stage l that are entrained on day d. It has two components—the rate of water withdrawn for each facility, described above, and the daily entrainment density, described below.

Daily Entrainment Density—Daily density by species was estimated based on in-plant entrainment sampling as follows:

$$\vartheta_{ld} = \frac{\sum_i B_{ldi}}{\sum_i V_{di}}$$

where

ϑ_{ld} = the density of life stage l entrained on day d;

B_{ldi} = the total number of life stage l caught in sample i on day d; and

V_{di} = the water volume sampled during sample i on day d.

At Bowline Point (HRU, 1988a, 1990a) and Roseton (HRU, 1990e), density was estimated separately for each operating unit, while at Indian Point (HRU, 1988b, 1990c) and Danskammer (HRU, 1993), density was estimated for the combined units. For each species and life stage, data files contained the sample date, the time and volume of the sample, and the total count of organisms collected.

For sampling events that spanned multiple days, the total number caught and volume sampled were assigned among days based on the ratio of the number of hours out of each day which were in the sample to the total number of hours in the sample. At Bowline Point samples were sometimes taken at only one of the units. On any day that samples were taken at only one unit, the density computed in the sampled unit was used as the estimate of the density in the unsampled unit. To adjust for the fact that sampling did not occur on each day, the density for days on which no sampling occurred was estimated using linear interpolation between the estimated density on proximate days.

4. RESULTS

The annual CMR estimates are presented in Tables X-20a through g, X-21a through f, X-22a through g, and X-23a through g. Tables X-20a through g present the results for 12 regions and estimated through-plant mortality and Tables X-21a through f present the results for 13 regions and estimated through-plant mortality. Tables X-22a through g present the results for 12 regions and assumed 100% through-plant mortality and Tables X-23a through g present the results for 13 regions and assumed 100% through-plant mortality. Estimates for spottail shiner for 13 regions are not presented because the riverwide abundance for this species is estimated using the Beach Seine Survey, which only samples 12 regions. Estimates for Westchester RESCO are only presented for 1984-1995 because the plant began operation in 1984.

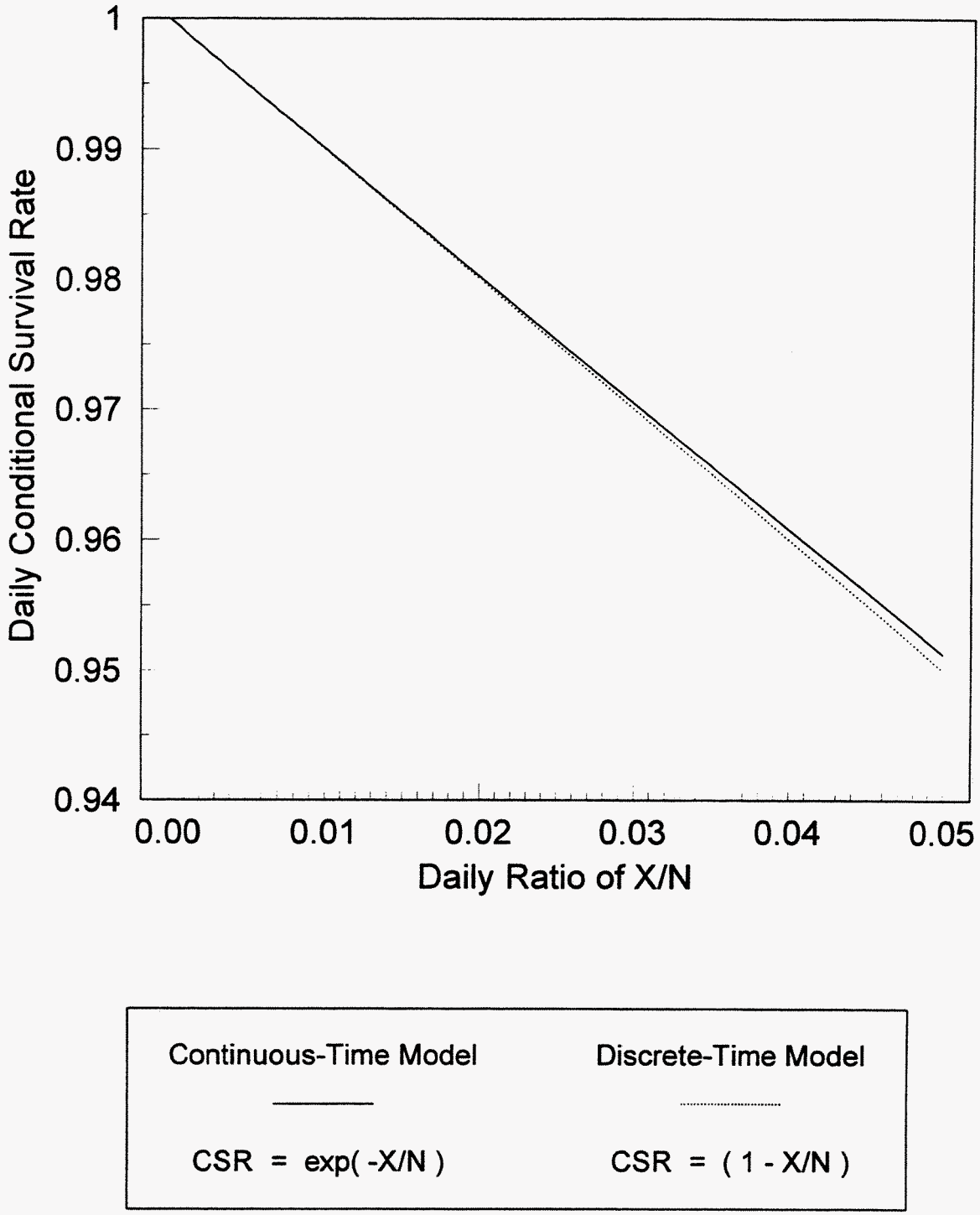


Figure X-1. Comparison of daily conditional survival rates as a function of the quotient of the number killed by entrainment to the river-wide abundance (*X/N*) based on discrete-time and continuous-time models.

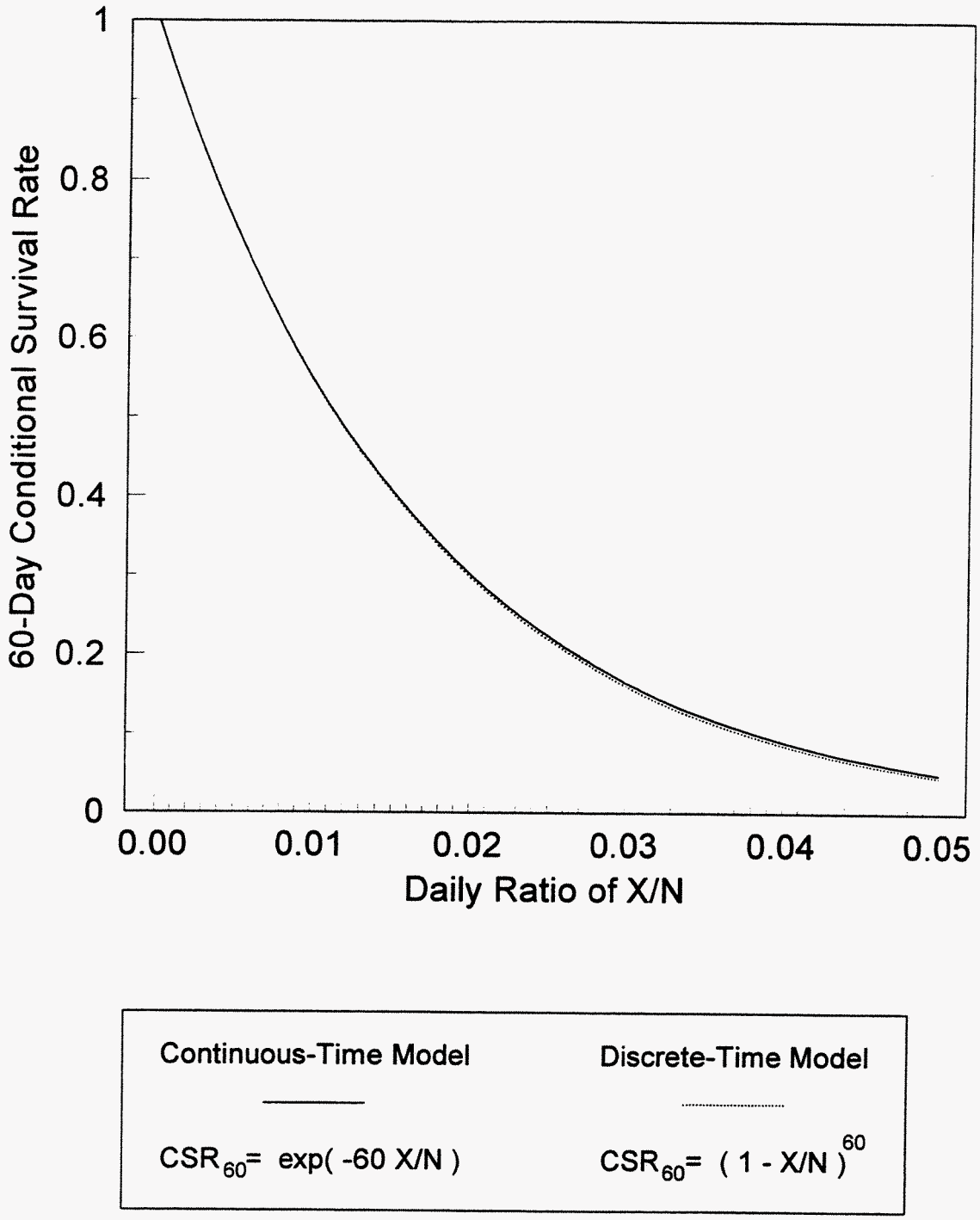


Figure X-2. Comparison of conditional survival rates (for 60 days) as a function of the quotient of the number killed by entrainment to the river-wide abundance (*X/N*) based on discrete-time and continuous-time models.

Table X-1.—Summary of Longitudinal River Survey unsampled areas.

Region (River Miles)	Habitat Stratum				
	Channel	Bottom	Shoal	Shore	Beach
12 (RM 140 - RM 152)	[13]	[7]	[6]	[1]	[<1]
12 (RM 125 - RM 139)	[19]	[6]	[10]	[6]	[2]
11 (RM 107 - RM 124)	[84]	[42]	[21]	[10]	[3]
10 (RM 94 - RM 106)	[113]	[43]	[8]	[9]	[3]
9 (RM 86 - RM 93)	[94]	[35]	[6]	[4]	[1]
8 (RM 77 - RM 85)	[131]	[32]	[1]	[1]	[<1]
7 (RM 62 - RM 76)	[229]	[63]	[1]	[4]	[1]
6 (RM 56 - RM 61)	[95]	[37]	[1]	[5]	[2]
5 (RM 47 - RM 55)	[179]	[26]	[1]	[1]	[<1]
4 (RM 39 - RM 46)	[162]	[33]	[6]	[5]	[2]
3 (RM 34 - RM 38)	[61]	[33]	[35]	[14]	[5]
2 (RM 24 - RM 33)	[138]	[62]	[91]	[23]	[8]
1 (RM 12 - RM 23)	[143]	[59]	[21]	[4]	[1]
0 (RM 0 - RM 11)	[142]	[48]	[19]	[0]	[0]
River-wide (RM 0 - RM 152)	[1,603]	[528]	[229]	[88]	[29]

Notes:

Unsampled in All Years Unsampled in Some Years [Volume in 1,000,000 cu.m.]

Stratum Definitions:

Channel—Water more than 10 ft (3m) from the river bottom in more than 20 ft (6m) depth.

Bottom—Water within 10 ft (3m) of the river bottom in more than 20 ft (6m) depth.

Shoal—Water between 10 ft (3m) and 20 ft (6m) depth.

Shore—Water between 5 ft (1.5m) and 10 ft (3m) depth.

Beach—Water less than 5 ft (1.5m) depth.

[Note: In Year Class Reports, the Shoal stratum is defined as all water less than 20 ft (6m) depth. In Table X-1 (above), the portion of the River with less than 20 ft depth is divided into 3 strata: Shoal (10-20 ft depth), Shore (5-10 ft depth), and Beach (0-5 ft depth), which correspond to the strata sampled during the 1986/87. Unsampled Areas Study. The sum of Shoal (10-20 ft), Shore (5-10 ft) and Beach (0-5 ft) volumes in Table 1 equals the Shoal volume reported in Year Class Reports].

Table X-2a.—CMR estimates based on 12-region ETMs and CEMR models. For all estimates, Region 12 is defined to include river miles 125-152.

Years	Water Withdrawal Facility	Taxon						
		American shad	River herring	Striped bass	White perch	Bay anchovy	Atlantic tomcod	Spottail shiner
1974 through 1980	Bowline Point	ι	ι	ι	ι	ι	ι	ι
	Indian Point	ι	ι	ι	ι	ι	ι	ι
	Roseton	ι	ι	ι	ι	ι	ι	ι
	Danskammer	ι	ι	ι	ι	ι	ι	ι
	Lovett	ι	ι	ι	ι	ι	ι	ι
	Empire State Plaza	ι	ι	ι	ι	ι	ι	ι
	Albany Steam Station	ι	ι	ι	ι	ι	ι	ι
	Westchester RESCO	ι	ι	ι	ι	ι	ι	ι
1981 through 1987	Bowline Point					ι	ι	ι
	Indian Point [a]	ι	ι	ι	ι	ι	ι	ι
	Roseton					ι	ι	ι
	Danskammer [b]	ι	ι	ι	ι	ι	ι	ι
	Lovett	ι	ι	ι	ι	ι	ι	ι
	Empire State Plaza	ι	ι	ι	ι	ι	ι	ι
	Albany Steam Station	ι	ι	ι	ι	ι	ι	ι
	Westchester RESCO	ι	ι	ι	ι	ι	ι	ι
1988 through 1997	Bowline Point	ι	ι	ι	ι	ι	ι	ι
	Indian Point	ι	ι	ι	ι	ι	ι	ι
	Roseton	ι	ι	ι	ι	ι	ι	ι
	Danskammer	ι	ι	ι	ι	ι	ι	ι
	Lovett	ι	ι	ι	ι	ι	ι	ι
	Empire State Plaza	ι	ι	ι	ι	ι	ι	ι
	Albany Steam Station	ι	ι	ι	ι	ι	ι	ι
	Westchester RESCO	ι	ι	ι	ι	ι	ι	ι

ι ETM CEMR

a CMR estimates based on ETM for 1982, and CEMR for the remainder.

b CMR estimates based on ETM for 1981, and CEMR for the remainder.

Table X-2b.—CMR estimates based on 13-region ETM models. For all estimates, Region 12 is defined to include river miles 125-152.

		Taxon						
Years	**Water Withdrawal Facility**	**American shad**	**River herring**	**Striped bass**	**White perch**	**Bay anchovy**	**Atlantic tomcod**	**Spottail shiner**
1974	Bowline Point	φ	φ	φ	φ	φ	φ	φ
through	Indian Point	φ	φ	φ	φ	φ	φ	φ
1980	Roseton	φ	φ	φ	φ	φ	φ	φ
	Danskammer	φ	φ	φ	φ	φ	φ	φ
	Lovett	φ	φ	φ	φ	φ	φ	φ
	Empire State Plaza	φ	φ	φ	φ	φ	φ	φ
	Albany Steam Station	φ	φ	φ	φ	φ	φ	φ
	Westchester RESCO	φ	φ	φ	φ	φ	φ	φ
1981	Bowline Point					φ	φ	φ
through	Indian Point [a]	φ	φ	φ	φ	φ	φ	φ
1987	Roseton					φ	φ	φ
	Danskammer [b]	φ	φ	φ	φ	φ	φ	φ
	Lovett	φ	φ	φ	φ	φ	φ	φ
	Empire State Plaza	φ	φ	φ	φ	φ	φ	φ
	Albany Steam Station	φ	φ	φ	φ	φ	φ	φ
	Westchester RESCO	φ	φ	φ	φ	φ	φ	φ
1988	Bowline Point							
through	Indian Point							
1995	Roseton							
	Danskammer							
	Lovett							
	Empire State Plaza							
	Albany Steam Station							
	Westchester RESCO							

φ ETM—Region 0 densities predicted from Region 1 densities ETM—Region 0 densities based on observations from Region 0
CEMR

a CMR estimates based on ETM for 1982, and CEMR for the remainder.

b CMR estimates based on ETM for 1981, and CEMR for the remainder.

Table X-3.—List of component parameters in the modified ETM and the CEMR models[a].

Parameter	ETM	CEMR
D_{wkl}		
V_k		
P_{wk}		
$W_{w,l}$		
R_s		
S		
J		
L		
δ_{dsl}		
f_{dl}		
NE_{dl}		
N_{dsl}		
RPC_{dl}		

[a] Bullet indicates presence.

Table X-4.—Definition of component parameters in the modified ETM and the CEMR models.

Parameter	Definition	Eqn.
D_{wkl}	average proportion of river-wide abundance of life stage l individuals during week $s+j$ that are in region k, with $\sum_{k=1}^{K} D_{s+j,kl} = 1$ for each week, cohort and life-stage	(1)
V_k	volume of region k (units of m^3)	(2)
P_{wk}	rate of water withdrawal from region k in week $s+j$ (units of $m^3\ d^{-1}$)	(2)
W_{wl}	ratio of the average intake density to average regional density of life-stage l individuals during week $s+j$ in region k	(2)
R_s	proportion of spawning that occurred in week S, so that $\sum_{s=1}^{S} R_s = 1$	(1)
S	s = week 1, 2, 3, ..., S of the spawning period (subscript S will also denote cohorts born in those weeks)	(1)
J	j = age 0, 1, 2, ..., J of entrainable individuals in weeks	(1)
L	l = life stage 1, 2, 3, ..., L	(1)
δ_{dsl}	the proportion of day d that individuals of cohort s spend in life-stage l ($\sum_{l} \delta_{dsl} = 1$ for each day of entrainment vulnerability for cohort s)	(4)
f_{dl}	the fraction of life-stage l individuals entering the intake on day d that eventually are killed by plant passage	(6)
NE_{dl}	the number of individuals in life-stage l that are entrained on day d	(6)
N_{dsl}	the river-wide abundance of cohort s individuals that are in life-stage l on day d	(5)
RPC_{dl}	q_{1dl} / q_{2dl}, the ratio of the gear efficiencies for larvae of life-stage l on day d	(8)

Table X-5.—Facilities withdrawing 50 million gallons per day (mgd) or greater from the Hudson River.

Facility	River Mile	Permitted Discharge[a] (gpm)
Empire State Plaza	146	75,000
Albany Steam Station	142	357,000
Danskammer Point Generating Station	66	318,000
Roseton Generating Station	66	641,000
Charles Point Resource Recovery Facility (Westchester RESCO)	43	38,000
Indian Point Station	43	1,680,000
Lovett Generating Station	42	345,000
Bowline Point Generating Station	37	768,000

[a] NYSDEC SPDES files

Table X-6.—Volumes of river segments.

	Volume (m^3)			Area (m^2)
Region	**Channel**	**Bottom**	**Shoal**	**Shore Zone**
0	141809822	48455129	18747833	0
1	143452543	59312978	26654767	3389000
2	138000768	62125705	121684992	20446000
3	61309016	32517633	53910105	12101000
4	162269471	33418632	12648163	4147000
5	178830022	25977862	2647885	1186000
6	94882267	36768629	8140123	4793000
7	228975052	63168132	5990260	3193000
8	131165041	32012000	2307625	558000
9	93657021	35479990	12332868	3874000
10	113143296	42845077	20307338	7900000
11	83924081	42281206	34526456	8854000
12	32025080	13517183	25606842	6114000

Source: Versar (1987).

Table X-7.—Life stage duration estimates for striped bass, American shad, white perch, Atlantic tomcod, bay anchovy, river herring, and spottail shiner.

	Life Stage Duration (days)[a]			
Species	**Egg**	**YSL**	**PYS**	**JUV**
Striped bass	1.2-4.0[b]	3.4-10.2[b]	28	28
American shad	2.2-13.4[b]	4.5-7.0[b]	21	28
White perch	1.0-4.3[b]	5	32	28
Atlantic tomcod	-	28	42	21
Bay anchovy	1	1	30	42
River herring	4	3	28	28
Spottail shiner	-	-	-	83[c]

Notes:

[a] Boreman et al. (1982)

[b] Range of values estimated based on water temperature

[c] See text

Table X-8.—Sampling program(s) used to estimate river-wide abundance and/or distributions.

Species	Life Stage			
	EGG	YSL	PYS	JUV
American shad	LRS	LRS	LRS	LRS PYSL projection + FSS[a]
Atlantic tomcod[b]	not applicable	LRS	LRS	LRS
Bay anchovy[c]	LRS	LRS	LRS	LRS PYSL projection + FSS[a]
River herring	LRS	LRS	LRS	LRS abundance + FSS[d]
Striped bass	LRS	LRS	LRS	LRS PYSL projection + FSS[a]
Spottail shiner[b]	not applicable	not applicable	not applicable	BSS
White perch	LRS	LRS	LRS	LRS PYSL projection + FSS[a]

Notes:

[a] Juvenile abundances for CEMR estimates were first estimated using projections of juvenile abundance based upon PYSL cohort abundances and survival rates, then further revised based upon FSS estimates of older juvenile abundance. See text for details of revision methods. Distribution patterns for ETM based solely upon LRS.

[b] No river-wide abundance estimates were constructed for Atlantic tomcod nor spottail shiner, because the CEMR model was never used for these species. Data from indicated sampling programs were used solely for the distribution patterns required by the ETM model.

[c] All life stage abundances for bay anchovy used solely for weekly CEMR estimates, generated only for purposes of calibrating ETM.

[d] Juvenile abundances for CEMR estimates from LRS were revised based upon FSS estimates of older JUV abundance. See text for details of abundance revision method. Distribution patterns for ETM based solely on LRS.

Table X-9.—Coefficients for predicting densities in unsampled strata, by species and life stage (Coastal 1991b).

Species	Life Stage	Unsampled Stratum		
		Beaches	Shores	Shoals
American shad	Egg	0.03	0.03	0.14
	YSL	1.00	1.00	1.00
	PYS	3.05	23.14	0.84
Striped bass	Egg	0.07	1.00	2.21
	YSL	1.82	1.00	8.40
	PYS	0.65	3.08	2.24
White perch	Egg	0.51	0.03	0.58
	YSL	1.19	1.04	1.25
	PYS	0.69	1.00	1.01

Table X-10a.—Coefficients for prediction equations for predicting densities in Region 0 based on densities in Region 1.

Taxon	Life Stage	Stratum	$\hat{\alpha}$	$\hat{\beta}$
Atlantic tomcod	PYSL	Bottom	-0.97	1.00
Atlantic tomcod	Juveniles	Bottom	-1.91	0.49
Atlantic tomcod	Juveniles	Channel	-2.53	0.52
Bay anchovy	Eggs	Bottom	-0.25	0.75
Bay anchovy	Eggs	Channel	0.18	0.84
Bay anchovy	PYSL	Bottom	-0.03	0.82
Bay anchovy	PYSL	Channel	-0.22	0.82
Bay anchovy	Juveniles	Bottom	-1.01	0.88
Bay anchovy	Juveniles	Channel	-1.92	0.76
River herring	PYSL	Bottom	0.67	1.13
River herring	Juveniles	Bottom	-3.00	0.38
Striped bass	PYSL	Bottom	-3.48	0.69
Striped bass	PYSL	Channel	-3.46	0.49

Table X-10b.—Coefficients for prediction equations for predicting densities in the northern portion of Region 12 based on densities in the southern portion of Region 12.

Taxon	Life Stage	Stratum	$\hat{\alpha}$	$\hat{\beta}$
American shad	YSL	Bottom	-1.31	0.56
American shad	YSL	Channel	-0.98	0.85
River herring	YSL	Bottom	-1.13	0.57
River herring	YSL	Channel	-0.32	0.68
River herring	PYSL	Bottom	-1.82	0.46
River herring	PYSL	Channel	-1.42	0.61
River herring	Juveniles	Bottom	-3.30	0.60
White perch	YSL	Bottom	-2.85	0.59
White perch	YSL	Channel	-2.41	0.36

Table X-11a.—Estimates of relative probability of capture (RPC) for striped bass and white perch (Coastal 1991a).

Species	Length (mm)	RPC Plant density/River density
Striped bass	0-4.5	0.76
	-6.5	0.22
	-8.5	0.33
	-10.5	0.57
	-12.5	0.98
	-14.5	1.75
	-16.5	2.72
	-18.5	4.00
	-20.5	3.21
	>20.5	5.26
White perch	0-4.5	0.09
	-6.5	0.16
	-8.5	0.24
	-10.5	0.43
	-12.5	0.77
	-14.5	1.84
	>14.5	3.24

Table X-11b.—Estimates for relative probability of capture (RPC) for bay anchovy.

Species	Length (mm)	RPC Plant density/River density
Bay anchovy	0-7.5	3.05
	-12.5	0.27
	-17.5	0.26
	-22.5	1.59
	>22.5	2.60

Table X-12a.—Overall W estimates by stage and plant for 12 regions (see text).

Species	Stage	Plant				
		Bowline Point	Indian Point	Roseton	Danskammer	Albany Steam
American shad	Egg	0.0000	0.4318	0.1852	0.2828	0.3552
	YSL	0.0000	0.1850	0.1639	0.2883	1.4162
	PYSL	0.6119	0.4335	1.1576	1.7852	3.1204
	JUV	0.0037	0.0224	0.0139	0.0538	0.0000
Bay anchovy	Egg	0.0015	0.4059	0.0000	0.0000	1.0000
	YSL	0.0396	0.8933	NA	NA	1.0000
	PYSL	0.4450	0.5636	0.6571	0.6521	1.0000
	JUV	0.0051	0.0056	0.0053	0.0011	1.0000
River herring	Egg	0.5584	3.4291	11.9278	39.3233	0.3552
	YSL	0.1202	1.4007	0.3864	0.5523	1.4162
	PYSL	0.4637	0.8596	0.8210	1.0325	3.1204
	JUV	0.0435	0.0422	0.1549	0.2117	0.0000
Striped bass	Egg	0.0289	0.0504	0.3208	0.7795	1.0000
	YSL	0.1959	0.3472	0.7034	1.3433	1.0000
	PYSL	0.4104	1.5324	1.0316	2.1697	1.0000
	JUV	0.0572	0.0784	0.1861	0.2212	1.0000
White perch	Egg	3.8776	0.6469	2.2064	8.5748	0.5269
	YSL	0.2157	0.7286	2.8533	4.7590	0.7609
	PYSL	0.3828	1.3302	0.7564	0.8317	0.2147
	JUV	0.0125	0.0512	0.0621	0.0541	0.0000

Table X-12b.—Overall W estimates by stage and plant for 13 regions (see text).

Species	Stage	Plant			
		Bowline Point	Indian Point	Roseton	Danskammer
American shad	Egg	0.0000	0.4318	0.1852	0.2828
	YSL	0.0000	0.1850	0.1639	0.2883
	PYSL	0.6119	0.4335	1.1576	1.7852
	JUV	0.0024	0.0140	0.0123	0.0451
Bay anchovy	Egg	0.0015	0.4047	0.0000	0.0000
	YSL	0.0396	0.8944	1	1
	PYSL	0.4450	0.5640	0.6576	0.6512
	JUV	0.0057	0.0058	0.0072	0.0018
River herring	Egg	0.5584	3.4291	11.9278	39.3233
	YSL	0.1202	1.4007	0.3863	0.5522
	PYSL	0.4638	0.8593	0.8210	1.0325
	JUV	0.0434	0.0427	0.1560	0.2133
Striped bass	Egg	0.0289	0.0504	0.3208	0.7795
	YSL	0.1959	0.3472	0.7034	1.3433
	PYSL	0.4104	1.5324	1.0316	2.1696
	JUV	0.0558	0.0755	0.1921	0.2323
White perch	Egg	3.8776	0.6469	2.2064	8.5748
	YSL	0.2157	0.7285	2.8533	4.7590
	PYSL	0.3828	1.3303	0.7565	0.8318
	JUV	0.0109	0.0378	0.0237	0.0174

Table X-13.—Flow rate (gallons per minute) as a function of plant operating condition at Bowline Point Generating Station.

Unit Operating Condition	Flow Rate (gpm)[a]
3 pumps full	384,000
2 pumps full (condenser open)	316,000
2 pumps full (condenser closed)	285,000
2 pumps throttled	257,000
1 pump full	185,000
1 pump throttled	150,000

[a] EA (1985c), HRU (1989b)

Table X-14.—Flow rate (gallons per minute) as a function of plant operating condition at Roseton Generating Station.

Plant OperatingCondition		
Number of Pumps	Number of Units	Flow Rate[a] (gpm)
1	1	218,000
	2	228,000
2	1	376,000
	1 full 1 at 5%	378,000
3	1	526,000
	1 full 1 at 5%	528,000
	2	561,000
4	2	641,000

[a] LMS (1985c), HRU (1989b)

Table X-15.—Proportion of water withdrawal originating in each region of the river.

Region	Power Plant							
	Bowline[a]	Lovett[a]	Indian Point[a]	RESCO[b]	Roseton[a]	Dans-kammer[a]	Albany Steam[b]	Empire State[b]
YK	0	0	0	0	0	0	0	0
TZ	0.271	0	0	0	0	0	0	0
CH	0.358	0.369	0.298	0.164	0	0	0	0
IP	0.371	0.549	0.562	0.586	0	0	0	0
WP	0	0.082	0.140	0.250	0	0	0	0
CW	0	0	0	0	0.273	0.196	0	0
PK	0	0	0	0	0.727	0.804	0	0
HP	0	0	0	0	0	0	0	0
KG	0	0	0	0	0	0	0	0
SG		0	0	0	0	0	0	0
CK	0	0	0	0	0	0	0	0
AL	0	0	0	0	0	0	1.0	1.0

[a] Boreman et al. (1982)

[b] Appendix titled "Parameters used in ETM estimates for 1974-1980 and 1981-1991".

Table X-16.—Mechanical mortality rate estimates by species and life stage (see text).

Species	Life Stage			
	EGG	YSL	PYS	JUV
American shad	1.0	0.794	0.794	0.794
Atlantic tomcod	1.0	0.683	0.469	0.425
Bay anchovy	1.0	1.0	1.0	1.0
River herring	1.0	0.794	0.794	0.794
Striped bass	1.0	0.266	0.287	0.254
Spottail shiner	1.0	0.129	0.129	0.129
White perch	1.0	0.566	0.566	0.464

Table X-17.—Coefficients used to estimate boundary temperatures (X_1 and X_2) for the double hinged line model used to estimate thermal mortality rates for striped bass and white perch (see text).

	Life Stage			
Coefficient	**EGGS**	**YSL**	**PYSL**	**JUV**
a1	21.762	53.875	29.672	24.120
a2	39.246	24.537	41.254	36.266
b1	0.943	-1.354	0.147	0.516
b2	0.136	1.090	-0.031	0.142
c1	-1.110	-0.407	-0.312	-0.806
c2	-1.741	-2.672	-1.471	-1.122

Table X-18.—Boundary temperatures (EC) used in estimating thermal mortality rates for American shad, Atlantic tomcod, river herring, and spottail shiner, using a double hinged model. Thermal mortality was 0 at temperatures below X_1, 100% at temperatures above X_2, and interpolated linearly from 0 to 100% between X_1 and X_2.

	Life Stage					
	YSL		**PYS**		**JUV**	
Species	X_1	X_2	X_1	X_2	X_1	X_2
American shad	33.5	38.0	29.8	32.9	29.8	32.9
Atlantic tomcod	24.2	28.2	24.8	28.7	24.8	28.7
River herring	33.5	38.0	29.8	32.9	29.8	32.9
Spottail shiner	--	--	--	--	35.1	36.9

Table X-19.—Monthly projected generating load as percent of dependable maximum net generation for Units 3 and 4 and Danskammer. From Table VII-8, Boreman et al. (1982).

	Month				
Unit	**April**	**May**	**June**	**July**	**August**
3	76.0	74.0	70.0	70.0	78.0
4	74.0	72.0	65.0	67.0	67.0

Table X-20a Annual CMR values by year for American Shad for 12 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	0.1	0.24	0.15	0.88	0.68	0.11	1.02	.	3.15
1975	0.11	0.38	2.68	2.35	1	1.84	30.91	.	36.51
1976	0.22	0.34	2.01	1.3	0.59	1.9	31.33	.	35.59
1977	0.02	0.49	1.42	0.99	1.22	0.38	2.96	.	7.27
1978	0.09	0.26	1.92	1.33	0.43	0.78	14.9	.	18.93
1979	0.04	0.21	1.06	0.98	0.07	1.71	26.6	.	29.55
1980	0	0.04	0.31	0.31	0.14	2	35.99	.	37.77
1981	0.02	0.2	0.35	0.81	0.24	0.95	13.29	.	15.5
1982	0.16	0.47	0.33	0.91	1.04	0.72	8.17	.	11.46
1983	0.02	0.09	0.74	1.19	0.6	1.28	15.68	.	18.95
1984	0.05	7.57	1.08	0.89	1.12	0.98	10.84	0.32	21.18
1985	0	0	0.17	0.27	0.07	1.63	17.77	0.03	19.55
1986	0	3.56	0.32	0.73	0.09	0.46	5.92	0.02	10.73
1987	0.01	0	0.42	0.3	0.12	3.82	26.61	0.05	30.04
1988	0.01	0.2	0.2	0.24	0.86	2.19	36.45	0.18	38.89
1989	0.2	0.32	1.16	0.97	1.21	1.96	35.44	0.24	39.25
1990	0.09	0.46	1.34	1.4	1.5	3.43	49.83	0.29	53.97
1991	0.01	0.09	0.41	0.47	0.77	1.51	30.64	0.12	32.96
1992	0.01	0.07	0.22	0.16	0.5	1.34	50.85	0.16	52.04
1993	0.01	0.17	0.23	0.24	1.19	1.29	6.46	0.32	9.64
1994	0.03	0.13	0.37	0.27	0.47	2.61	18.32	0.13	21.56
1995	0.01	0.13	0.39	0.37	0.61	1.33	9.75	0.12	12.39
1996	0.03	0.45	0.25	0.37	0.64	1.27	3.39	0.17	6.41
1997	0.01	0.06	0.3	0.5	0.71	2	13.64	0.13	16.8

Table X-20b.—Annual CMR values by year for Atlantic Tomcod for 12 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	5.91	3.93	0.27	0.63	3.16	0	0	.	13.24
1975	9.2	6.8	1.2	0.25	2.72	0	0	.	18.87
1976	10.65	8.8	0.96	0.37	2.89	0	0	.	21.93
1977	5.49	10.33	3.42	1.02	1.16	0	0	.	19.92
1978	9.23	10.71	2.32	0.81	2.98	0	0	.	23.82
1979	6.89	19.32	2.35	0.72	1.57	0	0	.	28.31
1980	6.15	25.75	1.82	0.59	5.17	0	0	.	35.5
1981	8.21	12.14	1.66	0.61	4.18	0	0	.	24.47
1982	6.82	17.99	1.74	0.71	4.13	0	0	.	28.53
1983	6.97	8.07	1.6	0.59	2.41	0	0	.	18.36
1984	5.99	17.32	1.63	0.7	1.53	0	0	1	25.98
1985	6.9	35.03	2.04	0.79	4.06	0	0	1.91	44.68
1986	8.64	12.01	1.84	0.72	3.79	0	0.02	1.8	26
1987	4.75	15.37	2.21	0.88	1.87	0	0	1.03	24.12
1988	7.53	25.33	1.86	0.8	3.47	0	0	1.68	36.2
1989	7.95	4.61	1.72	0.68	2.88	0	0	1.06	17.64
1990	7.12	5.84	2.02	0.82	2.74	0	0	0.88	18.07
1991	7.1	7.33	1.83	0.64	6.15	0	0.02	1.05	22.04
1992	7.68	14.9	1.66	0.51	2.79	0	0	1.04	26.06
1993	5.63	3.9	1.05	0.29	1.48	0	0	0.83	12.58
1994	4.72	8.03	1.58	0.47	2.61	0	0	0.85	17.11
1995	7.43	6.67	1.33	0.55	3.71	0	0.01	1.82	19.86
1996	1.62	9.06	0.84	0.31	1.17	0	0	0.55	13.08
1997	0.61	15.63	1.65	0.75	2.16	0	0	1.07	20.78

Table X-20c.—Annual CMR values by year for Bay Anchovy for 12 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	5.73	8.21	0.21	0.05	8.46	0	0.01	.	21
1975	4.63	7.09	0.41	0.08	6.51	0.05	0.65	.	18.14
1976	4.32	4.06	0.65	0.1	3.85	0	0.05	.	12.45
1977	5.28	14.14	0.66	0.09	8.2	0.01	0.19	.	26.06
1978	6.66	13.76	1.14	0.17	8.29	0	0	.	27.14
1979	6.69	11.29	1.3	0.2	4.38	0	0.03	.	22.07
1980	6.75	19.26	0.62	0.11	9.48	0	0.02	.	32.35
1981	4.55	20.42	0.61	0.13	9.7	0	0.01	.	31.92
1982	2.26	4.8	0.73	0.16	5.75	0	0.03	.	13.11
1983	3.41	9.97	1.05	0.24	6.86	0	0	.	20.06
1984	3.42	7.03	0.94	0.24	5.07	0	0.01	0.89	16.52
1985	3.35	10.73	0.86	0.22	8.64	0.05	0.55	1.18	23.41
1986	2.36	5.99	0.43	0.07	4.98	0	0.01	0.8	13.92
1987	6.24	11.02	0.87	0.12	6.14	0.01	0.12	1.31	23.59
1988	6.08	20.15	1.52	0.39	7.56	0.02	0.31	1.24	33.07
1989	4.53	9.69	0.56	0.04	5.31	0	0.01	0.66	19.4
1990	6.34	25.17	1.72	0.43	9.91	0	0.03	1.3	39.04
1991	4.51	11.11	2.44	0.68	8.02	0	0.01	1.1	25.19
1992	3.94	7.75	0.41	0.08	7.63	0.01	0.27	0.83	19.44
1993	3.43	7.65	0.93	0.33	7.46	0.01	0.15	0.88	19.35
1994	3.47	8.16	0.24	0.06	8.23	0.02	0.12	1.03	19.83
1995	3.83	15.95	2.45	1.01	7.2	0.01	0.05	1.03	28.35
1996	1.46	18.24	0.1	0.05	7.99	0	0	1.06	26.77
1997	3.92	7.47	2.35	1.12	8.37	0.01	0.04	1.04	22.2

Table X-20d.—Annual CMR values by year for River Herring for 12 Regions and estimated flow-through mortality (actual flow).. See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	0.17	0.85	0.65	2.97	0.47	1.76	22.03	.	27.25
1975	0.18	1.45	13.1	13.34	0.45	1.54	18.6	.	40.9
1976	0.79	1.89	5.81	4.52	0.58	1.62	19.83	.	31.35
1977	0.49	2.59	6.31	8.89	0.43	1.57	17.58	.	33.16
1978	0.2	1.32	3.14	2.19	0.34	1.75	20.95	.	27.79
1979	0.09	2.25	4.26	3.5	0.1	1.85	18.34	.	27.76
1980	0.06	0.63	3	2.82	0.48	1.23	18.58	.	25.08
1981	0.03	0.61	2.4	2.62	0.23	0.3	6.59	.	12.26
1982	0.15	1.03	3.33	1.87	1.51	0.42	3.46	.	11.25
1983	0.3	13.25	18.96	17.18	1.09	0.91	8.26	.	47.81
1984	0.15	5.33	1.65	1.76	1.26	1.1	15.57	0.33	24.95
1985	0	0.02	1.02	1.87	0.01	1.16	11.02	0	14.61
1986	0.01	0.92	1.73	3.77	0.1	0.26	3.83	0.03	10.26
1987	0.47	0.04	2.75	2.47	0.06	3.82	25.98	0.02	32.87
1988	0.04	0.55	3.77	4.54	0.19	1.35	16.05	0.05	24.55
1989	0.41	1.63	4.99	3.77	1.17	1.75	23.55	0.24	33.67
1990	0.85	3.18	2.52	2.23	1.24	1.95	21	0.3	30.21
1991	0.08	0.42	1.69	1.27	0.27	1.31	17.81	0.05	21.91
1992	0.06	0.47	2.16	1.38	0.44	1.68	35.9	0.09	39.82
1993	0.04	0.32	1.08	0.97	0.41	0.95	8.21	0.12	11.73
1994	0.07	0.54	2.24	1.54	0.34	1.77	12.07	0.11	17.73
1995	0.02	0.15	4.46	4.2	0.13	1.37	5.44	0.04	14.94
1996	0.01	0.59	1.46	1.96	0.22	1.73	2.56	0.07	8.32
1997	0.25	0.99	3.37	6.7	1.61	2.54	8.24	0.39	21.96

Table X-20e.—Annual CMR values by year for Striped Bass for 12 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	0.87	5.67	0.39	2.16	2.96	0	0.03	.	11.6
1975	1.15	7.82	1.81	1.56	3.17	0.05	0.2	.	14.92
1976	1.65	4.76	2.68	2.55	1.62	0.05	0.34	.	12.94
1977	1.11	13.91	2.23	1.81	1.76	0.04	0.15	.	19.86
1978	1.59	8.59	1.53	1.19	2.13	0	0.01	.	14.36
1979	1.47	12.02	2.2	1.65	1.41	0.01	0.04	.	17.83
1980	1.17	11.92	3.37	2.73	2.35	0.02	0.09	.	20.19
1981	0.23	4.17	0.43	4.18	2.32	0.02	0.22	.	11.1
1982	3.88	7.07	3.75	4.88	2.75	0.01	0.04	.	20.52
1983	0.59	7.43	2.39	2.36	5.11	0.02	0.08	.	16.85
1984	2.73	17.29	1.72	1.87	1.72	0.01	0.03	1.29	24.76
1985	0.07	3.97	4.3	4.26	0.76	0.23	0.66	0.63	14.06
1986	1.03	16.4	4.06	5.04	1.59	0.01	0.08	1.26	26.82
1987	0.47	2.3	4.78	7.43	0.72	0.08	0.21	0.69	15.73
1988	1.15	11.69	2.99	3.48	2.14	0.02	0.15	1.39	21.25
1989	1.11	6.09	2.39	2.41	1.83	0.01	0.04	1.15	14.2
1990	0.95	6.19	4.07	4.45	1.85	0.02	0.11	0.91	17.27
1991	0.8	4.98	3.77	4.15	6.14	0.23	1.15	1.12	20.43
1992	0.92	6.21	2.96	2.48	2.43	0.01	0.42	1.52	15.86
1993	0.53	5.62	1.28	1.86	1.36	0.02	0.14	0.93	11.26
1994	0.79	6.83	1.69	1	2.18	0.02	0.03	1.32	13.21
1995	0.45	4.25	3.01	2.68	1.24	0.06	0.1	0.84	12.04
1996	0.11	11.69	1.53	1.91	1.42	0.01	0.01	1	16.87
1997	0.51	1.39	3.02	3.47	1.9	0.04	0.07	1.3	11.18

Table X-20f.—Annual CMR values by year for Spottail Shiner for 12 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	0.49	0.87	0.22	0.66	0.24	3.32	5.75	.	11.11
1975	0.56	1.04	0.65	1.32	0.27	5.98	10.14	.	18.72
1976	1.17	1.38	1.14	1.03	0.38	3.04	5.48	.	12.93
1977	0.43	1.41	0.59	1	0.18	8.8	14.91	.	25.17
1978	0.79	2.32	0.73	1.14	0.47	5.87	10.01	.	19.82
1979	0.64	1.62	1.45	1.66	0.4	3.74	6.51	.	15.09
1980	0.23	1.66	1.06	2.26	0.3	4.59	7.96	.	16.94
1981	0.36	3.43	0.88	1.06	0.46	2	5.39	.	12.92
1982	0.6	2.06	0.91	1.07	0.36	3.96	6.68	.	14.77
1983	0.43	3.17	1.7	1.24	1.37	4.72	8.11	.	19.16
1984	0.55	1.58	0.79	1	0.19	5.25	9.35	0.28	17.82
1985	0.35	1.77	0.92	1.15	0.41	5.41	6.48	0.36	15.84
1986	0.42	1.55	1.44	1.91	0.34	3.69	4.69	0.4	13.64
1987	0.43	1.53	1.39	1.06	0.16	6.22	8.42	0.28	18.2
1988	0.39	4.1	1.3	2.66	0.52	5.43	7.57	0.29	20.43
1989	0.7	8.32	0.93	1.73	0.76	4.12	7.12	0.35	21.94
1990	0.46	2.18	1.07	2.06	0.26	4.79	7.61	0.3	17.48
1991	0.62	3.92	1.14	3.06	2.66	3.46	8.57	0.45	21.73
1992	0.31	0.99	1.09	0.48	0.24	2.15	6.35	0.3	11.44
1993	0.32	0.89	0.83	0.64	0.56	2.82	4.94	0.28	10.84
1994	0.36	1.1	1.2	0.75	0.38	3.96	5.18	0.27	12.56
1995	0.27	2.54	0.86	0.56	0.28	2.9	2.78	0.19	9.98
1996	0.2	1.89	0.59	0.56	0.48	4.34	2.85	0.34	10.78
1997	0.29	0.64	1.02	0.62	0.33	4.69	3.17	0.34	10.67

Table X-20g.—Annual CMR values by year for White Perch for 12 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	9.1	7.45	1.14	4.89	2.73	0.27	0.98	.	24.03
1975	2.96	8.65	7.82	7.86	1.93	0.4	1.81	.	27.8
1976	2.18	3.22	6.66	7.1	0.69	0.47	1.99	.	20.48
1977	2.12	7.28	7.24	5.96	1	0.49	1.35	.	23.07
1978	1.17	5.28	6.88	3.64	0.61	0.93	1.74	.	18.74
1979	0.86	8.03	7.39	4.95	0.43	0.25	1.17	.	21.22
1980	0.4	3.38	7.81	6.9	0.74	0.39	2.03	.	19.99
1981	0.32	6.46	1.7	5.5	1.32	0.16	0.92	.	15.44
1982	0.17	4.34	2.29	2.18	1.28	0.5	2.3	.	12.4
1983	1.05	18.14	7.08	4.84	3.16	0.39	1.57	.	32.01
1984	0.65	8.88	3.88	3.31	0.98	0.5	1.76	0.44	18.93
1985	0.03	0.55	3.53	3.88	0.24	0.31	0.78	0.12	9.14
1986	0.28	4.07	9.4	14.44	0.61	0.08	0.3	0.29	26.79
1987	0.01	0.66	6.87	7.54	0.38	0.64	0.68	0.22	16.09
1988	0.56	7.99	7.51	6.24	1.8	0.57	1.4	0.65	24.1
1989	0.8	4.07	8.54	5.88	1.3	0.48	2.62	0.54	22.06
1990	0.41	3.52	7.63	6.49	1.07	0.89	2.49	0.35	20.93
1991	0.24	1.46	9.99	7.44	1.85	0.29	0.99	0.37	20.93
1992	0.29	2.73	7.13	4.79	1.29	0.21	1.94	0.54	17.61
1993	0.13	2.36	3.31	3.71	1.14	0.21	0.38	0.42	11.15
1994	0.29	3.14	6.72	3.24	0.89	0.41	0.62	0.39	14.83
1995	0.1	1.93	5.56	4.62	0.47	0.37	0.34	0.27	13.02
1996	0.07	4.9	4.54	4.13	0.5	0.59	0.31	0.23	14.44
1997	0.2	1.31	5.53	7.04	1.66	0.53	0.73	0.49	16.41

Table X-21a.—Annual CMR values by year for American Shad for 13 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	0.10	0.22	0.15	0.82	0.68	0.11	1.02	.	3.06
1975	0.11	0.35	2.67	2.31	1.00	1.84	30.91	.	36.45
1976	0.22	0.33	2.01	1.28	0.59	1.90	31.36	.	35.61
1977	0.02	0.38	1.42	0.96	1.22	0.38	2.96	.	7.14
1978	0.09	0.24	1.92	1.29	0.43	0.78	14.90	.	18.88
1979	0.04	0.20	1.06	0.96	0.07	1.72	26.61	.	29.53
1980	0.00	0.03	0.31	0.28	0.14	2.00	35.99	.	37.74
1981	0.02	0.20	0.35	0.79	0.24	0.95	13.29	.	15.47
1982	0.16	0.44	0.33	0.91	1.03	0.72	8.17	.	11.43
1983	0.02	0.09	0.74	1.19	0.60	1.28	15.69	.	18.94
1984	0.05	7.50	1.08	0.71	1.11	0.98	10.84	0.32	20.97
1985	0.00	0.00	0.17	0.27	0.07	1.63	17.77	0.03	19.55
1986	0.00	3.56	0.32	0.73	0.09	0.46	5.92	0.02	10.73
1987	0.01	0.00	0.42	0.30	0.12	3.82	26.61	0.05	30.04
1988	0.01	0.15	0.20	0.22	0.86	2.19	36.45	0.18	38.84
1989	0.20	0.28	1.16	0.91	1.20	1.95	35.44	0.24	39.18
1990	0.08	0.43	2.24	1.88	1.68	2.97	42.36	0.31	47.69
1991	0.01	0.07	0.41	0.44	0.74	1.51	30.64	0.12	32.90
1992	0.01	0.05	0.22	0.15	0.48	1.34	50.85	0.15	52.02
1993	0.01	0.13	0.23	0.22	1.19	1.29	6.46	0.32	9.58
1994	0.03	0.12	0.37	0.25	0.47	2.61	18.32	0.13	21.53
1995	0.01	0.10	0.39	0.35	0.61	1.33	9.75	0.12	12.34
1996	0.03	0.42	0.24	0.32	0.65	1.29	3.47	0.17	6.45
1997	0.01	0.05	0.32	0.50	0.76	1.99	13.65	0.14	16.86

Table X-21b.—Annual CMR values by year for Atlantic Tomcod for 13 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	5.61	3.65	0.26	0.62	2.98	0.00	0.00	.	12.55
1975	9.16	6.75	1.20	0.25	2.71	0.00	0.00	.	18.78
1976	10.60	8.76	0.94	0.36	2.89	0.00	0.00	.	21.82
1977	5.43	10.15	3.41	1.02	1.14	0.00	0.00	.	19.69
1978	9.18	10.60	2.32	0.81	2.96	0.00	0.00	.	23.66
1979	6.85	18.80	2.33	0.71	1.53	0.00	0.00	.	27.78
1980	6.10	25.47	1.81	0.58	5.13	0.00	0.00	.	35.19
1981	7.88	11.68	1.65	0.60	4.01	0.00	0.00	.	23.65
1982	6.57	17.47	1.72	0.70	3.95	0.00	0.00	.	27.72
1983	6.65	7.69	1.59	0.59	2.31	0.00	0.00	.	17.65
1984	5.77	16.58	1.61	0.70	1.45	0.00	0.00	0.95	25.03
1985	6.70	34.50	2.03	0.78	3.95	0.00	0.00	1.86	44.01
1986	8.22	11.36	1.82	0.70	3.58	0.00	0.02	1.69	24.82
1987	4.53	14.61	2.17	0.86	1.79	0.00	0.00	0.98	23.11
1988	7.15	23.94	1.84	0.78	3.25	0.00	0.00	1.57	34.50
1989	7.47	4.49	1.72	0.68	2.74	0.00	0.00	0.99	16.93
1990	6.72	5.52	2.00	0.80	2.62	0.00	0.00	0.82	17.25
1991	6.65	6.99	1.81	0.63	5.71	0.00	0.01	0.98	20.91
1992	7.25	14.11	1.66	0.51	2.65	0.00	0.00	0.98	24.87
1993	5.38	3.67	1.05	0.29	1.42	0.00	0.00	0.78	12.03
1994	4.48	7.57	1.57	0.47	2.47	0.00	0.00	0.80	16.31
1995	6.75	5.77	1.19	0.50	3.36	0.00	0.01	1.58	17.85
1996	1.61	8.47	0.84	0.31	1.09	0.00	0.00	0.52	12.39
1997	0.55	10.35	1.63	0.74	1.47	0.00	0.00	0.71	14.83

Table X-21c.—Annual CMR values by year for Bay Anchovy for 13 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	5.00	7.31	0.05	0.04	7.95	0.00	0.01	.	19.03
1975	4.20	6.61	0.18	0.07	6.10	0.05	0.63	.	16.76
1976	3.67	3.45	0.20	0.07	3.41	0.00	0.06	.	10.47
1977	4.96	13.78	0.22	0.07	8.00	0.02	0.21	.	25.00
1978	6.00	12.54	0.48	0.14	7.86	0.00	0.00	.	24.71
1979	6.30	10.80	0.52	0.16	4.11	0.00	0.04	.	20.43
1980	6.35	18.44	0.21	0.09	9.07	0.00	0.02	.	30.77
1981	4.01	18.56	0.23	0.11	8.94	0.00	0.01	.	29.06
1982	1.82	4.19	0.31	0.14	5.29	0.00	0.02	.	11.32
1983	2.95	9.04	0.51	0.21	6.34	0.00	0.00	.	17.93
1984	3.01	6.26	0.43	0.20	4.63	0.00	0.01	0.82	14.55
1985	3.07	10.06	0.47	0.20	8.17	0.05	0.57	1.11	21.84
1986	1.84	5.07	0.13	0.06	4.52	0.00	0.01	0.71	11.84
1987	5.50	9.99	0.38	0.11	5.67	0.01	0.14	1.21	21.25
1988	5.21	17.73	0.76	0.29	6.83	0.02	0.25	1.13	29.11
1989	3.59	7.96	0.11	0.03	4.62	0.00	0.01	0.57	15.97
1990	5.24	20.85	1.07	0.40	8.48	0.00	0.03	1.10	33.12
1991	3.72	9.09	1.44	0.59	6.99	0.00	0.01	0.95	21.01
1992	3.55	7.12	0.20	0.08	6.82	0.01	0.20	0.74	17.54
1993	3.17	7.08	0.50	0.29	7.03	0.01	0.15	0.82	17.81
1994	2.69	5.94	0.09	0.04	6.85	0.01	0.07	0.85	15.66
1995	3.55	14.99	1.82	0.96	6.74	0.01	0.05	0.96	26.40
1996	1.27	15.55	0.07	0.05	7.19	0.00	0.00	0.94	23.44
1997	3.61	6.62	1.78	0.98	7.95	0.01	0.05	0.98	20.25

Table X-21d.—Annual CMR values by year for River Herring for 13 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation. The values shown for the Albany Steam Station are the same as for 12 regions.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	0.17	0.83	0.64	2.91	0.47	1.76	22.03	.	27.18
1975	0.19	1.42	13.00	13.17	0.45	1.53	18.57	.	40.67
1976	0.79	1.85	5.70	4.38	0.58	1.61	19.78	.	31.11
1977	0.49	2.47	6.26	8.81	0.43	1.57	17.58	.	32.98
1978	0.21	1.26	2.99	2.01	0.34	1.75	20.95	.	27.51
1979	0.09	2.24	4.10	3.22	0.10	1.85	18.34	.	27.41
1980	0.06	0.48	2.87	2.62	0.48	1.23	18.58	.	24.71
1981	0.02	0.57	2.30	2.46	0.23	0.30	6.59	.	11.99
1982	0.17	0.81	1.90	1.87	1.51	0.42	3.46	.	9.74
1983	0.31	3.05	4.60	4.97	1.09	0.91	8.26	.	21.21
1984	0.15	5.34	1.65	1.56	1.26	1.10	15.57	0.33	24.80
1985	0.00	0.02	1.03	1.95	0.01	1.16	11.02	0.00	14.69
1986	0.01	0.92	1.62	3.70	0.10	0.26	3.83	0.03	10.09
1987	0.01	0.04	2.89	2.04	0.06	3.82	25.98	0.02	32.36
1988	0.04	0.51	3.59	4.26	0.19	1.35	16.01	0.05	24.12
1989	0.41	1.41	4.53	3.09	1.17	1.74	23.49	0.24	32.67
1990	0.85	2.94	2.31	1.94	1.24	1.95	20.96	0.30	29.65
1991	0.08	0.41	1.55	1.07	0.27	1.31	17.80	0.05	21.62
1992	0.06	0.41	2.04	1.20	0.43	1.68	35.74	0.09	39.45
1993	0.04	0.23	0.91	0.69	0.41	0.95	8.21	0.12	11.25
1994	0.07	0.49	1.96	1.18	0.34	1.75	11.95	0.11	17.03
1995	0.02	0.12	4.23	3.80	0.13	1.37	5.44	0.04	14.34
1996	0.01	0.49	1.31	1.55	0.21	1.73	2.56	0.07	7.70
1997	0.22	0.60	4.83	6.09	1.28	2.08	9.13	0.29	22.37

Table X-21e.—Annual CMR values by year for Striped Bass for 13 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	0.72	5.65	0.38	2.16	2.96	0.00	0.03	.	11.43
1975	0.99	7.78	1.71	1.54	3.16	0.05	0.20	.	14.64
1976	1.45	4.73	2.62	2.54	1.61	0.05	0.34	.	12.68
1977	0.98	13.89	2.15	1.80	1.76	0.04	0.15	.	19.67
1978	1.35	8.55	1.41	1.19	2.13	0.00	0.01	.	14.00
1979	1.09	11.92	2.14	1.64	1.41	0.01	0.04	.	17.36
1980	0.95	11.87	3.27	2.72	2.35	0.02	0.09	.	19.88
1981	0.23	4.17	0.43	4.15	2.32	0.02	0.22	.	11.07
1982	0.67	6.99	2.90	4.84	2.74	0.01	0.04	.	17.02
1983	0.58	7.36	2.34	2.33	5.10	0.02	0.08	.	16.72
1984	2.72	17.25	1.72	1.87	1.72	0.01	0.03	1.28	24.71
1985	0.07	3.97	2.09	2.57	0.76	0.23	0.66	0.63	10.53
1986	0.98	16.26	3.99	5.04	1.59	0.01	0.08	1.26	26.61
1987	0.47	2.30	4.75	7.43	0.72	0.08	0.21	0.68	15.69
1988	0.94	11.63	2.90	3.47	2.13	0.02	0.14	1.39	20.94
1989	0.96	5.96	2.28	2.39	1.82	0.01	0.04	1.14	13.82
1990	0.67	6.12	3.97	4.44	1.85	0.02	0.11	0.91	16.88
1991	0.67	4.95	3.62	4.13	6.14	0.23	1.15	1.12	20.16
1992	0.78	6.16	2.87	2.46	2.42	0.01	0.42	1.52	15.60
1993	0.41	5.60	1.25	1.86	1.36	0.02	0.14	0.93	11.12
1994	0.71	6.81	1.54	0.99	2.18	0.02	0.03	1.32	12.97
1995	0.36	4.22	2.91	2.67	1.24	0.06	0.10	0.84	11.82
1996	0.10	12.01	1.44	1.93	1.46	0.02	0.01	1.01	17.16
1997	0.46	1.42	3.00	3.62	1.92	0.04	0.07	1.33	11.31

Table X-21f.—Annual CMR values by year for Spottail Shiner for 13 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation. The values shown for the Albany Steam Station are the same as for 12 regions.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	0.49	0.87	0.22	0.66	0.24	3.32	5.75	.	11.11
1975	0.56	1.04	0.65	1.32	0.27	5.98	10.14	.	18.72
1976	1.17	1.38	1.14	1.03	0.38	3.04	5.48	.	12.93
1977	0.43	1.41	0.59	1.00	0.18	8.80	14.91	.	25.17
1978	0.79	2.32	0.73	1.14	0.47	5.87	10.01	.	19.82
1979	0.64	1.62	1.45	1.66	0.40	3.74	6.51	.	15.09
1980	0.23	1.66	1.06	2.26	0.30	4.59	7.96	.	16.94
1981	0.36	3.43	0.88	1.06	0.46	2.00	5.39	.	12.92
1982	0.60	2.06	0.91	1.07	0.36	3.96	6.68	.	14.77
1983	0.43	3.17	1.70	1.24	1.37	4.72	8.11	.	19.16
1984	0.55	1.58	0.79	1.00	0.19	5.25	9.35	0.28	17.82
1985	0.35	1.77	0.92	1.15	0.41	5.41	6.48	0.36	15.84
1986	0.42	1.55	1.44	1.91	0.34	3.69	4.69	0.40	13.64
1987	0.43	1.53	1.39	1.06	0.16	6.22	8.42	0.28	18.20
1988	0.39	4.10	1.30	2.66	0.52	5.43	7.57	0.29	20.43
1989	0.70	8.32	0.93	1.73	0.76	4.12	7.12	0.35	21.94
1990	0.46	2.18	1.07	2.06	0.26	4.79	7.61	0.30	17.48
1991	0.62	3.92	1.14	3.06	2.66	3.46	8.57	0.45	21.73
1992	0.31	0.99	1.09	0.48	0.24	2.15	6.35	0.30	11.44
1993	0.32	0.89	0.83	0.64	0.56	2.82	4.94	0.28	10.84
1994	0.36	1.10	1.20	0.75	0.38	3.96	5.18	0.27	12.56
1995	0.27	2.54	0.86	0.56	0.28	2.90	2.78	0.19	9.98
1996	0.20	1.89	0.59	0.56	0.48	4.34	2.85	0.34	10.78
1997	0.29	0.64	1.02	0.62	0.33	4.69	3.17	0.34	10.67

Table X-21g.—Annual CMR values by year for White Perch for 13 Regions and estimated flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation. The values shown for the Albany Steam Station are the same as for 12 regions.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	9.10	7.45	0.80	4.21	2.73	0.27	0.98	.	23.21
1975	2.96	8.65	6.40	6.89	1.93	0.40	1.81	.	25.90
1976	2.18	3.22	5.98	6.79	0.69	0.47	1.99	.	19.63
1977	2.11	7.27	5.82	5.28	1.00	0.49	1.35	.	21.30
1978	1.17	5.28	4.27	2.63	0.61	0.93	1.74	.	15.57
1979	0.85	8.02	5.91	4.23	0.43	0.25	1.17	.	19.34
1980	0.38	3.36	6.04	5.94	0.73	0.39	2.03	.	17.58
1981	0.32	6.54	1.72	3.74	1.32	0.16	0.92	.	13.96
1982	0.17	4.33	2.49	2.18	1.28	0.50	2.30	.	12.57
1983	1.01	17.23	5.78	3.97	3.16	0.39	1.57	.	29.62
1984	0.65	8.92	3.88	3.31	0.98	0.50	1.76	0.44	18.97
1985	0.05	0.55	3.53	3.88	0.24	0.31	0.78	0.12	9.15
1986	0.28	4.07	9.40	14.44	0.61	0.08	0.30	0.28	26.79
1987	0.01	0.66	6.87	7.54	0.38	0.64	0.68	0.22	16.09
1988	0.53	7.94	4.93	4.88	1.80	0.57	1.40	0.65	20.79
1989	0.78	4.03	6.66	4.98	1.30	0.48	2.62	0.54	19.65
1990	0.38	3.48	5.40	5.27	1.07	0.89	2.49	0.35	17.91
1991	0.22	1.40	7.45	6.08	1.70	0.29	0.99	0.34	17.29
1992	0.28	2.70	6.17	4.31	1.29	0.21	1.94	0.54	16.31
1993	0.12	2.34	1.77	2.96	1.14	0.21	0.38	0.42	9.00
1994	0.28	3.14	4.56	2.19	0.89	0.42	0.64	0.39	11.92
1995	0.09	1.92	5.04	4.29	0.47	0.37	0.34	0.27	12.22
1996	0.07	4.88	2.90	2.61	0.50	0.58	0.30	0.23	11.55
1997	0.16	1.29	4.29	6.24	1.66	0.53	0.73	0.49	14.54

Table X-22a.—Annual CMR values by year for American Shad for 12 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	0.13	0.3	0.19	1.05	0.75	0.11	1.24	.	3.71
1975	0.13	0.48	3.35	2.54	1.13	1.84	36.56	.	42.36
1976	0.28	0.42	2.51	1.59	0.64	1.9	37.04	.	41.54
1977	0.03	0.61	1.77	1.16	1.49	0.38	3.38	.	8.52
1978	0.11	0.31	2.4	1.49	0.45	0.78	18.09	.	22.55
1979	0.05	0.24	1.32	1.13	0.08	1.71	31.72	.	34.76
1980	0	0.04	0.39	0.35	0.15	2	42.26	.	43.94
1981	0.03	0.22	0.43	0.95	0.25	0.95	15.64	.	18
1982	0.19	0.57	0.41	1.07	1.25	0.72	10	.	13.73
1983	0.02	0.11	0.87	1.4	0.61	1.28	18.16	.	21.63
1984	0.07	9.4	1.36	1.06	1.36	0.98	12.58	0.32	24.8
1985	0	0	0.22	0.32	0.08	1.63	20.51	0.03	22.32
1986	0	4.49	0.4	0.85	0.1	0.46	6.58	0.02	12.41
1987	0.01	0	0.53	0.36	0.15	3.82	31.75	0.05	35.07
1988	0.01	0.21	0.24	0.26	0.93	2.19	42.78	0.18	45.05
1989	0.25	0.33	1.45	1.08	1.33	1.96	41.7	0.24	45.47
1990	0.11	0.49	1.68	1.7	1.53	3.43	57.42	0.29	61.22
1991	0.01	0.11	0.5	0.48	0.77	1.51	36.23	0.12	38.43
1992	0.01	0.09	0.27	0.19	0.59	1.34	58.82	0.16	59.9
1993	0.01	0.2	0.27	0.26	1.39	1.29	7.95	0.32	11.35
1994	0.04	0.15	0.44	0.3	0.52	2.61	22.24	0.13	25.46
1995	0.01	0.14	0.48	0.45	0.66	1.33	12.09	0.12	14.86
1996	0.04	0.51	0.31	0.43	0.68	1.27	4.16	0.17	7.39
1997	0.01	0.07	0.34	0.58	0.79	2	16.61	0.13	19.84

Table X-22b.—Annual CMR values by year for Atlantic Tomcod for 12 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	10.7	7.55	0.43	0.94	5.41	0	0.01	.	22.98
1975	16.13	12.7	1.79	0.35	4.57	0	0.01	.	31.62
1976	19.7	14.44	1.71	0.62	4.84	0	0.01	.	36.15
1977	9.92	15.47	4.99	1.47	1.63	0	0	.	29.88
1978	16.95	18.1	3.72	1.26	5.25	0	0.01	.	38.75
1979	10.93	27.28	4.15	1.12	2.42	0	0	.	40.1
1980	11.22	39.43	3.03	0.77	8.74	0	0	.	52.78
1981	14.1	21.98	2.57	0.93	7.57	0	0	.	40.21
1982	12.09	26.48	2.78	1.1	7.47	0	0	.	42.5
1983	12.34	13.17	2.44	0.9	3.95	0	0	.	29.32
1984	10.65	24.77	2.51	1.07	2.75	0	0	1	37.57
1985	11.56	39.97	3.4	1.24	6.9	0	0	1.91	53.75
1986	14.61	21.12	2.88	1.11	6.69	0	0.04	1.8	40.74
1987	8.48	22.02	3.64	1.39	3	0	0	1.03	34.9
1988	13.59	33.66	2.92	1.18	6.46	0	0	1.68	49.42
1989	14.43	6.3	2.58	1.01	4.77	0	0	1.06	27.15
1990	12.99	9.83	3.23	1.28	4.41	0	0	0.88	28.98
1991	12.64	11.71	2.68	0.89	6.17	0	0.04	1.05	30.96
1992	13.47	24.09	2.51	0.79	4.87	0	0	1.04	40.19
1993	9.51	5.49	1.57	0.44	2.28	0	0	0.83	18.78
1994	8.07	12.59	2.38	0.71	4.31	0	0	0.85	26.1
1995	12.74	12.44	2.41	0.96	6.27	0	0.02	1.82	32.06
1996	2.49	14.36	1.28	0.48	2	0	0	0.55	20.04
1997	1.11	28.03	2.45	1.13	4.15	0	0	1.07	34.92

Table X-22c.—Annual CMR values by year for Bay Anchovy for 12 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	5.73	8.21	0.21	0.05	8.46	0	0.01	.	21
1975	4.63	7.09	0.41	0.08	6.51	0.05	0.65	.	18.14
1976	4.32	4.06	0.65	0.1	3.85	0	0.05	.	12.45
1977	5.28	14.14	0.66	0.09	8.2	0.01	0.19	.	26.06
1978	6.66	13.76	1.14	0.17	8.29	0	0	.	27.14
1979	6.69	11.29	1.3	0.2	4.38	0	0.03	.	22.07
1980	6.75	19.26	0.62	0.11	9.48	0	0.02	.	32.35
1981	4.55	20.42	0.61	0.13	9.7	0	0.01	.	31.92
1982	2.26	4.8	0.73	0.16	5.75	0	0.03	.	13.11
1983	3.41	9.97	1.05	0.24	6.86	0	0	.	20.06
1984	3.42	7.03	0.94	0.24	5.07	0	0.01	0.89	16.52
1985	3.35	10.73	0.86	0.22	8.64	0.05	0.55	1.18	23.41
1986	2.36	5.99	0.43	0.07	4.98	0	0.01	0.8	13.92
1987	6.24	11.02	0.87	0.12	6.14	0.01	0.12	1.31	23.59
1988	6.08	20.15	1.52	0.39	7.56	0.02	0.31	1.24	33.07
1989	4.53	9.69	0.56	0.04	5.31	0	0.01	0.66	19.4
1990	6.34	25.17	1.72	0.43	9.91	0	0.03	1.3	39.04
1991	4.51	11.11	2.44	0.68	8.02	0	0.01	1.1	25.19
1992	3.94	7.75	0.41	0.08	7.63	0.01	0.27	0.83	19.44
1993	3.43	7.65	0.93	0.33	7.46	0.01	0.15	0.88	19.35
1994	3.47	8.16	0.24	0.06	8.23	0.02	0.12	1.03	19.83
1995	3.83	15.95	2.45	1.01	7.2	0.01	0.05	1.03	28.35
1996	1.46	18.24	0.1	0.05	7.99	0	0	1.06	26.77
1997	3.92	7.47	2.35	1.12	8.37	0.01	0.04	1.04	22.2

Table X-22d.—Annual CMR values by year for River Herring for 12 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	0.21	1.07	0.76	3.31	0.58	1.76	25.26	.	30.84
1975	0.23	1.82	13.65	13.49	0.55	1.54	22.06	.	44.16
1976	0.99	2.37	6.8	4.96	0.71	1.62	23.64	.	36.13
1977	0.61	3.2	7.01	9.12	0.52	1.57	21.25	.	37.3
1978	0.26	1.61	3.77	2.29	0.37	1.75	25.39	.	32.61
1979	0.11	2.74	5.05	3.76	0.13	1.85	21.42	.	31.62
1980	0.07	0.72	3.42	2.98	0.58	1.23	22.24	.	29.02
1981	0.03	0.74	2.97	3.09	0.26	0.3	8.19	.	14.82
1982	0.19	1.27	4.12	2.15	1.88	0.42	4.28	.	13.54
1983	0.36	14	21.73	20.02	1.18	0.91	9.58	.	52.51
1984	0.18	6.66	2.07	2.1	1.54	1.1	18.73	0.33	29.55
1985	0	0.02	1.26	2.06	0.01	1.16	13.25	0	17.1
1986	0.01	1.15	2.11	4.05	0.12	0.26	4.68	0.03	11.88
1987	0.59	0.05	3.05	2.78	0.06	3.82	31.35	0.02	38.22
1988	0.05	0.66	4.41	4.83	0.23	1.35	19.41	0.05	28.38
1989	0.51	1.7	6.07	4.12	1.28	1.75	28.02	0.24	38.66
1990	1.07	3.86	3.05	2.55	1.38	1.95	24.83	0.3	34.89
1991	0.1	0.52	2.05	1.36	0.27	1.31	21.39	0.05	25.74
1992	0.07	0.59	2.66	1.66	0.54	1.68	41.74	0.09	45.87
1993	0.05	0.39	1.26	1.06	0.48	0.95	10.15	0.12	13.96
1994	0.09	0.65	2.62	1.68	0.39	1.77	14.87	0.11	20.92
1995	0.03	0.18	4.9	4.51	0.16	1.37	6.69	0.04	16.76
1996	0.01	0.66	1.79	2.22	0.24	1.73	3.16	0.07	9.5
1997	0.31	1.23	3.78	7.16	1.95	2.54	9.82	0.39	24.5

Table X-22e.—Annual CMR values by year for Striped Bass for 12 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	3.08	18.22	1.32	7.04	7.28	0	0.05	.	32.62
1975	3.97	24.31	6.01	4.93	7.98	0.05	0.65	.	40.65
1976	5.7	15.4	8.73	7.31	4.91	0.05	0.76	.	36.34
1977	3.86	40.44	7.39	5.72	5.67	0.04	0.52	.	53.11
1978	5.46	26.07	5.28	3.51	6.3	0	0.03	.	40.16
1979	5.28	35.64	6.57	4.65	4.44	0.01	0.1	.	48.16
1980	4.15	28.73	10.66	8.35	7.24	0.02	0.27	.	48.27
1981	0.8	13.5	1.5	9.57	6.19	0.02	0.32	.	28.54
1982	14.39	22.55	12.87	12.08	9.09	0.01	0.14	.	53.9
1983	2.08	23.71	8.23	5.28	7.91	0.02	0.24	.	40.36
1984	9.5	41.43	6.12	4.09	5.39	0.01	0.12	1.29	55.48
1985	0.25	12.87	14.86	9.86	2.37	0.23	2.53	0.63	37.07
1986	3.55	46.68	13.52	12.03	5.48	0.01	0.15	1.26	63.54
1987	1.68	7.3	13.06	15.07	2.57	0.08	0.76	0.69	35.43
1988	4.12	34.65	9.24	9.28	7.47	0.02	0.22	1.39	53.04
1989	3.94	9.09	8.05	7.24	6.14	0.01	0.14	1.15	31
1990	3.49	18.62	12.31	11.39	6.78	0.02	0.26	0.91	43.78
1991	2.84	16.42	10.99	9.66	6.2	0.23	4.39	1.12	42.23
1992	3.26	20.18	9.03	7.25	8.52	0.01	0.5	1.52	41.6
1993	1.92	18.21	4.24	5.61	4.53	0.02	0.31	0.93	31.65
1994	2.79	21.95	5.75	3.37	7.29	0.02	0.12	1.32	36.87
1995	1.64	14.21	10.16	9.02	4.23	0.06	0.38	0.84	34.79
1996	0.41	33.65	5.11	6.16	4.83	0.01	0.05	1	44.59
1997	1.82	4.79	9.29	9.31	6.09	0.04	0.21	1.3	28.91

Table X-22f.—Annual CMR values by year for Spottail Shiner for 12 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	3.71	6.34	1.72	2.36	1.84	3.32	36.93	.	48.2
1975	4.27	7.73	4.95	2.78	2.06	5.98	56.28	.	67.14
1976	8.69	10.09	8.54	3.1	2.89	3.04	35.4	.	55.74
1977	3.26	10.23	4.51	1.82	1.27	8.8	71.62	.	79.19
1978	6	12.01	5.49	1.75	2.02	5.87	55.99	.	68.82
1979	4.85	10.64	10.74	3.81	1.26	3.74	40.74	.	58.88
1980	1.79	5.74	7.93	3.31	0.88	4.59	47.57	.	59.14
1981	2.74	12.24	6.06	2.91	2.09	2	34.97	.	51.43
1982	4.53	9.85	6.86	3.12	2.64	3.96	41.54	.	57.55
1983	3.19	8.77	8.3	3.5	1.69	4.72	48.17	.	62.06
1984	3.44	6.71	5.9	2.85	1.38	5.25	53.38	0.28	64.22
1985	2.43	8.88	6.93	3.14	2	5.41	40.55	0.36	55.99
1986	3.22	11.11	10.66	5.18	1.95	3.69	31.13	0.4	52.8
1987	3.28	6.33	8.03	2.9	1.04	6.22	49.55	0.28	62.22
1988	3.01	11.13	9.13	4.06	1.62	5.43	45.79	0.29	62.2
1989	5.27	13.94	6.98	2.77	2.32	4.12	43.72	0.35	61.28
1990	3.53	11.49	7.97	3.73	1.79	4.79	45.95	0.3	61.88
1991	4.69	13.5	8.54	3.82	2.66	3.46	50.14	0.45	66.17
1992	2.38	7.37	8.18	3.65	1.82	2.15	39.93	0.3	53.97
1993	2.15	6.11	6.04	3.28	1.62	2.82	32.56	0.28	46.32
1994	2.18	5.66	7.39	3.88	1.68	3.96	33.84	0.27	48.82
1995	1.61	6.61	5.09	3.19	1.2	2.9	19.65	0.19	35.05
1996	1.51	13.76	4.45	4.28	1.91	4.34	20.06	0.34	41.92
1997	1.91	4.85	6.45	3.48	1.81	4.69	22.04	0.34	38.73

Table X-22g.—Annual CMR values by year for White Perch for 12 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	9.62	11.11	1.98	7.1	3.79	0.27	1.16	.	30.61
1975	3.86	14.49	11.81	10.18	3.32	0.4	2.32	.	38.75
1976	2.86	5.53	9.65	8.52	1.24	0.47	2.66	.	27.42
1977	2.41	11.96	12.2	8.42	1.85	0.49	2.1	.	33.94
1978	1.74	8.97	12.36	5.99	1.08	0.93	2.81	.	29.8
1979	1.22	13.46	12.3	7.25	0.78	0.25	1.72	.	32.36
1980	0.59	5.19	12.75	9.5	1.45	0.39	2.85	.	29.03
1981	0.56	11.06	2.87	8.46	2.54	0.16	1.51	.	24.64
1982	0.28	7.53	3.88	3.17	2.4	0.5	2.57	.	18.79
1983	1.83	28.88	12.41	7.25	4.68	0.39	2.04	.	47.24
1984	1.13	15.02	6.67	4.94	1.84	0.5	2.87	0.44	29.61
1985	0.06	0.96	5.88	5.53	0.47	0.31	1.19	0.12	13.82
1986	0.54	7.13	16.85	19.47	1.15	0.08	0.47	0.29	39.38
1987	0.01	1.13	12.54	10.71	0.78	0.64	1.1	0.22	24.9
1988	0.99	13.59	13.34	9.46	3.45	0.57	1.95	0.65	37.22
1989	1.36	5.3	15.06	9.78	2.41	0.48	2.89	0.54	32.85
1990	0.71	5.9	13.39	9.89	2.14	0.89	3.54	0.35	32.02
1991	0.37	2.63	17.24	11.53	1.85	0.29	1.41	0.37	31.73
1992	0.51	4.84	12.36	8.06	2.54	0.21	2.27	0.54	27.89
1993	0.25	4.15	6.26	6.03	2.27	0.21	0.53	0.42	18.63
1994	0.5	5.45	12	5.59	1.61	0.41	0.83	0.39	24.34
1995	0.17	3.41	8.79	6.58	0.87	0.37	0.53	0.27	19.52
1996	0.13	8.32	8.25	7.27	0.89	0.59	0.39	0.23	23.72
1997	0.35	2.34	9.34	9.98	3.32	0.53	1.01	0.49	24.76

Table X-23a.—Annual CMR values by year for American Shad for 13 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	0.13	0.27	0.19	0.98	0.75	0.11	1.24	.	3.62
1975	0.13	0.44	3.34	2.49	1.13	1.84	36.57	.	42.31
1976	0.28	0.40	2.52	1.57	0.64	1.90	37.08	.	41.56
1977	0.03	0.47	1.77	1.13	1.49	0.38	3.38	.	8.37
1978	0.11	0.29	2.40	1.45	0.45	0.78	18.09	.	22.50
1979	0.05	0.23	1.32	1.11	0.08	1.72	31.72	.	34.75
1980	0.00	0.03	0.39	0.31	0.15	2.00	42.26	.	43.92
1981	0.02	0.22	0.43	0.93	0.24	0.95	15.64	.	17.97
1982	0.19	0.54	0.42	1.07	1.25	0.72	10.00	.	13.70
1983	0.02	0.11	0.87	1.40	0.60	1.28	18.17	.	21.62
1984	0.07	9.33	1.36	0.85	1.35	0.98	12.58	0.32	24.57
1985	0.00	0.00	0.22	0.32	0.08	1.63	20.51	0.03	22.32
1986	0.00	4.49	0.40	0.85	0.10	0.46	6.58	0.02	12.40
1987	0.01	0.00	0.53	0.36	0.15	3.82	31.75	0.05	35.07
1988	0.01	0.16	0.24	0.23	0.93	2.19	42.78	0.18	45.00
1989	0.25	0.29	1.45	1.02	1.32	1.95	41.70	0.24	45.40
1990	0.10	0.45	2.66	2.08	1.69	2.97	49.40	0.31	54.40
1991	0.01	0.08	0.50	0.44	0.74	1.51	36.23	0.12	38.37
1992	0.01	0.06	0.27	0.18	0.56	1.34	58.82	0.15	59.87
1993	0.01	0.15	0.27	0.24	1.39	1.29	7.95	0.32	11.29
1994	0.04	0.14	0.44	0.28	0.52	2.61	22.24	0.13	25.43
1995	0.01	0.11	0.48	0.43	0.66	1.33	12.09	0.12	14.82
1996	0.04	0.49	0.30	0.38	0.69	1.29	4.27	0.17	7.45
1997	0.01	0.06	0.37	0.58	0.85	1.99	16.63	0.14	19.91

Table X-23b.—Annual CMR values by year for Atlantic Tomcod for 13 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	10.10	6.98	0.42	0.93	5.05	0.00	0.01	.	21.67
1975	16.04	12.59	1.78	0.35	4.54	0.00	0.01	.	31.44
1976	19.59	14.36	1.67	0.61	4.82	0.00	0.01	.	35.95
1977	9.79	15.20	4.98	1.47	1.60	0.00	0.00	.	29.53
1978	16.84	17.94	3.71	1.26	5.21	0.00	0.01	.	38.51
1979	10.85	26.69	4.10	1.11	2.38	0.00	0.00	.	39.50
1980	11.11	39.05	3.00	0.76	8.67	0.00	0.00	.	52.37
1981	13.48	21.14	2.54	0.92	7.22	0.00	0.00	.	38.88
1982	11.59	25.60	2.75	1.09	7.10	0.00	0.00	.	41.22
1983	11.72	12.46	2.41	0.89	3.75	0.00	0.00	.	28.06
1984	10.21	23.56	2.48	1.05	2.57	0.00	0.00	0.95	36.09
1985	11.17	39.05	3.38	1.23	6.67	0.00	0.00	1.86	52.67
1986	13.81	19.91	2.83	1.08	6.29	0.00	0.03	1.69	38.89
1987	8.01	20.79	3.57	1.36	2.84	0.00	0.00	0.98	33.32
1988	12.80	31.77	2.88	1.15	6.00	0.00	0.00	1.57	47.15
1989	13.48	6.17	2.57	1.01	4.50	0.00	0.00	0.99	25.96
1990	12.19	9.17	3.17	1.24	4.18	0.00	0.00	0.82	27.52
1991	11.76	11.07	2.66	0.88	5.73	0.00	0.03	0.98	29.34
1992	12.63	22.65	2.50	0.78	4.60	0.00	0.00	0.98	38.24
1993	9.01	5.16	1.56	0.44	2.17	0.00	0.00	0.78	17.90
1994	7.59	11.77	2.36	0.70	4.04	0.00	0.00	0.80	24.75
1995	11.39	10.58	2.10	0.85	5.56	0.00	0.02	1.58	28.53
1996	2.45	13.41	1.26	0.47	1.85	0.00	0.00	0.52	18.96
1997	0.97	18.07	2.41	1.11	2.71	0.00	0.00	0.71	24.37

Table X-23c.—Annual CMR values by year for Bay Anchovy for 13 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	5.00	7.31	0.05	0.04	7.95	0.00	0.01	.	19.03
1975	4.20	6.61	0.18	0.07	6.10	0.05	0.63	.	16.76
1976	3.67	3.45	0.20	0.07	3.41	0.00	0.06	.	10.47
1977	4.96	13.78	0.22	0.07	8.00	0.02	0.21	.	25.00
1978	6.00	12.54	0.48	0.14	7.86	0.00	0.00	.	24.71
1979	6.30	10.80	0.52	0.16	4.11	0.00	0.04	.	20.43
1980	6.35	18.44	0.21	0.09	9.07	0.00	0.02	.	30.77
1981	4.01	18.56	0.23	0.11	8.94	0.00	0.01	.	29.06
1982	1.82	4.19	0.31	0.14	5.29	0.00	0.02	.	11.32
1983	2.95	9.04	0.51	0.21	6.34	0.00	0.00	.	17.93
1984	3.01	6.26	0.43	0.20	4.63	0.00	0.01	0.82	14.55
1985	3.07	10.06	0.47	0.20	8.17	0.05	0.57	1.11	21.84
1986	1.84	5.07	0.13	0.06	4.52	0.00	0.01	0.71	11.84
1987	5.50	9.99	0.38	0.11	5.67	0.01	0.14	1.21	21.25
1988	5.21	17.73	0.76	0.29	6.83	0.02	0.25	1.13	29.11
1989	3.59	7.96	0.11	0.03	4.62	0.00	0.01	0.57	15.97
1990	5.24	20.85	1.07	0.40	8.48	0.00	0.03	1.10	33.12
1991	3.72	9.09	1.44	0.59	6.99	0.00	0.01	0.95	21.01
1992	3.55	7.12	0.20	0.08	6.82	0.01	0.20	0.74	17.54
1993	3.17	7.08	0.50	0.29	7.03	0.01	0.15	0.82	17.81
1994	2.69	5.94	0.09	0.04	6.85	0.01	0.07	0.85	15.66
1995	3.55	14.99	1.82	0.96	6.74	0.01	0.05	0.96	26.40
1996	1.27	15.55	0.07	0.05	7.19	0.00	0.00	0.94	23.44
1997	3.61	6.62	1.78	0.98	7.95	0.01	0.05	0.98	20.25

Table X-23d.—Annual CMR values by year for River Herring for 13 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	0.21	1.04	0.75	3.26	0.58	1.76	25.26	.	30.78
1975	0.23	1.78	13.54	13.31	0.55	1.53	22.03	.	43.92
1976	1.00	2.32	6.67	4.82	0.71	1.61	23.59	.	35.88
1977	0.62	3.05	6.95	9.04	0.52	1.57	21.25	.	37.11
1978	0.26	1.55	3.60	2.12	0.37	1.75	25.39	.	32.33
1979	0.11	2.72	4.85	3.47	0.13	1.85	21.42	.	31.26
1980	0.08	0.55	3.27	2.78	0.58	1.23	22.24	.	28.64
1981	0.02	0.70	2.85	2.90	0.26	0.30	8.19	.	14.51
1982	0.21	1.00	2.35	2.15	1.88	0.42	4.28	.	11.72
1983	0.37	3.80	5.38	5.81	1.18	0.91	9.58	.	24.37
1984	0.19	6.67	2.07	1.86	1.53	1.10	18.73	0.33	29.38
1985	0.00	0.02	1.27	2.15	0.01	1.16	13.25	0.00	17.20
1986	0.01	1.16	1.98	3.97	0.12	0.26	4.68	0.03	11.69
1987	0.01	0.05	3.20	2.28	0.06	3.82	31.35	0.02	37.63
1988	0.05	0.61	4.20	4.54	0.23	1.35	19.36	0.05	27.93
1989	0.52	1.47	5.54	3.40	1.28	1.74	27.96	0.24	37.64
1990	1.07	3.61	2.82	2.26	1.38	1.95	24.79	0.30	34.33
1991	0.10	0.50	1.89	1.16	0.27	1.31	21.37	0.05	25.45
1992	0.07	0.52	2.52	1.46	0.54	1.68	41.55	0.09	45.47
1993	0.05	0.28	1.06	0.77	0.48	0.95	10.15	0.12	13.44
1994	0.09	0.59	2.31	1.31	0.39	1.75	14.73	0.11	20.18
1995	0.03	0.15	4.63	4.05	0.16	1.37	6.68	0.04	16.09
1996	0.01	0.55	1.61	1.76	0.23	1.73	3.16	0.07	8.80
1997	0.27	0.74	5.28	6.42	1.50	2.08	11.07	0.29	24.96

Table X-23e.—Annual CMR values by year for Striped Bass for 13 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	2.51	18.16	1.28	7.02	7.28	0.00	0.05	.	32.13
1975	3.37	24.17	5.65	4.88	7.96	0.05	0.65	.	39.89
1976	4.96	15.31	8.54	7.28	4.90	0.05	0.76	.	35.60
1977	3.37	40.38	7.11	5.70	5.67	0.04	0.52	.	52.67
1978	4.53	25.94	4.84	3.48	6.30	0.00	0.03	.	39.17
1979	3.84	35.39	6.34	4.62	4.43	0.01	0.10	.	47.01
1980	3.32	28.59	10.30	8.32	7.24	0.02	0.27	.	47.49
1981	0.80	13.50	1.50	9.50	6.19	0.02	0.32	.	28.48
1982	2.41	22.30	9.78	11.99	9.06	0.01	0.14	.	45.32
1983	2.07	23.50	8.02	5.23	7.90	0.02	0.24	.	40.01
1984	9.47	41.32	6.12	4.09	5.37	0.01	0.12	1.28	55.37
1985	0.25	12.87	7.20	6.32	2.37	0.23	2.53	0.63	28.71
1986	3.36	46.33	13.29	12.02	5.48	0.01	0.15	1.26	63.13
1987	1.68	7.29	12.94	15.06	2.57	0.08	0.76	0.68	35.31
1988	3.32	34.50	8.93	9.25	7.44	0.02	0.22	1.39	52.34
1989	3.36	8.82	7.65	7.17	6.12	0.01	0.14	1.14	29.99
1990	2.42	18.42	11.95	11.36	6.78	0.02	0.26	0.91	42.77
1991	2.36	16.32	10.43	9.60	6.20	0.23	4.39	1.12	41.47
1992	2.73	20.02	8.69	7.20	8.50	0.01	0.50	1.52	40.90
1993	1.46	18.17	4.14	5.59	4.52	0.02	0.31	0.93	31.20
1994	2.47	21.87	5.19	3.33	7.29	0.02	0.12	1.32	36.20
1995	1.26	14.09	9.79	8.98	4.23	0.06	0.38	0.84	34.15
1996	0.36	34.28	4.78	6.25	4.96	0.02	0.05	1.01	45.04
1997	1.61	4.88	9.19	9.89	6.19	0.04	0.20	1.33	29.29

Table X-23f.—Annual CMR values by year for Spottail Shiner for 13 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	3.71	6.34	1.72	2.36	1.84	3.32	36.93	.	48.20
1975	4.27	7.73	4.95	2.78	2.06	5.98	56.28	.	67.14
1976	8.69	10.09	8.54	3.10	2.89	3.04	35.40	.	55.74
1977	3.26	10.23	4.51	1.82	1.27	8.80	71.62	.	79.19
1978	6.00	12.01	5.49	1.75	2.02	5.87	55.99	.	68.82
1979	4.85	10.64	10.74	3.81	1.26	3.74	40.74	.	58.88
1980	1.79	5.74	7.93	3.31	0.88	4.59	47.57	.	59.14
1981	2.74	12.24	6.06	2.91	2.09	2.00	34.97	.	51.43
1982	4.53	9.85	6.86	3.12	2.64	3.96	41.54	.	57.55
1983	3.19	8.77	8.30	3.50	1.69	4.72	48.17	.	62.06
1984	3.44	6.71	5.90	2.85	1.38	5.25	53.38	0.28	64.22
1985	2.43	8.88	6.93	3.14	2.00	5.41	40.55	0.36	55.99
1986	3.22	11.11	10.66	5.18	1.95	3.69	31.13	0.40	52.80
1987	3.28	6.33	8.03	2.90	1.04	6.22	49.55	0.28	62.22
1988	3.01	11.13	9.13	4.06	1.62	5.43	45.79	0.29	62.20
1989	5.27	13.94	6.98	2.77	2.32	4.12	43.72	0.35	61.28
1990	3.53	11.49	7.97	3.73	1.79	4.79	45.95	0.30	61.88
1991	4.69	13.50	8.54	3.82	2.66	3.46	50.14	0.45	66.17
1992	2.38	7.37	8.18	3.65	1.82	2.15	39.93	0.30	53.97
1993	2.15	6.11	6.04	3.28	1.62	2.82	32.56	0.28	46.32
1994	2.18	5.66	7.39	3.88	1.68	3.96	33.84	0.27	48.82
1995	1.61	6.61	5.09	3.19	1.20	2.90	19.65	0.19	35.05
1996	1.51	13.76	4.45	4.28	1.91	4.34	20.06	0.34	41.92
1997	1.91	4.85	6.45	3.48	1.81	4.69	22.04	0.34	38.73

Table X-23g.—Annual CMR values by year for White Perch for 13 Regions and 100% flow-through mortality (actual flow). See Tables X-2a and b for model used in CMR estimation.

YEAR	BOWLINE POINT	INDIAN POINT	ROSETON	DANSKAMMER	LOVETT	EMPIRE STATE PLAZA	ALBANY STEAM STATION	WESTCHESTER RESCO	RIVERWIDE
1974	9.60	11.09	1.25	5.66	3.79	0.27	1.16	.	28.99
1975	3.84	14.48	8.85	8.16	3.32	0.40	2.32	.	35.26
1976	2.85	5.51	8.24	7.88	1.24	0.47	2.66	.	25.75
1977	2.38	11.93	9.27	7.01	1.85	0.49	2.10	.	30.64
1978	1.73	8.96	6.98	3.84	1.08	0.93	2.81	.	23.78
1979	1.20	13.44	9.24	5.78	0.78	0.25	1.72	.	28.86
1980	0.56	5.14	9.10	7.62	1.44	0.39	2.85	.	24.46
1981	0.56	11.23	2.91	5.65	2.54	0.16	1.51	.	22.50
1982	0.28	7.50	4.31	3.17	2.39	0.50	2.57	.	19.13
1983	1.75	27.51	9.84	5.85	4.68	0.39	2.04	.	43.78
1984	1.13	15.10	6.67	4.94	1.84	0.50	2.87	0.44	29.67
1985	0.09	0.96	5.88	5.53	0.47	0.31	1.19	0.12	13.84
1986	0.54	7.13	16.85	19.47	1.15	0.08	0.47	0.28	39.38
1987	0.01	1.14	12.54	10.71	0.78	0.64	1.10	0.22	24.90
1988	0.93	13.50	8.05	6.80	3.45	0.57	1.95	0.65	31.32
1989	1.34	5.23	11.28	7.94	2.41	0.48	2.89	0.54	28.35
1990	0.65	5.81	8.83	7.50	2.14	0.89	3.54	0.35	26.44
1991	0.33	2.51	12.13	8.79	1.70	0.29	1.41	0.34	25.00
1992	0.49	4.78	10.41	7.07	2.54	0.21	2.27	0.54	25.42
1993	0.21	4.10	3.03	4.44	2.27	0.21	0.53	0.42	14.33
1994	0.50	5.44	7.54	3.35	1.61	0.42	0.85	0.39	18.64
1995	0.16	3.38	7.71	5.90	0.87	0.37	0.53	0.27	17.92
1996	0.13	8.28	4.82	4.08	0.88	0.58	0.39	0.23	18.09
1997	0.28	2.29	6.81	8.50	3.31	0.53	1.02	0.49	21.30

References

Bigelow, H.B., and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. Fishery Bulletin of the Fish and Wildlife Service Vol. 53.

Boreman, J. 1981. Life Histories of Seven Fish Species that Inhabit the Hudson River Estuary. Lab. Ref. Doc. No. 81-34. National Marine Fisheries Service, Woods Hole, Massachusetts.

Boreman, J. 1983. Simulation of striped bass egg and larva development based on temperature. Transactions of the American Fisheries Society. 112:286-292.

Boreman, J., L.W. Barnthouse, D.S. Vaughan, C.P. Goodyear, and S.W. Christensen. 1982. Entrainment Impact Estimates for Six Fish Populations Inhabiting the Hudson River Estuary. Oak Ridge National Laboratory Environmental Sciences Division Publication No. 1790.

Boreman, J., and C. P. Goodyear. 1988. Estimates of entrainment mortality for striped bass and other fish species inhabiting the Hudson River estuary. American Fisheries Society Monograph 4:152-160.

Boreman, J., C. P. Goodyear, and S. W. Christensen. 1978. An empirical transport model for evaluating entrainment of aquatic organisms by power plants. U.S. Fish and Wildlife Service, Report FWS/OBS-78/90, Ann Arbor, Michigan.

Boreman, J., C. P. Goodyear, and S. W. Christensen. 1981. An empirical methodology for estimating entrainment losses at power plants sited on estuaries. Transactions of the American Fisheries Society 110:255-262.

Coastal (Coastal Environmental Services, Inc.). 1991a. Assessment of the Mitigative Value of Outages and Flow Reductions. Volume I. Prepared for Central Hudson Gas and Electric Corporation, Poughkeepsie, New York.

Coastal (Coastal Environmental Services, Inc.). 1991b. Assessment of the Mitigative Value of Outages and Flow Reductions. Volume II. Prepared for Central Hudson Gas and Electric Corporation, Poughkeepsie, New York.

EA (Ecological Analysts, Inc.). 1977. Survival of Entrained Ichthyoplankton and Macroinvertebrates at Hudson River Power Plants. Prepared for Central Hudson Gas and Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc.

EA (Ecological Analysts, Inc.). 1978. Hudson River Thermal Effects. Studies for Representative Species. Prepared for Central Hudson Gas and Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc.

EA (Ecological Analysts, Inc.). 1979. Indian Point Generating Station Entrainment Survival and Related Studies. 1978 Annual Report. Prepared for Consolidated Edison Company of New York, Inc. and New York Power Authority. New York, New York.

EA (Ecological Analysts, Inc.). 1980. Roseton Generating Station Entrainment Survival Studies. 1978 Annual Report. Prepared for Consolidated Edison Company of New York, Inc. and New York Power Authority. New York, New York.

EA (Ecological Analysts, Inc.). 1981a. Bowline Point Generating Station Entrainment Abundance Survival Studies, 1979 Annual Report with Overview of 1975-1979 Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, NY.

EA (Ecological Analysts, Inc.). 1981b. Indian Point Generating Station Entrainment Survival and Related Studies. 1979 Annual Report. Prepared for Consolidated Edison Company of New York, Inc. and New York Power Authority. New York, New York.

EA (Ecological Analysts, Inc.). 1982. Indian Point Generating Station Entrainment Survival and Related Studies. 1980 Annual Report. Prepared for Central Hudson Gas & Electric. Poughkeepsie, New York.

EA (Ecological Analysts, Inc.). 1983. Roseton Generating Station Entrainment Survival Studies. 1980 Annual Report. Prepared for Central Hudson Gas & Electric. Poughkeepsie, New York.

EA (Ecological Analysts, Inc.). 1984. Indian Point Generating Station Entrainment Abundance and Outage Evaluation. 1983 Annual Report. Prepared for Consolidated Edison Company of New York, Inc. and New York Power Authority. New York, New York.

EA (Ecological Analysts, Inc.). 1985a. Indian Point Generating Station Entrainment Abundance and Outage Evaluation. 1984 Annual Report. Prepared for Prepared for Consolidated Edison of New York, Inc., and New York Power Authority. New York, New York.

EA (Ecological Analysts, Inc.). 1985b. Roseton and Danskammer Point Generating Station Impingement Monitoring Program. 1984 Annual Report. Prepared for Central Hudson Gas & Electric. Poughkeepsie, New York.

EA (Ecological Analysts, Inc.). 1985c. Bowline Point Generating Station Entrainment Abundance and Unit Outage Evaluation. 1984 Annual Report. Prepared for Orange & Rockland Utilities, Inc., Pearl River, New York.

EA (Ecological Analysts, Inc.). 1986. Roseton and Danskammer Point Generating Station Impingement Monitoring Program. 1985 Annual Report. Prepared for Prepared for Central Hudson Gas & Electric. Poughkeepsie, New York.

EA (Ecological Analysts, Inc.). 1987. Indian Point Generating Station 1988 Entrainment Survival Study. Prepared for Consolidated Edison Company of New York, Inc. and New York Power Authority. New York, New York.

Glebe, B.D., and W.C. Leggett. 1981. Temporal, intra-population differences in energy allocation and use by American shad (*Alosa sapidissima*) during the spawning migration. Canadian Journal of Fisheries and Aquatic Sciences 38:795-805.

Heimbuch, D. G., D. J. Dunning and J. R. Young. 1992. Post-yolk-sac larvae abundance as an index of year class strength of striped bass in the Hudson River. Pages 376-391 *in* C. L. Smith editor. Estuarine Research in the 1980s. State University of New York Press, Albany, New York.

HRU (Hudson River Utilities). 1988a. Bowline Point entrainment (1981-1986) ASCII data files. Received December 1988.

HRU (Hudson River Utilities). 1988b. Indian Point entrainment (1983-1986) ASCII data files. Received December 1988.

HRU (Hudson River Utilities). 1988c. Longitudinal River Survey, Fall Shoals Survey, and Beach Seine Survey ASCII data files (Levels 3 and 4). Received December 1988.

HRU (Hudson River Utilities). 1988d. Water quality (1981-1987) ASCII data files. Received December 1988.

HRU (Hudson River Utilities). 1989a. Longitudinal River Survey, Fall Shoals Survey, and Beach Seine Survey (1980-1987) SAS data sets (Level 5). Received June 1989.

HRU (Hudson River Utilities). 1989b. Roseton and Bowline Point flow rate algorithms ASCII file. Received February 1989.

HRU (Hudson River Utilities). 1990a. Bowline Point entrainment (1987) SAS data sets. Received June 1990.

HRU (Hudson River Utilities). 1990b. Bowline Point plant operations (1981-1987) SAS data sets. Received June 1990.

HRU (Hudson River Utilities). 1990c. Indian Point entrainment (1981, 1987) SAS data sets. Received June 1990.

HRU (Hudson River Utilities). 1990d. Indian Point plant operations (1981-1987) SAS data sets. Received June 1990.

HRU (Hudson River Utilities). 1990e. Roseton entrainment (1981-1987) SAS data sets. Received June 1990.

HRU (Hudson River Utilities). 1990f. Roseton plant operations (1981-1987) SAS data sets. Received June 1990.

HRU (Hudson River Utilities). 1991a. Indian Point plant operations (1975-1990) SAS data sets. Received August 1991.

HRU (Hudson River Utilities). 1991b. Poughkeepsie waterworks (1974-1987) SAS data set. Received May 1991.

HRU (Hudson River Utilities). 1992a. Indian Point efficient flow rates. Received May 1992.

HRU (Hudson River Utilities). 1992b. Thermal mortality SAS data sets. Received October 1992.

HRU (Hudson River Utilities). 1993. Danskammer entrainment (1982-1987) SAS data sets. Received February 1993.

Kellogg, R.L., R.J. Ligotino, and S.M. Jinks. 1984. Thermal mortality prediction equations for entrainable striped bass. Transactions of the American Fisheries Society. 113:794-802.

LMS (Lawler, Matusky & Skelly Engineers). 1982a. 1981 Impingement Abundance Sampling at Roseton and Danskammer Point Generating Station: Annual Progress Report. Prepared for Central Hudson Gas & Electric. Poughkeepsie, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1982b. 1981 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1982c. 1981 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1983a. 1982 Impingement Abundance Sampling at Roseton and Danskammer Point Generating Station: Annual Progress Report. Prepared for Central Hudson Gas & Electric. Poughkeepsie, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1983b. 1982 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1983c. 1982 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1984a. Impingement Monitoring at Roseton and Danskammer. 1983 Annual Progress Report. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1984b. 1983 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1984c. 1983 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1984d. Albany Steam Generating Station, SPDES Aquatic Monitoring Program, October 1982 – Spetember 1983. Prepared for Niagara Mohawk Power Corporation. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1985a. Entrainment Abundance Monitoring Program at the Roseton and Danskammer Point Generating Stations. 1984 Progress Report. Prepared for Central Hudson Gas & Electric Corporation. Poughkeepsie, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1985b. 1984 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1985c. 1984 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1986a. 1985 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1986b. 1985 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1986c. Entrainment Abundance Monitoring Program at the Roseton and Danskammer Point Generating Stations. 1985 Progress Report. Prepared for Central Hudson Gas & Electric. Poughkeepsie, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1987a. 1986 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1987b. 1986 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1987c. Impingement Monitoring Program at the Roseton and Danskammer Point Generating Station. 1986 Annual Report. Prepared for Central Hudson Gas & Electric. Poughkeepsie, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1988a. ETM/EIM Applications for Outage Evaluation at Three Hudson River Generating Stations. Prepared under contract with Consolidated Edison Company of New York, Inc. New York, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1988b. 1987 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1988c. 1987 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1988d. Impingement Monitoring Program at the Roseton and Danskammer Point Generating Station. 1987 Annual Progress Report. Prepared for Central Hudson Gas & Electric. Poughkeepsie, New York.

Mansueti, R.J. 1964. Movements, reproduction, and mortality of the white perch, *Roccus americanus*, in the Patuxent Estuary, Maryland. Chesapeake Science 5:3-45.

McCann, J.A. 1959. Life history studies of the spottail shiner of Clear Lake, Iowa, with particular reference to some sampling problems. Transactions of the American Fisheries Society. 88:336-343.

Metzger, S. G., R. G. Keppel, P. Geoghegan, and A. W. Wells. 1992. Abundance of selected Hudson River fish species in previously unsampled regions: effect on standing crop estimates. Pages 348-375 *in* C. L. Smith editor. Estuarine Research in the 1980s. State University of New York Press, Albany, New York.

NAI (Normandeau Associates, Inc.). 1987. Indian Point Generating Station Entrainment Abundance Program. 1986 Annual Report. Prepared for Consolidated Edison Company of New York, Inc, and New York Power Authority. New York, New York.

NAI (Normandeau Associates, Inc.). 1988. Indian Point Generating Station Entrainment Abundance Program. 1987 Annual Report. Prepared for Consolidated Edison Company of New York, Inc, and New York Power Authority. New York, New York.

NYSDEC (New York State Department of Environmental Conservation). 1993. Flow rates at Hudson River water withdrawal facilities ASCII data set. Received March 1993.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Saksen, W. 1993. Personal communication between W. Saksen, Orange and Rockland Utilities, Inc., and S. Cairns, Coastal Environmental Services, Inc.

Sandler, R. and D. Schoenbrod (Editors). 1981. The Hudson River Power Plant Settlement. New York University School of Law. New York, New York.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada, Ottawa.

Versar, Inc. 1987. 1985 Year Class Report for the Hudson River Estuary Monitoring Program, Volumes I and II. Prepared for Consolidated Edison Company of NY, Inc.

Young, J. 1993. Personal communication between J. Young, Consolidated Edison Co. of New York, Inc., and L. Zugner, Niagara Mohawk Power Corporation. April 1993.

Young, J.R., R.J. Klauda, and W.P. Dey. 1988. Population estimates for juvenile striped bass and white perch in the Hudson River estuary. American Fisheries Society Monograph 4:89-101.

Appendix VI-I-C

Sensitivity Analysis Regarding the Effect of Morone PYSL Identification on the Assessment of Effects of Power Plant Entrainment on Striped Bass and White Perch Populations in the Hudson River

SENSITIVITY ANALYSIS REGARDING THE EFFECT OF MORONE PYSL IDENTIFICATION ON THE ASSESSMENT OF EFFECTS OF POWER PLANT ENTRAINMENT ON STRIPED BASS AND WHITE PERCH POPULATIONS IN THE HUDSON RIVER

Prepared for

New York Power Authority
123 Main Street
White Plains, NY 10601

Prepared by
PBS&J
4201 Northview Drive, Suite 302
Bowie, MD 20716

June 1999

Executive Summary

Sensitivity analyses were conducted to assess the magnitude of potential effects of mis-identification of *Morone* PYSL (i.e. striped bass and white perch post yolk-sac larvae) on estimates of conditional mortality rates due to entrainment and characterizations of abundance based on sampling of this life stage. In the other sections of this Draft Environmental Impact Statement (DEIS) the CEMR methodology is used for estimating the conditional entrainment mortality rate for striped bass and white perch The sensitivity analyses presented here focus on questions regarding the effects of mis-identification of PYSL *Morone* on CEMR estimates and also address effects on abundance estimates and indices.

The sensitivity analyses consisted of four steps:

- Step 1—Identification of parameters in CEMR that could be affected by mis-identification of *Morone* PYSL,
- Step 2—Definition of bounds for each component parameter,
- Step 3—Computation of CEMR estimates for striped bass and white perch with each parameter set at the defined bounds, and
- Step 4—Comparison of the CEMR estimates for striped bass and white perch that
- are reported elsewhere in the DEIS to the range of estimates from the sensitivity analyses.

The sensitivity analyses were conducted for three plants on the Hudson River (Bowline Point, Indian Point and Roseton) for the years 1981 and 1983 through 1987 (entrainment sampling was not conducted at Indian Point in 1982). Four entrainable life-stages (eggs, yolk-sac larvae, PYSL, and juveniles) are included in the CEMR estimates.

Five component parameters, potentially affected by mis-identification of *Morone* PYSL, were identified:

- Riverwide abundance of PYSL,
- Riverwide abundance of juveniles as measured by the PYSL forecast,
- Numbers of PYSL entrained,
- Relative probability of capture (RPC), and
- Mechanical mortality rates;

and three types of bounds for the component parameters were defined:

- Reported estimates (i.e., estimates based on *Morone* PYSL identified to species),
- Alternate estimates (i.e., estimates that did not require data on *Morone* PYSL identified to species), and

- Extreme bounds (i.e., bounds defined by assuming that all *Morone* PYSL were mis-identified, or that all *Morone* PYSL were striped bass, or that all *Morone* PYSL were white perch).

Eight scenarios were selected for the sensitivity analyses. Each scenario consisted of one specified bound for each of the five component parameters that may have been affected by identification of *Morone* PYSL to species. For example, one scenario was defined as follows:

- Alternate estimates for riverwide abundance of PYSL,
- Alternate estimates of PYSL forecast for juvenile abundance,
- Reported estimates for number of PYSL entrained,
- Reported estimates for RPC, and
- Reported estimates for mechanical mortality rates.

Four of the scenarios were selected to assess the effect on CEMR of possible mis-identification in each component parameter separately. One scenario was selected to assess the combined effect of possible mis-identification in all component parameters. For these five scenarios, the effect of possible mis-identification was addressed with the alternative estimates of the component parameters. In addition, two scenarios were selected that were intended to consider the case of the component parameters set to extreme bounds. The eighth scenario (DEIS)represented the methods used for the CEMR estimates reported elsewhere in this document (i.e., reported values used for all component parameters).

For both striped bass and white perch, the CEMR estimates from the sensitivity analyses, which were based on alternate component parameter estimates, had a range of values that was very similar to the DEIS scenario estimates . Also, the CEMR estimates for striped bass fell within the range of estimates that were computed with the component parameters set to extreme bounds. The white perch CEMR estimates for the DEIS scenario were higher or within the range of estimates computed with the component parameters set to extreme bounds.

These findings corroborate the range of CEMR values estimated and used elsewhere in this document and do not support the hypothesis that the reported CEMR estimates are severely biased due to the presence of misidentified *Morone* PYSL.

Also, alternate PYSL index values, which were computed from intermediate results from the sensitivity analyses, displayed a high degree of correlation with the reported PYSL index values. The high degree of correlation suggests that the reported PYSL indices are useful measures for characterizing long-term inter-annual variability and trends.

Table of Contents

EXECUTIVE SUMMARY i

INTRODUCTION ..... 1~~13~~

METHODS ..... 5~~53~~

CEMR MODEL ..... 5~~53~~
BOUNDS FOR RIVERWIDE ABUNDANCE OF PYSL ..... 6~~63~~
BOUNDS FOR RIVERWIDE ABUNDANCE OF JUVENILES ..... 11~~113~~
BOUNDS FOR NUMBER ENTRAINED ..... 12~~123~~
BOUNDS FOR RELATIVE PROBABILITY OF CAPTURE (RPC) ..... 14~~143~~
BOUNDS FOR MECHANICAL MORTALITY RATES ..... 15~~153~~
SCENARIOS FOR SENSITIVITY ANALYSES ..... 16~~163~~

RESULTS ..... 20~~203~~

CEMR SENSITIVITY ANALYSES ..... 20~~203~~
INTERMEDIATE RESULTS ..... 21~~213~~

DISCUSSION ..... 29~~293~~

CEMR SENSITIVITY ANALYSES ..... 29~~293~~
INDICES OF PYSL ABUNDANCE ..... 30~~303~~

CONCLUSIONS ..... 31~~313~~

REFERENCES ..... 32~~323~~

Introduction

Estimates of the conditional mortality rate due to entrainment are based on data collected by the Utilities' sponsored Long River Ichthyoplankton and Fall Shoals Juvenile surveys, and discharge sampling programs at each of the plants. Estimates are calculated separately for seven taxa (American shad, Atlantic tomcod, bay anchovy, river herring, spottail shiner, striped bass and white perch).

Some laboratory studies of archived ichthyoplankton samples from the Long River Survey and discharge sampling programs found some mis-identified striped bass and white perch (*Morone)* larvae. Houde et. al. (1991) examined archived Long River Survey (LRS) samples from 1989 and 1990 as part of a feasibility study to determine whether the age and growth rate of Hudson River striped bass larvae could be determined from otoliths. Based upon identification methods of Olney et. al. (1983), they concluded that 21% of the larvae that they received from the Utilities (larvae originally identified as striped bass) were white perch.

In response to this finding, the Hudson River Foundation sponsored a study by Schmidt (1993) to examine additional archived samples for the presence of mis-identified *Morone* larvae. Schmidt examined larvae collected by the LRS in 1981 and 1987, and larvae collected in discharge sampling programs at Indian Point in 1978 and at Roseton in 1982. For the 1981 LRS specimens (>8mm), he concluded that 61.7% of the larvae labeled striped bass were actually white perch, and that 3% of the larvae labeled white perch were actually striped bass. For the 1987 LRS specimens (>8mm), he concluded that 4.6% of the larvae labeled striped bass were actually white perch, and that 9.5% of the larvae labeled white perch were actually striped bass. For the 1978 Indian Point discharge specimens (>8mm), he concluded that 50.6% of the larvae labeled striped bass were actually white perch, and that 4% of the larvae labeled white perch were actually striped bass. For the 1982 Roseton discharge specimens (>8mm), he concluded that 66.9% of the larvae labeled striped bass were actually white perch, and that 0% of the larvae labeled white perch were actually striped bass.

Schmidt also examined specimens of yolk-sac larvae (YSL) in the sample. He concluded that the extent of mis-identification of *Morone* YSL was negligible and warranted no further investigation.

The Utilities conducted a preliminary assessment of the effects of mis-identification on the integrity of the Utilities' ichthyoplankton database by correlating annual post yolk-sac larvae (PYSL) indices of abundance with annual YSL indices of abundance. Based on Schmidt's conclusion regarding YSL, the YSL indices should not be affected by mis-identification and should provide a reliable baseline for comparison. The correlation between striped bass PYSL and YSL indices of abundance was statistically significant ($p<0.001$) with a correlation coefficient of 0.95 (Figure 1). The correlation between white perch PYSL and YSL indices of abundance was also significant ($p<0.001$) and had a correlation coefficient of 0.83 (Figure 2). .

In spite of the good correlations, twot approaches to further address uncertainties regarding potential effects of mis-identifcation on conditional entrainment mortality rate and abundance estimators were identified. The first was to attempt to develop a means for correcting the mis-identification errors in the database (e.g. using results from the Schmidt study). If this was not feasible, then the second approach was to assess the magnitude of error that could be propagated to estimates of conditional mortality rates.

Although both the Houde et. al. (1991) and Schmidt (1993) studies demonstrated the presence of mis-identification of *Morone* larvae in the Utilities' database, neither study was designed to produce a correction factor or factors that could be applied to the database. Both studies focused on samples that were thought to bracket key conditions, rather than samples that were randomly selected to be statistically representative. Furthermore, Schmidt (1993) acknowledged that objective identification criteria could not be applied to *Morone* PYSL smaller than 8mm. Any corrections to the database would have to address PYSL smaller than 8mm becausea large proportion of all PYSL in the river are smaller than 8mm.

Because the database could not be corrected for mis-identification errors, a sensitivity analysis was conducted to assess the magnitude of potential effects of mis-identification of *Morone* PYSL on estimates of conditional mortality rates due to entrainment. . The sensitivity analyses directly address the effects of mis-identification of PYSL *Morone* on conditional mortality rate estimates from the Conditional Entrainment Mortality Rate (CEMR) model .

The approach used for the sensitivity analyses consisted of four steps:

- Step 1—Identification of parameters in CEMR that could have been affected by mis-identification of *Morone* PYSL,
- Step 2—Definition of bounds for each parameter that are consistent with existing data,
  - Alternative parameter estimates that are based on data other than species-specific *Morone* PYSL data (e.g. *Morone* PYSL data not keyed to species, and species-specific yolk-sac-larvae data and juvenile data),
  - Extreme bounds that bracket possible conditions,
- Step 3—Computation of CEMR estimates for striped bass and white perch with each parameter set at the defined bounds, and
- Step 4—Comparison of the CEMR estimates for striped bass and white perch to the range of estimates from the sensitivity analyses.

The sensitivity analyses were conducted for three plants on the Hudson River (Bowline Point, Indian Point and Roseton), for the years 1981 and 1983 through 1987. All four entrainable life-stages (eggs, yolk-sac larvae, PYSL, and juveniles) were included in the CEMR estimates.

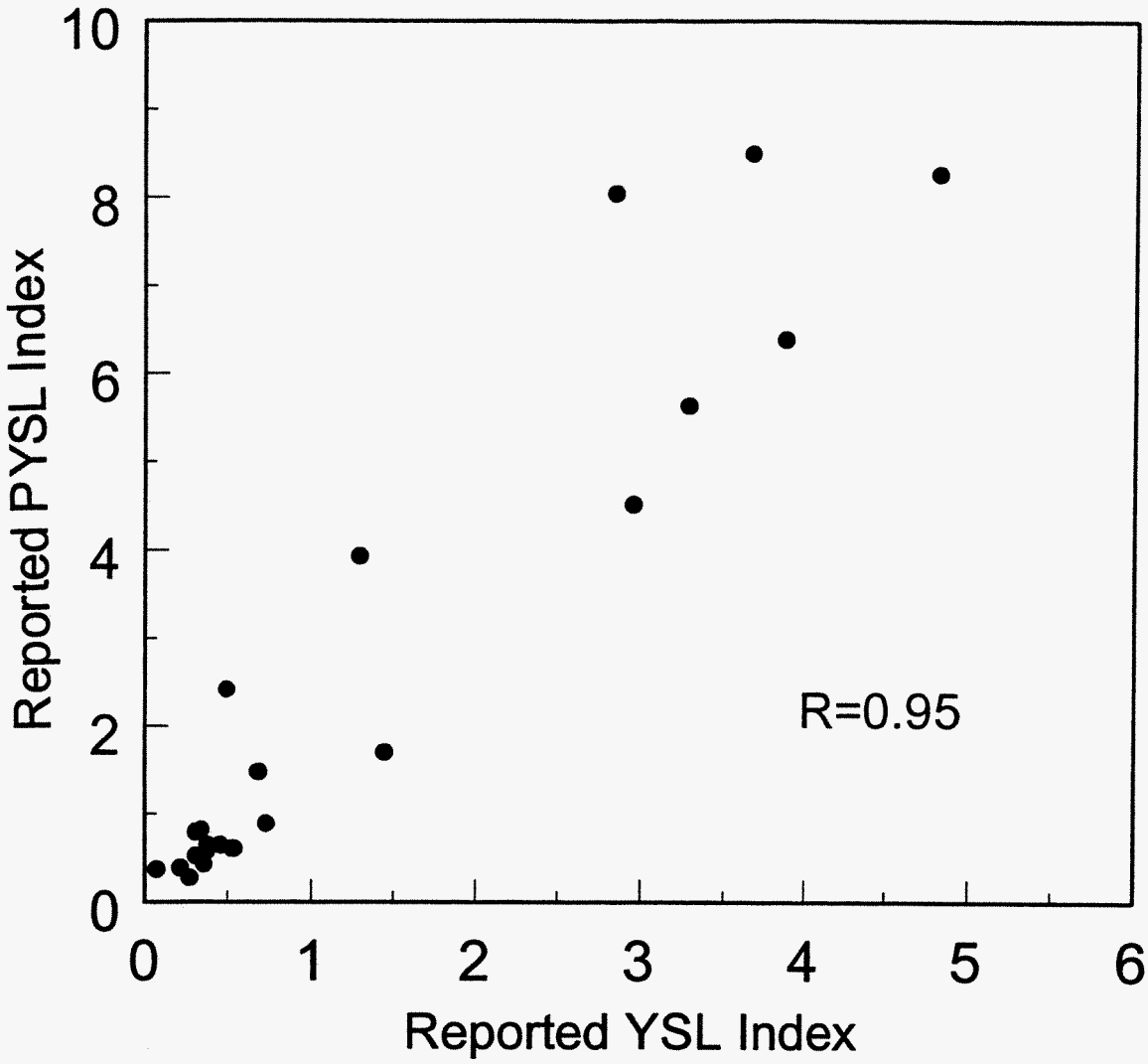


Figure 1.—Correlation between reported PYSL indices of abundance and YSL indices of abundance for striped bass.

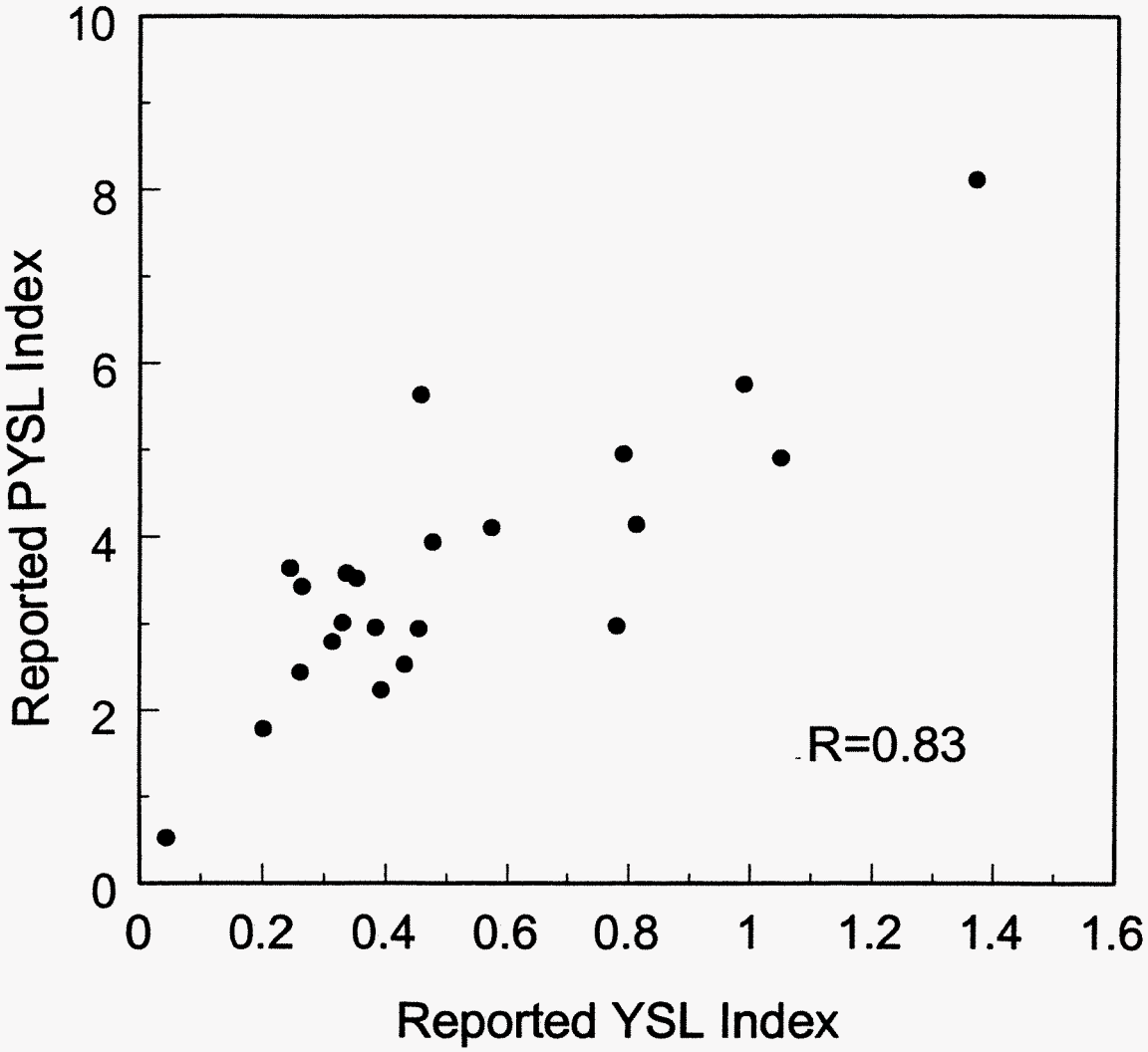


Figure 2.—Correlation between reported PYSL indices of abundance and YSL indices of abundance for white perch.

Methods

CEMR Model

The CEMR model represents the conditional mortality rate due to entrainment (m_T) as a weighted average of cohort-specific conditional mortality rates. Each cohort-specific conditional mortality rate is represented as the complement of the cohort-specific conditional survival rate, and each cohort-specific survival rate is represented as the product of daily conditional survival rates. Separate estimates are computed for each plant using the following formulation (the plant-specific CEMR estimates are subsequently combined to produce an estimate of the overall CEMR):

$$m_T = 1 - \sum_{s=1}^{S} R_s \left[\prod_{d=s}^{s+J} \left[\prod_{l=1}^{L} \left(1 - \frac{NE'_{dl} \quad f_{dl}}{N'_{dl}} RPC_{dl} \right)^{\delta_{dsl}} \right] \right] \qquad (1)$$

where

s = day 1,2,3,...,S of the spawning period (subscript s also denotes cohorts spawned on the day)

R_s = proportion of the spawning that occurred on day s

J = maximum entrainable age

l = life-stage 1,2,3,...L

NE'_{dl} = the measured number of life-stage l individuals entrained on day d (not adjusted for efficiency of pump sampling gear)

N'_{dl} = the measured riverwide abundance of life-stage l individuals on day d (not adjusted for efficiency of ichthyoplankton sampling gear)

f_{dl} = the through-plant mortality rate (i.e., the fraction of the ichthyoplankton entrained that die from entrainment) for life-stage l ichthyoplankton on day d; f_{dl} is assumed to consist of a mechanical mortality rate (f_{Ml}) and a thermal mortality rate (f_{Tdl}):

$$f_{dl} = 1 - (1 - f_{Ml})(1 - f_{Tdl})$$

RPC_{dl} = the ratio of gear efficiencies (ichthyoplankton trawl / pump sampling gear) for larvae of life-stage l on day d

δ_{dsl} = the proportion of day d that individuals of cohort s spend in life-stage l.

Estimates of the following parameters would be affected by identification of *Morone* PYSL to species:

- The riverwide abundance of PYSL (N'_{dl} with l = PYSL),
- The riverwide abundance of juveniles (N'_{dl} with l = juvenile),
- The number of PYSL entrained (NE'_{dl} with l = PYSL),
- The relative probability of capture (RPC_{dl} with l = PYSL), and
- The mechanical mortality rate (f_{Mdl} with l = PYSL).

The estimate of the riverwide abundance of juveniles would be affected because a forecast of PYSL abundances was used to characterize the abundance of juveniles. This approach was chosen based on an evaluation of alternative sampling programs (Heimbuch, et. al. 1992). The authors found that most of the water volume inhabited by *Morone* larvae was subject to sampling by the riverwide larval sampling program (i.e., the Long River Survey), whereas only a small fraction of the water volume inhabited by *Morone* juveniles was subject to sampling by the juvenile sampling programs (i.e., the Fall Shoals and Beach Seine Surveys). The authors concluded that the Long River Survey was better suited for assessing abundance than the Fall Shoals and Beach Seine Surveys.

Bounds for Riverwide Abundance of PYSL

The approach to setting bounds for the riverwide abundance of PYSL striped bass and white perch was to develop alternative estimates that were based on data other than species-specific *Morone* PYSL data. An approach was developed that allowed the relative abundance of the two species to be estimated from the distribution pattern of PYSL of the two species and the overall distribution pattern of *Morone* PYSL. The approach required estimates of distribution patterns for striped bass and white perch that did not rely on species-specific *Morone* PYSL data. Distribution patterns for striped bass and white perch PYSL were interpolated from distribution patterns of yolk-sac larvae (YSL) and juveniles for each year these data were collected.

The interpolated distribution patterns for striped bass and white perch were computed in two stages. In the first stage, their PYSL distribution patterns for the period from the 5% week of *Morone* PYSL (i.e., the week defined so that 5% of the sum of weekly abundance estimates were observed before the 5% week) to the 95% week of *Morone* PYSL (i.e. the week defined so that 95% of the sum of weekly abundance estimates were observed after the 95% week) were computed. In the second stage, PYSL distribution patterns were derived for the four-week period following the 95% week of *Morone* PYSL.

The distribution patterns for a species in the first stage were derived by projecting the YSL distribution pattern for each weekly cohort for a four-week period. The projected distribution patterns were based on weekly upriver-downriver movements of *Morone* PYSL. For

each week within the first stage, a weighted average of the cohort-specific distribution patterns was computed. The relative abundance of the cohort was the weighting factor for each cohort. This procedure for projecting the YSL distribution patterns can be represented algebraically as follows for each species:

$$d'_{kt} = \frac{\sum_{c=(t-3)}^{t} N_{YSL\,c}\, d'_{ckt}}{\sum_{c=(t-3)}^{t} N_{YSL\,c}} \qquad (2)$$

where

d'_{kt} = (projected) proportion of PYSL present in week t that are in region k (t = 5% PYSL week to the 95% PYSL week)

$N_{YSL\,c}$ = relative abundance of weekly cohort c as YSL

d'_{ckt} = (projected) proportion of weekly cohort c PYSL present in week t that are in region k

$$d'_{ckt} = \frac{\sum_{j=1}^{12} q_{jckt}\, d_{cjc}}{\sum_{k=1}^{12}\left[\sum_{j=1}^{12} q_{jckt}\, d_{cjc}\right]} \qquad (3)$$

and,

q_{jckt} = a transition probability that represents the proportion of weekly cohort c YSL that originally were in region j in week c, and later were in region k in week t

d_{cjc} = the proportion of weekly cohort c YSL that were in region j in week c

The transition probability (q_{jckt}) is estimated based on the average weekly upriver/downriver movement patterns of all *Morone* PYSL.

$$q_{jckt} = \sum_{i=L_k}^{U_k} \frac{\delta_{i(jct)}}{U_j - L_j} \qquad (4)$$

where

L_k = river mile of the lower boundary of region k

U_k = river mile of the upper boundary of region k

$\delta_{i(jct)}$ = 1 if $(L_j + G_{ct}) \le i < (U_j + G_{ct})$ and is equal to 0 otherwise

G_{ct} = the average upriver/downriver shift in the distribution of all *Morone* PYSL from week c to week t:

$$G_{ct} = \left[\frac{RM_{YSL} - RM_{PYSL}}{WK_{YSL} - WK_{PYSL}} \right] \bullet (t - c) \qquad (5)$$

and, WK_l = the abundance-weighted, average week of the presence of all lifestage l *Morone* (l = YSL or PYSL)

$$WK_l = \frac{\sum_{k=1}^{12} \sum_t M_{lkt}\, t}{\sum_{k=1}^{12} \sum_t M_{lkt}} \qquad (6)$$

M_{lkt} = the abundance of all lifestage l *Morone* in region k in week t

RM_l = the abundance-weighted, average location (rivermile) of all lifestage l *Morone*

$$RM_l = \frac{\sum_{k=1}^{12} \sum_t M_{lkt} \left[\frac{(U_k - L_k + 1)}{2} \right]}{\sum_{k=1}^{12} \sum_t M_{lkt}} \qquad (7)$$

The distribution patterns in the second stage (four weeks following the 95% week of *Morone* PYSL) were derived by interpolating between the projected PYSL distribution pattern in the 95% week of *Morone* PYSL and the average distribution pattern of juveniles. This procedure can be represented algebraically as follows for each species.

$$d'_{kt} = \frac{d'_{kt^*} + (t - t^*) \left(\frac{D_{kt^{**}} - d'_{kt^*}}{t^{**} - t^*} \right)}{\sum_{k=1}^{12} \left[d'_{kt^*} + (t - t^*) \left(\frac{D_{kt^{**}} - d'_{kt^*}}{t^{**} - t^*} \right) \right]} \qquad (8)$$

where

d'_{kt} = (interpolated) proportion of PYSL present in week t that are in region k ($t = t^*+1, t^*+2, \ldots, t^*+4$)

t^* = the 95% week of *Morone* PYSL

t^{**} = minimum of the second week of juvenile distribution data (from the Beach Seine Survey), and week $t^* + 5$

D_{kt}^{**} = the average proportion of juveniles in region k during a four-week period beginning with week $t^{**} - 1$; this parameter was estimated from Beach Seine Survey data

Alternative estimates of weekly abundances of striped bass and white perch were derived from the interpolated distribution patterns (as described above) for both species, the observed weekly distribution patterns for *Morone* PYSL, and the weekly estimates of total *Morone* PYSL abundances. The distribution pattern for *Morone* PYSL is a weighted average of the distribution patterns for striped bass and white perch, where the weighting factors are the relative abundances of the two species. Therefore, given the species-specific distribution patterns and the overall *Morone* PYSL distribution pattern, the weighting factors (i.e. the relative abundances) can be determined. The absolute abundance for each species then can be estimated as the product of the species' relative abundance times the total *Morone* PYSL abundance.

The relationship between the species-specific distribution patterns and the overall *Morone* PYSL distribution pattern can be represented algebraically as follows.

$$d_{MOR\,kt} = \frac{d'_{SB\,kt}\ N_{SB\,t} + d'_{WP\,kt}\ N_{WP\,t}}{N_{SB\,t} + N_{WP\,t}} \qquad (9)$$

where

$d_{MOR\,kt}$ = the observed proportion of *Morone* PYSL in region k during week t

$d'_{SB\,kt}$ = the proportion of striped bass PYSL in region k during week t (estimated by projection/interpolation as described above)

$d'_{WP\,kt}$ = the proportion of white perch PYSL in region k during week t (estimated by projection/interpolation as described above)

$N_{SB\,t}$ = the riverwide abundance of striped bass PYSL during week t

$N_{WP\,t}$ = the riverwide abundance of white perch PYSL during week t

Rearranging equation (9) gives:

$$\frac{d_{MOR\,kt} - d'_{SB\,kt}}{d'_{WP\,kt} - d_{MOR\,kt}} = \frac{N_{WP\,t}}{N_{SB\,t}}$$

and,

$$p_{SB\,kt} = \frac{N_{SB\,t}}{N_{SB\,t} + N_{WP\,t}} = \frac{d_{MOR\,kt} - d'_{WP\,kt}}{d'_{SB\,kt} - d'_{WP\,kt}} \qquad (10)$$

where

$p_{SB\,kt}$ = the proportion of the riverwide abundance of *Morone* PYSL in week t that is striped bass (computed using data from region k)

Equation (10) shows that the proportion of the riverwide abundance of *Morone* PYSL that is striped bass can be derived using only the distribution pattern of *Morone* PYSL and distribution patterns of the two species. Therefore, with alternate estimates (that do not rely on *Morone* PYSL data keyed to species) for the distribution patterns of the two species, the proportion of the riverwide abundance of *Morone* PYSL that is striped bass can be ascertained without the use of *Morone* PYSL data identified to species.

For each year, separate estimates of $p_{SB\,kt}$ were computed for each region and week. As can be seen from equation (10), this method of estimation is not applicable to a specific region and week if $d'_{SB\,kt}$ is equal to $d'_{WP\,kt}$ (because this would cause the denominator to be equal to zero). As a practical matter, estimates of $p_{SB\,kt}$ based on equation (10) will be very imprecise if $d'_{SB\,kt}$ and $d'_{WP\,kt}$ have similar values. Therefore, for each year, only the top 25% of regions and weeks with the largest difference between $d'_{SB\,kt}$ and $d'_{WP\,kt}$ were used to estimate $p_{SB\,kt}$. These region- and week-specific estimates for each year were averaged (using an arctangent transformation for proportions) to produce a single, weighted average estimate for each year. A simple average was computed for each week and then a weighted average of the weekly values was computed. The weighting factors were the week-specific abundance estimates for *Morone* PYSL:

$$\bar{p}_{SB\,y} = \mathrm{Tan}\left[\frac{\sum_t \hat{N}_{MOR\,kty}\left[\dfrac{\sum_{k=1}^{12}\delta_{kty}\ \mathrm{ArcTan}\left(p_{SB\,kty}\right)}{\sum_{k=1}^{12}\delta_{kty}}\right]}{\sum_t \hat{N}_{MOR\,kty}}\right] \quad (11)$$

where

δ_{kty} = 1 if region *k* and week *t* was included in the top 25% of regions and weeks with the largest difference between $d'_{SB\,kt}$ and $d'_{WP\,kt}$,

= 0 otherwise.

An annual average was used because week- and region-specific estimates had very low precision. By taking an average, more data were included in the estimate, which greatly improved precision.

Alternative estimates of daily abundances of striped bass and white perch PYSL then were estimated as follows.

$$\tilde{N}'_{SB\,dly} = \bar{p}_{SB\,y} N'_{MOR\,dly} \quad (12)$$

and,

$$\tilde{N}'_{WP\,dly} = \left[1 - \bar{p}_{SB\,y}\right] N'_{MOR\,dly} \quad (13)$$

where

$N'_{MOR\ d\ l\ y}$ = an estimate of the riverwide abundance of *Morone* PYSL on day *d*.

Bounds for Riverwide Abundance of Juveniles

The PYSL forecast used for estimating the weekly abundance of juvenile striped bass and white perch is a sum of cohort-specific, weekly juvenile abundance estimates. Each weekly, cohort-specific juvenile abundance estimate is computed as the product of: 1) a cohort-specific PYSL abundance estimate, and 2) a survival term that represents the fraction of the PYSL cohort abundance that is still alive at the beginning of the week.

Using the PYSL forecast approach, alternative estimates of juvenile abundance were computed in two steps. First the PYSL forecast method was applied to *Morone* PYSL data to produce estimates of the abundance of *Morone* juveniles (striped bass and white perch combined). Then the year-specific estimates of the proportion of total *Morone* PYSL that are striped bass ($\overline{p}_{SB\ y}$) were used to apportion the total abundance to the two species.

The total abundance of *Morone* juveniles was estimated by projecting forward the abundance of PYSL *Morone*:

$$\hat{N}_{MOR\ y\ t\ JUV} = \sum_{c} \hat{N}_{MOR\ y\ c\ PYSL_c} \left[S_P^{lsd_P} S_J^{t-(c+lsd_P)+1} \right] \qquad (14)$$

where

$\hat{N}_{MOR\ y\ t\ JUV}$ = estimated abundance of *Morone* juveniles in week *t*

$\hat{N}_{MOR\ y\ c\ PYSL_c}$ = estimated initial abundance of *Morone* PYSL cohort *c* in week *c*

S_P = the median of annual estimates of weekly survival fractions for *Morone* PYSL

S_J = the median of annual estimates of weekly survival fractions for *Morone* juveniles

lsd_P = the life stage duration of *Morone* PYSL (taken to be the midpoint between the PYSL life-stage duration of striped bass [28 days] and the PYSL life-stage duration of white perch [32 days]

The alternative estimates for daily abundances of striped bass and white perch juveniles were calculated as:

$$\tilde{N}_{SB\ y\ d\ JUV} = \overline{p}_{SB\ y} \hat{N}_{MOR\ y\ d\ JUV} \qquad (15)$$

and,

$$\tilde{N}_{WP\ y\ d\ JUV} = \left[1 - \overline{p}_{SB\ y} \right] \hat{N}_{MOR\ y\ d\ JUV} \qquad (16)$$

where $\hat{N}_{MOR\ y\ d\ JUV} = \hat{N}_{MOR\ y\ t\ JUV}$ for $d \in t$.

The initial abundances of *Morone* PYSL cohorts and the PYSL survival fraction were estimated from weekly riverwide *Morone* PYSL abundances. The weekly riverwide PYSL abundance is the sum of cohort-specific abundances and can be represented in terms of the following non-linear regression, which was used to estimate the underlying parameters (i.e., the initial abundance of PYSL cohorts and the PYSL survival fraction):

$$\hat{N}_{MOR\ yt\ PYSL} = \sum_{c} \hat{N}_{MOR\ yc\ PYSL_c} S_{P\ y}^{t-c} \Delta_{cty} \qquad (17)$$

where

$\hat{N}_{MOR\ yt\ PYSL}$ = an estimate of riverwide abundance of *Morone* PYSL in week t in year y

$S_{P\ y}$ = the average weekly survival fraction for PYSL in year y

Δ_{cty} = the fraction of week t in year y that cohort c spends in the PYSL life stage

The PYSL survival fraction estimates were adjusted for the effects of changes in gear avoidance with size. Data from the relative probability of capture (RPC) study at Indian Point were used to assess the degree of gear avoidance. The observed RPC for *Morone* PYSL varied as a function of length of larvae: smaller larvae apparently were extruded through collection nets in discharge sampling devices, and larger larvae apparently avoided ichthyoplankton nets towed in the river. Under the assumption that extrusion through collection nets in discharge sampling devices decreased linearly with age, the progressive increase with age of gear avoidance (of river sampling nets) was characterized.

Catch curve analyses of catch-per-haul data from the Beach Seine Survey were used to estimate the *Morone* juvenile survival fraction. The analyses were restricted to weeks in which all juvenile *Morone* were recruited to the beach seine gear. A median of year-specific estimates was used for the PYSL forecast of juvenile abundance.

Bounds for Number Entrained

Two approaches were used for setting bounds on the number of striped bass and white perch PYSL entrained. The first approach was to compute alternative estimates for the number of PYSL entrained. The alternative estimates were based on interpolated estimates of distribution patterns of PYSL, and an ETM-like model to assess the fraction of the riverwide population that was entrained. The second approach was to set extreme bounds under the assumption that all *Morone* PYSL observed in the discharge canal samples were either one species or the other (i.e., assume that all *Morone* PYSL were striped bass or that all *Morone* PYSL were white perch).

In the first approach, the estimated total number of *Morone* PYSL entrained was apportioned to the two species. The proportion of the total number of *Morone* PYSL entrained that was striped bass was estimated in 3 steps. First, the fraction of the riverwide population of striped bass PYSL that was entrained was estimated using part of the ETM and interpolated distribution pattern data:

$$FE_{SB\ t} = \sum_{k=1}^{12} d_{S'B\ k\ t} \frac{V_{plnt\ k\ t}}{V_k} \tag{18}$$

where

$FE_{SB\ t}$ = the fraction of the riverwide population of striped bass that was entrained in week t

$V_{plnt\ k\ t}$ = the volume of water withdrawn from region k, during week t, by plant *plnt*

V_k = the volume of region k

Next, the relative number of striped bass entrained ($RNE_{SB\ t}$) was computed as the product of the fraction entrained and the proportion of the riverwide abundance of *Morone* PYSL that were striped bass:

$$RNE_{SB\ t} = FE_{SB\ t}\ x\ \bar{p}_{SB\ t} \tag{19}$$

Similar calculations were performed for white perch:

$$FE_{WP\ t} = \sum_{k=1}^{12} d'_{WP\ k\ t} \frac{V_{plnt\ k\ t}}{V_k} \tag{20}$$

and

$$RNE_{WP\ t} = FE_{WP\ t}\ x \left(1 - \bar{p}_{SB\ t} \right) \tag{21}$$

For each species, the proportion of the total number of *Morone* PYSL entrained was then estimated as the ratio of the relative number entrained for the species divided by the sum of the relative numbers entrained:

$$PE_{SB\ t} = \frac{RNE_{SB\ t}}{RNE_{SB\ t} + RNE_{WP\ t}} \tag{22}$$

and

$$PE_{WP\ t} = \frac{RNE_{WP\ t}}{RNE_{SB\ t} + RNE_{WP\ t}} \tag{23}$$

The alternative estimates for the number entrained for each species ($\widetilde{NE}'_{SB\ t}$ and $\widetilde{NE}'_{WP\ t}$) were defined as:

$$\widetilde{NE}'_{SB\ t} = PE_{SB\ t}\ x\ NE'_{MOR\ t} \tag{24}$$

and

$$\widetilde{NE}'_{WP\ t} = PE_{WP\ t}\ x\ NE'_{MOR\ t} \tag{25}$$

where

$NE'_{MOR\ t}$ = the reported total number of *Morone* PYSL entrained in week *t*.

For the second approach, the extreme bounds for the number PYSL entrained were defined by assuming that all *Morone* PYSL in the entrainment samples were either one species or the other. That is either 100% of the entrained *Morone* PYSL were striped bass and 0% were white perch, or 0% were striped bass and 100% were white perch.

Bounds for Relative Probability of Capture (RPC)

Estimates of the relative probability of capture that were used in the DEIS were based on field data collected during a special study at Indian Point (Ref.). Separate, length-specific estimates of RPC were computed for striped bass and white perch based on laboratory identification of collected *Morone* larvae. Therefore, this parameter (RPC) could be affected by mis-identification of *Morone* PYSL.

Bounds based on alternate estimates as well as extreme bounds for RPC were defined for the sensitivity analyses. The extreme bounds were defined by assuming that all *Morone* PYSL from the RPC studies were mis-identified—all larvae reported to be striped bass were actually white perch and visa versa. Accordingly the extreme bounds for RPC values for striped bass were defined to be the reported white perch RPC values, and the extreme bounds for white perch RPC values were defined to be the reported striped bass RPC values.

Alternate estimates of RPC for each length class were computed using *Morone* PYSL data (not identified to species) from the RPC field study at Indian Point. The alternate estimates were computed using the same method as described in the DEIS for computing the species-specific estimates of RPC (Coastal, 1991).

In the RPC field study, ichthyoplankton in the withdrawal zone of Indian Point was sampled with the same gear used in annual Long River Ichthyoplankton sampling program. Paired with each sample taken in the withdrawal zone was a sample taken in the plant discharge canal. The discharge sample was collected with the same gear used for the discharge sampling program which produced data for estimating numbers entrained. Each withdrawal zone sample and paired discharge sample were timed so that both sampling devices sampled the same parcel of water. The ratio of the density of ichthyoplankton observed in the discharge sample to the density of ichthyoplankton observed in the withdrawal zone sample was taken to be an estimate of the relative probability of capture.

The field data from each pair of samples were sorted into 2-mm length classes (i.e., 2.5-4.5mm, 4.5-6.5mm, etc.) and separate estimates of RPC were computed for each length class. Then the pair-specific estimates were averaged over all samples from the field study. A weighted arctangent average was used to compute the average in order to avoid problems with estimates of density in the withdrawal zone being equal to zero (the arctangent of any number divided by zero is 90 degrees). The total number of ichthyoplankton collected in the paired sample (i.e., the number collected in the withdrawal zone plus the number collected in the discharge canal) was used as the weighting factor.

The alternate estimates of relative probability of capture for each length class, l, were computed as:

$$\widetilde{RPC}_{MOR\ l} = \text{Tan}\left[\frac{\sum_i n_i \text{ ArcTan}\left(\frac{DEN_{MOR\ l,Di}}{DEN_{MOR\ l,Wi}}\right)}{\sum_i n_i}\right] \tag{26}$$

where

$DEN_{MOR\ l,Di}$ = the observed density of *Morone* larvae in the discharge sample from paired sample, i, that were in length class l.

$DEN_{MOR\ l,Wi}$ = the observed density of *Morone* larvae in the withdrawal zone sample from paired sample, i, that were in length class l.

n_i = the total number of *Morone* in length class, l, collected in paired sample i.

Bounds for Mechanical Mortality Rates

The mechanical mortality rate estimates reported in the DEIS were based on field studies involving the collection of ichthyoplankton in the power plant intakes and discharges (Ref.). Ichthyoplankton collected in each sample were held for 24 hours and the number of fish that were still alive was then recorded. Separate estimates of mechanical mortality rates were computed for striped bass and white perch based on laboratory identification of collected *Morone* larvae. Therefore, the estimates of mechanical mortality rate could be affected by mis-identification of *Morone* PYSL.

Bounds based on alternate estimates as well as extreme bounds for mechanical mortality rates were defined for the sensitivity analyses. The extreme bounds were defined by assuming that all *Morone* PYSL from the mechanical mortality rate studies were mis-identified. That is all PYSL reported to be striped bass were actually white perch and visa versa. Accordingly the extreme bound for the mechanical mortality rate for striped bass PYSL was defined to be the reported white perch PYSL mechanical mortality rate estimate, and the extreme bound for white perch PYSL was defined to be the reported striped bass PYSL mechanical mortality rate estimate.

The approach used for computing alternate estimates of mechanical mortality rates was the same as the approach used for alternate estimates of RPC. The alternate estimates of mechanical mortality rates were based on *Morone* PYSL data (not identified to species) from the mechanical mortality rate field studies. The alternate estimates were computed using the same method as described in the DEIS for computing the species-specific estimates of mechanical mortality rates.

For each plant and year in which mechanical mortality rate studies were conducted, an estimate of the mechanical mortality rate (m_m) for *Morone* PYSL was computed as:

$$m_m = 1 - \frac{S_D}{S_I} \tag{27}$$

where

S_D = the fraction of *Morone* PYSL ichthyoplankton collected in the discharge canal that were still alive 24 hours after sample collection

S_I = the fraction of *Morone* PYSL ichthyoplankton collected in the intake that were still alive 24 hours after sample collection

An overall estimate ($f_{MOR,ml}$) was then computed by calculating a weighted average of all year and plant specific estimates.

$$f_{MOR,ml} = \sum_i wt_i \quad m_{m\,i} \tag{28}$$

where the subscript, *i*, indicates a specific year and plant. The weighting factor for each year- and plant-specific estimate was the inverse of the variance for the estimate. The weighting factor (*wt*) was computed as:

$$wt = \left[\left(\frac{S_D}{S_I}\right)^2 \left(\frac{S_I\,(1 - S_I)}{n_I\ S_I^2}\right) \right]^{-1} \tag{29}$$

where

n_D = the total number of *Morone* PYSL collected in the discharge samples for the plant and year

n_I = the total number of *Morone* PYSL collected in the intake samples for the plant and year

Scenarios for Sensitivity Analyses

Methods for specifying bounds for the component parameters (i.e. riverwide abundance, numbers entrained, RPC, and mechanical mortality rate) of the CEMR model are described in the preceding sections. For each component parameter, three types of bounds were considered:

- Reported estimates (i.e., estimates based on *Morone* PYSL identified to species),
- Alternative estimates (i.e., estimates that did not require data on *Morone* PYSL identified to species), and
- Extreme bounds (i.e., bounds defined by assuming that all *Morone* PYSL were mis-identified, or that all *Morone* PYSL were striped bass, or that all *Morone* PYSL were white perch).

From this set of bounds for the component parameters, eight scenarios were selected for the sensitivity analyses. Each scenario consisted of one specified bound for each of the five component parameters that may have been affected by identification of *Morone* PYSL to species. For example, one scenario (labeled A1) was defined as follows:

- Alternative estimates for riverwide abundance of PYSL and juveniles (To simplify the analyses, the PYSL and juvenile riverwide abundance estimates were treated in the same manner in all selected scenarios. Either alternative estimates for riverwide abundances were used for both life-stages or the reported estimates were used for both life-stages),
- Reported estimates for number of PYSL entrained,
- Reported estimates for RPC, and
- Reported estimates for mechanical mortality rates.

Four of the scenarios (labeled A1-A4) were selected to assess the effect on CEMR of possible mis-identification in each component parameter separately. One scenario (labeled B1) was selected to assess the combined effect of possible mis-identification in all component parameters. For these five scenarios, the effect of possible mis-identification was addressed with the alternative estimates of the component parameters. In addition, two scenarios (labeled C1 and C2) were selected that were intended to consider the case of extreme bounds. The eighth scenario represented the methods used for the CEMR estimates reported in the DEIS (i.e., reported values used for all component parameters). Table 1 lists the eight scenarios for striped bass, and Table 2 the eight scenarios for white perch.

Table 1.—Summary table of scenarios included in sensitivity analyses of CEMR for striped bass.

Scenario	Riverwide Abundances of PYSL and Juveniles	Number of PYSL Entrained	Relative Probability of Capture	Mechanical Mortality Rate
A1	* $\tilde{N}'_{SB\,dl}$	$NE'_{SB\,dl}$	$RPC_{SB\,dl}$	$f_{SB,Ml}$
A2	$N'_{SB\,dl}$	* $\tilde{N}E'_{SB\,dl}$	$RPC_{SB\,dl}$	$f_{SB,Ml}$
A3	$N'_{SB\,dl}$	$NE'_{SB\,dl}$	* $RPC_{MOR\,dl}$	$f_{SB,Ml}$
A4	$N'_{SB\,dl}$	$NE'_{SB\,dl}$	$RPC_{SB\,dl}$	* $f_{MOR,Ml}$
B1	* $\tilde{N}'_{SB\,dl}$	$NE'_{SB\,dl}$	* $RPC_{MOR\,dl}$	* $f_{MOR,Ml}$
C1	* $\tilde{N}'_{SB\,dl}$	** 0	** $RPC_{WP\,dl}$	** $f_{WP,Ml}$
C2	* $\tilde{N}'_{SB\,dl}$	** $NE'_{MOR\,dl}$	** $RPC_{WP\,dl}$	** $f_{WP,Ml}$
DEIS	$N'_{SB\,dl}$	$NE'_{SB\,dl}$	$RPC_{SB\,dl}$	$f_{SB,Ml}$

* Alternate Estimate
** Extreme Bound

Table 2.—Summary table of scenarios included in sensitivity analyses of CEMR for white perch.

Scenario	Riverwide Abundances of PYSL and Juveniles	Number of PYSL Entrained	Relative Probability of Capture	Mechanical Mortality Rate
A1	$* \tilde{N}'_{WP\,dl}$	$NE'_{WP\,dl}$	$RPC_{WP\,dl}$	$f_{WP,Ml}$
A2	$N'_{WP\,dl}$	$* \tilde{N}E'_{WP\,dl}$	$RPC_{WP\,dl}$	$f_{WP,Ml}$
A3	$N'_{WP\,dl}$	$NE'_{WP\,dl}$	$* RPC_{MOR\,dl}$	$f_{WP,Ml}$
A4	$N'_{WP\,dl}$	$NE'_{WP\,dl}$	$RPC_{WP\,dl}$	$* f_{MOR,Ml}$
B1	$* \tilde{N}'_{WP\,dl}$	$* \tilde{N}E'_{WP\,dl}$	$* RPC_{MOR\,dl}$	$* f_{MOR,Ml}$
C1	$* \tilde{N}'_{WP\,dl}$	$** NE'_{MOR\,dl}$	$** RPC_{SB\,dl}$	$** f_{SB,Ml}$
C2	$* \tilde{N}'_{WP\,dl}$	** 0	$** RPC_{SB\,dl}$	$** f_{SB,Ml}$
DEIS	$N'_{WP\,dl}$	$NE'_{WP\,dl}$	$RPC_{WP\,dl}$	$f_{WP,Ml}$

* Alternate Estimate
** Extreme Bound

Results

CEMR Sensitivity Analyses

Separate estimates of conditional entrainment mortality rate for striped bass and white perch were computed for 1981 and each year from 1983 through 1987, and for each of the eight scenarios listed in Tables 1 and 2. Annual CEMR estimates for striped bass ranged from 0.06 to 0.25 for the DEIS scenario, with an average of 0.14 (Table 3). For white perch the annual estimates under the DEIS scenario ranged from 0.04 to 0.22 and had an average of 0.10 (Table 4).

The effect of alternate estimates of riverwide abundances of PYSL and juveniles was addressed with scenario A1. The range of annual CEMR estimates for striped bass under scenario A1 was 0.02 to 0.11 with an average of 0.07. For white perch, the range of annual estimates for scenario A1 was 0.05 to 0.31 with an average of 0.12.

The effect of alternate estimates of numbers of PYSL entrained was addressed with scenario A2. The range of annual CEMR estimates for striped bass under scenario A2 was 0.07 to 0.25 with an average of 0.15. For white perch, the range of annual estimates for scenario A2 was 0.03 to 0.22 with an average of 0.10.

The effect of alternate estimates of relative probability of capture (RPC) was addressed with scenario A3. The range of annual CEMR estimates for striped bass under scenario A3 was 0.08 to 0.32 with an average of 0.18. For white perch, the range of annual estimates for scenario A3 was 0.03 to 0.17 with an average of 0.08.

The effect of alternate estimates of mechanical mortality rates for PYSL was addressed with scenario A4. The range of annual CEMR estimates for striped bass under scenario A4 was 0.06 to 0.24 with an average of 0.13. For white perch, the range of annual estimates for scenario A4 was 0.02 to 0.12 with an average of 0.05.

The combined effect of alternate estimates for all four component parameters (i.e., riverwide abundance of PYSL and juveniles, numbers of PYSL entrained, RPC, and mechanical mortality rate) was addressed with scenario B1. The range of annual CEMR estimates for striped bass under scenario B1 was 0.04 to 0.15 with an average of 0.09. For white perch, the range of annual estimates for scenario B1 was 0.01 to 0.09 with an average of 0.05.

The combined effect of extreme estimates for three parameters (i.e., numbers entrained, RPC and mechanical mortality rate) and alternative estimates for riverwide abundances of PYSL and juveniles was addressed with scenarios C1 (all entrained PYSL assumed to be white perch) and C2 (all entrained PYSL assumed to be striped bass). The range of annual CEMR estimates for striped bass under scenario C1 was 0.00 to 0.05 with an average of 0.02. For white perch, the range of annual estimates for scenario C1 was 0.02 to 0.10 with an average of 0.06. The range of annual CEMR estimates for striped bass under scenario C2 was 0.08 to 0.41 with an average of 0.23. For white perch, the range of annual estimates for scenario C2 was 0.00 to 0.01 with an average of 0.01.

Intermediate Results

Alternate estimates of riverwide abundance were computed as an intermediate step of the CEMR calculations. The alternate estimates of riverwide abundance were computed without the use of *Morone* PYSL data keyed to species and therefore are not subject to errors due to possible mis-identification. These alternate estimates provide a means for assessing the magnitude of bias that may be present in reported annual estimates of abundance.

Indices of striped bass PYSL abundance and white perch PYSL abundance are reported in the DEIS. Each annual index is the sum of weekly, relative abundances (i.e., weekly, riverwide average densities) over the period of presence of the PYSL life stage. Alternate indices of abundance were computed using the alternate weekly abundance estimates for each species. The alternate indices of abundance were computed as:

$$\tilde{I}_{SB\ l\ y} = \sum_{d} \tilde{N}'_{SB\ d\ l\ y} \tag{30}$$

$$\tilde{I}_{WP\ l\ y} = \sum_{d} \tilde{N}'_{WP\ d\ l\ y} \tag{31}$$

The summation over days includes all days from the beginning of the 5% PYSL week to the end of the 95% PYSL week for each species. This summation is consistent with the method for selecting the period of weeks included in the indices of PYSL abundances that are reported elsewhere in the DEIS.

Table 5 presents alternate indices of PYSL abundance, for the period 1974 through 1995, for striped bass and white perch. Table 5 also includes the PYSL indices for striped bass and white perch indices that are reported in the DEIS. The Pearson's correlation coefficient between the two sets of indices is 0.95 for striped bass (Figure 3), and is equal to 0.84 for white perch (Figure 4).

In addition to the correlation (which measures the similarity in inter-annual patterns) between the reported DEIS indices of abundance and the alternate indices of abundance, the average ratio of annual abundance indices was computed. Because all indices are measured in the same units (proportionate to riverwide average density), the average ratio of abundance indices provides information on the relative bias each index has in relation to the other. For each species, a weighted arctangent average of the annual ratios was computed using the sum of the two index values as the weight (i.e. years with larger index values were given greater weight). The (weighted arctangent) average ratio of the alternate indices over the DEIS indices of PYSL abundance was equal to 1.26 for striped bass and equal to 0.84 for white perch.

The alternate RPC estimates for striped bass are lower than the reported striped bass RPC estimates for all length classes. For white perch, alternate estimates for some length classes are higher and for other length classes are lower than the reported RPC estimates. Table 6 lists the alternate RPC estimates (and the reported, species-specific estimates).

The alternate estimate for mechanical mortality rate is lower than both of the reported, species-specific mechanical mortality rates. Although the alternate estimate for mechanical mortality rate is based on pooled *Morone* PYSL data, it was computed as a ratio of ratios and therefore would not necessarily fall in between the species-specific estimates. The alternate mechanical mortality rate estimate is 0.273, and the reported, species-specific estimates are 0.287 for striped bass PYSL and 0.566 for white perch PYSL.

Table 3.—Results of sensitivity analyses of CEMR estimates for striped bass, annotated with a summary of scenario definitions

	Scenario							
Year	A1	A2	A3	A4	B1	C1	C2	DEIS
1981	0.04	0.07	0.08	0.06	0.07	0.02	0.12	0.06
1983	0.04	0.20	0.15	0.11	0.07	0.01	0.18	0.12
1984	0.09	0.14	0.25	0.18	0.07	0.02	0.36	0.19
1985	0.02	0.14	0.08	0.06	0.04	0.00	0.08	0.06
1986	0.11	0.25	0.32	0.24	0.15	0.03	0.41	0.25
1987	0.10	0.10	0.17	0.12	0.11	0.05	0.24	0.13
Average	0.07	0.15	0.18	0.13	0.09	0.02	0.23	0.14
Component	Scenario							
Parameters	A1	A2	A3	A4	B1	C1	C2	DEIS
Riverwide Abundance	*	❍	❍	❍	*	*	*	❍
Numbers Entrained	❍	*	❍	❍	*	**	**	❍
RPC	❍	❍	*	❍	*	**	**	❍
Mechanical Mortality Rate	❍	❍	❍	*	*	**	**	❍

* indicates Alternate Estimate
** indicates Extreme Bound
❍ indicates Reported

Table 4.—Results of sensitivity analyses of CEMR estimates for white perch, annotated with a summary of scenario definitions.

Year	Scenario							
	A1	A2	A3	A4	B1	C1	C2	DEIS
1981	0.09	0.04	0.07	0.04	0.03	0.10	0.01	0.07
1983	0.31	0.12	0.17	0.12	0.07	0.08	0.01	0.22
1984	0.13	0.22	0.10	0.07	0.09	0.04	0.00	0.13
1985	0.05	0.03	0.03	0.02	0.01	0.02	0.01	0.05
1986	0.09	0.08	0.07	0.04	0.04	0.05	0.00	0.08
1987	0.06	0.11	0.05	0.03	0.06	0.07	0.01	0.06
Average	0.12	0.10	0.08	0.05	0.05	0.06	0.01	0.10

Component Parameters	Scenario							
	A1	A2	A3	A4	B1	C1	C2	DEIS
Riverwide Abundance	*	O	O	O	*	*	*	O
Numbers Entrained	O	*	O	O	*	**	**	O
RPC	O	O	*	O	*	**	**	O
Mechanical Mortality Rate	O	O	O	*	*	**	**	O

* indicates Alternate Estimate
** indicates Extreme Bound
O indicates Reported

Table 5.—Alternate PYSL abundance indices (based on *Morone* PYSL data not identified to species) and PYSL abundance indices reported elsewhere in the DEIS.

Year	Striped Bass		White Perch	
	Alternate PYSL Index	Reported PYSL Index	Alternate PYSL Index	Reported PYSL Index
1974	0.45	0.42	0.44	0.46
1975	0.57	0.69	1.94	1.78
1976	1.52	0.26	1.10	2.21
1977	1.70	0.60	1.44	2.43
1978	2.02	0.54	2.19	3.44
1979	2.30	0.47	1.98	3.57
1980	0.90	0.83	2.93	2.95
1981	3.61	2.48	2.54	3.47
1982	3.55	0.82	3.32	5.76
1983	1.86	0.59	1.97	2.98
1984	1.07	0.87	2.67	2.75
1985	2.67	0.40	3.73	5.64
1986	2.17	0.72	6.80	8.11
1987	2.32	1.70	3.52	3.97
1988	1.69	1.48	2.81	2.90
1989	4.60	4.54	4.14	4.06
1990	6.39	5.64	2.38	2.92
1991	8.29	8.00	3.37	3.64
1992	7.72	6.38	3.57	4.92
1993	7.16	8.25	6.34	4.96
1994	8.20	8.45	4.65	4.11
1995	4.03	3.94	2.45	2.50

Table 6.—Alternate (based on *Morone* larvae not identified to species) estimates of relative probability of capture (RPC) and estimates reported elsewhere in the DEIS.

		Reported RPC Estimates	
Length Class	Alternate RPC Estimates	Striped Bass	White Perch
2.5 - 4.5 mm	0.13	0.76	0.09
4.5 - 6.5 mm	0.15	0.22	0.16
6.5 - 8.5 mm	0.24	0.33	0.24
8.5 - 10.5 mm	0.44	0.57	0.43
10.5 - 12.5 mm	0.81	0.98	0.77
12.5 - 14.5 mm	1.66	1.75	1.84
14.5 - 16.5 mm	2.70	2.72	3.24
16.5 - 18.5 mm	3.50	4.00	1.00*
18.5 - 20.5 mm	3.01	3.21	1.00*
20.5 - 22.5 mm	3.95	5.26	1.00*

* Data were insufficient to compute RPC estimates; RPC assumed to be 1.00.

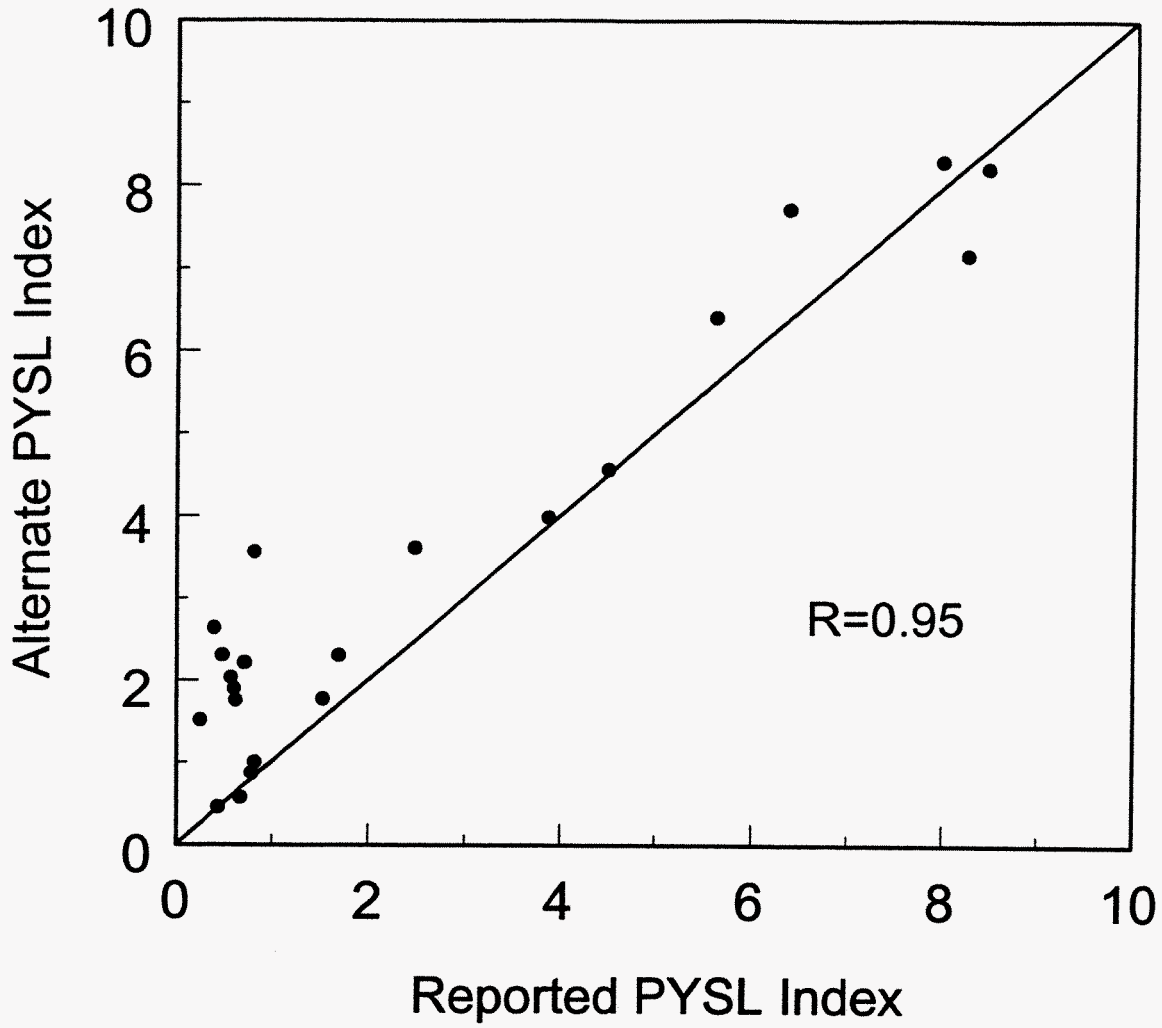


Figure 3.—Correlation between alternate striped bass PYSL index values and PYSL index values reported elsewhere in the DEIS.

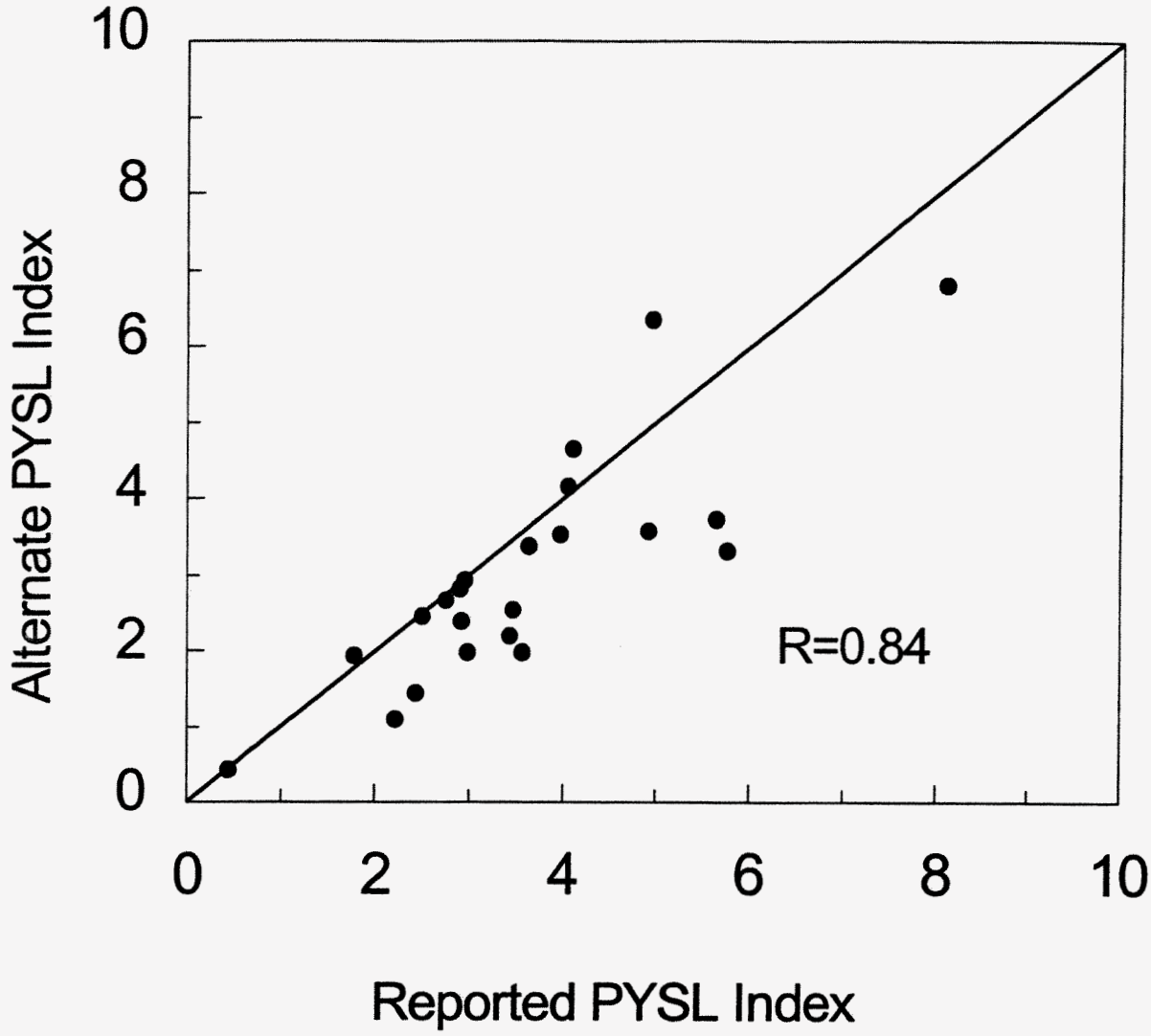


Figure 4.—Correlation between alternate white perch PYSL index values and PYSL index values reported elsewhere in the DEIS.

Discussion

CEMR Sensitivity Analyses

Estimates of CEMR from scenario A1 (effect of alternate estimates of riverwide abundance only) are consistently higher than the DEIS scenario estimates for white perch, and consistently lower than the DEIS estimates for striped bass. This indicates that the alternate estimates of riverwide abundance of striped bass are higher than the reported estimates, and the alternate estimates for white perch are lower than the reported estimates. Relative to the alternate abundance estimates (which may or may not be more accurate than the DEIS estimates), the reported riverwide abundance estimates for striped bass are low, and the reported riverwide abundance estimates for white perch are high.

At first glance this result may seem contrary to the findings of Houde et. al. (1991) and Schmidt (1993). They reported that a substantial fraction of PYSL (from the LRS) which were initially identified as striped bass were actually white perch. Yet, they reported relatively few white perch mis-identified as striped bass. This would suggest that the reported striped bass abundance estimates are too high, and the reported white perch estimates are too low.

However, the PYSL studied by Houde et. al. (1991) and Schmidt (1993) were larger PYSL (e.g. >8mm) that had sufficiently developed pterygiophores to allow species determination based on pterygiophore interdigitation. The larger PYSL represent a smaller proportion of the total PYSL population than the smaller PYSL due to the cumulative effects of mortality with increasing age (and size). Although a bias towards overestimating striped bass may have existed for the larger PYSL, it may be that a bias towards underestimating striped bass existed for the smaller PYSL (e.g. if smaller *Morone* PYSL were often classified as white perch, partially based on their smaller size). The net effect of two such sources of bias would be the pattern observed in the analyses of scenario A1.

There was not a consistent pattern in the results from the analyses of scenario A2. The CEMR estimates for striped bass are higher than the DEIS scenario estimates for some years and lower for others. As expected, for every year in which the striped bass CEMR estimate for scenario A2 is higher than the DEIS estimate, the scenario A2 estimate for white perch is lower than the DEIS white perch estimate. This is because the total number of *Morone* PYSL entrained was apportioned to the two species, so that when the numbers entrained for one species was set to a higher value, the numbers entrained for the other species had to be set to a lower value.

As expected, the striped bass CEMR estimates from scenario A3 are consistently higher than the DEIS estimates. This is because the alternate estimates of RPC are consistently lower than the reported RPC estimates for striped bass, and because the ratio of numbers entrained over riverwide abundance is divided by the RPC in CEMR calculations. The CEMR estimates from scenario A3 for white perch are lower than the DEIS estimates. This suggests that the length classes with higher alternate RPC estimates are the length classes contributing the most to CEMR.

The analysis of scenario A4 (the effect of alternate estimates of mechanical mortality

rates) also produced expected results. The CEMR estimates from scenario A4 for striped bass are slightly lower than the DEIS estimates, and the white perch estimates from scenario A4 are substantially lower than the DEIS estimates. This is because the alternate estimate of mechanical mortality rate for striped bass PYSL is similar to the reported estimate, whereas the alternate mechanical mortality rate for white perch is roughly one half the magnitude of the reported estimate.

The CEMR estimates for scenario B1 reflect the compounding effect of all four component parameters being set to alternative estimates. For striped bass, this compounding effect produced CEMR estimates that are consistently lower, albeit slightly lower, than the DEIS estimates. For white perch, the compounding effect produced substantially lower CEMR estimates in almost all years.

As expected, the CEMR estimates for scenario C1 for striped bass, and scenario C2 for white perch are much lower than the DEIS estimates . This is because scenario C1 assumed that all PYSL *Morone* entrained were white perch, and scenario C2 assumed that all PYSL *Morone* entrained were striped bass. Therefore, the only contributions to CEMR under these scenarios were from egg, YSL and juvenile life stages. The effect of the extreme bounds for numbers entrained overshadowed the effects that the bounds for any of the other component parameters had on the estimates.

The CEMR estimates for scenario C2 for striped bass are substantially higher than the DEIS estimates because all PYSL *Morone* entrained were assumed to be striped bass. The effect of this extreme bound for numbers entrained was coupled with the effect of the extreme bound for RPC (i.e., using the reported whiter perch RPC estimates which were lower than the reported striped bass RPC estimates). This combined effectoffset the opposite effects of the extreme bounds for mechanical mortality rate and of the alternate estimates for riverwide abundance (which would have lowered CEMR estimates). However, the CEMR estimates for scenario C1 for white perch (all *Morone* PYSL entrained assumed to be white perch) are lower than the DEIS estimates . This is because the effects of the extreme bound for mechanical mortality rate and the extreme bounds for RPC (i.e. the effect of lowering the CEMR estimate) are greater than the opposing effect of the extreme bounds for numbers entrained.

Indices of PYSL Abundance

The high correlations between the alternate PYSL abundance index values and the PYSL index values reported elsewhere in this DEIS, for both striped bass and white perch, are largely due to the wide range of index values in the historical record. If only the smaller index values from the earlier years were considered, the correlations would not be as high. Also, for some of the earlier years, the alternate PYSL index values are over 5 times as large as the reported PYSL index values.

This suggests that the reported PYSL index values in some individual years, from the early portion of the historical record, may not be reliable. Nevertheless, over the full period of record, the overall pattern of inter-annual variability is very similar for the alternate and reported PYSL indices, with much higher values exhibited in the later years.

In general, the alternate PYSL index values for striped bass are higher than the reported PYSL index values for striped bass. Consequently, the alternate white perch PYSL index values are generally lower than the reported values (because the sum represents the total *Morone* PYSL abundance). This suggests that, in relation to the alternate PYSL index values, the DEIS PYSL index values overstate the abundance of white perch and understate the abundance of striped bass. This pattern of relative bias is consistent with the CEMR sensitivity analysis results for scenario A1 discussed above, and could be reconciled with the findings of Houde, et. al. (1991) and Schmidt (1993) by considering the size classes of PYSL included in their analyses (as discussed above for scenario A1).

The degree of agreement between the alternate estimates and the DEIS estimates is greater in the later years than in the earlier years. This was the case for both the pattern of inter-annual variability and the magnitude of the annual index values (Table 5).

Conclusions

The CEMR estimates for striped bass and white perch that are reported elsewhere in this DEIS are very similar to alternate CEMR estimates that are not based on *Morone* PYSL data identified to species. Also, the CEMR estimates reported for striped bass fall within the range of estimates that were computed with the component parameters set to extreme bounds. The white perch CEMR estimates are higher or within the range of estimates computed with the component parameters set to extreme bounds.

These findings corroborate the range of CEMR values reported elsewhere in the DEIS and do not support the hypothesis that the reported CEMR estimates are severely biased due to the presence of misidentification of *Morone* PYSL.

Also, the alternate PYSL index values displayed a high degree of correlation with the reported PYSL index values. This suggests that for the purposes of characterizing long-term inter-annual variability and trends, the reported PYSL indices are useful measures.

References

Coastal Environmental Services, Inc. 1991. Assessment of the mitigative value of outages and flow reductions, Phase IV, Final Report, Volume 1. Prepared for Central Hudson Gas and Electric Corporation.

Heimbuch, D.G., D.J. Dunning and J.R. Young. 1992. Post-yolk-sac larvae abundance as an index of year class strength of striped bass in the Hudson River. In: Smith, C.L. (editor) Estuarine research in the 1980's: Hudson River Environmental Society, Seventh Symposium on Hudson River Ecology. State University of New York Press, Albany.

Houde, E.D., E.S. Rutherford and L.G. Moran. 1991. Otolith microstructure of Hudson River striped bass larvae. Contract Report to the Hudson River Foundation. [UMCEES]CBL 91-168.

Olney, J.E., G.C. Grant, F.E. Schultz, C.L. Cooper and J. Hageman. 1983. Pterygiophore-interdigitation patterns in larvae of four *Morone* species. Trans. Am. Fish. Soc. 112:525-531.

Schmidt, R.E. 1993. Identification of Hudson River *Morone* larvae. Report to the Hudson River Foundation.

APPENDIX VI-1-D-1

ESTIMATED NUMBER OF FISH KILLED DUE TO ENTRAINMENT

Table 1. Total number killed by entrainment based on in-plant sampling at Roseton 1 & 2 during 1981-1987

American Shad

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1		2.48E+03	8.80E+04	2.84E+04	2.98E+03	2.75E+03	9.67E+03	1.34E+05
2		9.48E+04	1.72E+05	2.52E+06	4.56E+04			2.83E+06
3	1.84E+06	1.32E+06	2.33E+06	6.51E+06	8.95E+05	6.81E+05	3.71E+05	1.39E+07
4	4.99E+04	1.12E+05	1.66E+05		9.99E+04	1.23E+05		5.51E+05
Grand Total	1.89E+06	1.53E+06	2.75E+06	9.05E+06	1.04E+06	8.06E+05	3.81E+05	1.75E+07

Bay Anchovy

Sum of Number Entrained	Year				
Lifestage	1981	1982	1985	1986	Grand Total
3	5.09E+05		1.80E+06	3.14E+06	5.45E+06
4	1.09E+06	1.02E+06			2.11E+06
Grand Total	1.60E+06	1.02E+06	1.80E+06	3.14E+06	7.57E+06

River Herring

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1	1.47E+07	8.43E+06	1.56E+07	4.37E+06	7.54E+06	1.00E+07	2.10E+06	6.27E+07
2	2.80E+06	6.87E+06	1.06E+07	5.89E+07	8.81E+06	1.02E+06	1.06E+05	8.91E+07
3	3.68E+08	2.15E+08	4.12E+08	4.57E+08	8.92E+07	1.36E+08	1.04E+08	1.78E+09
4	2.66E+06	5.27E+05	2.00E+06	4.42E+04	2.38E+05	4.46E+05		5.92E+06
Grand Total	3.89E+08	2.31E+08	4.40E+08	5.20E+08	1.06E+08	1.48E+08	1.06E+08	1.94E+09

Striped Bass

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1		2.77E+05	1.73E+05	2.19E+05	1.55E+05	1.64E+05	4.59E+06	5.57E+06
2	3.66E+06	1.79E+07	2.49E+06	2.62E+06	2.30E+06	2.98E+07	7.37E+07	1.33E+08
3	4.75E+06	2.14E+07	7.17E+06	1.09E+07	1.18E+07	1.14E+07	7.69E+07	1.44E+08
4	3.04E+05	3.32E+04	4.32E+04	3.22E+04	2.28E+04	1.14E+04		4.47E+05
Grand Total	8.72E+06	3.97E+07	9.88E+06	1.38E+07	1.43E+07	4.14E+07	1.55E+08	2.83E+08

White Perch

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1	1.27E+07	2.06E+07	2.63E+07	1.30E+07	2.99E+07	3.61E+07	2.54E+07	1.64E+08
2	4.72E+06	2.81E+07	4.38E+07	3.08E+07	1.57E+07	5.50E+07	3.68E+07	2.15E+08
3	3.25E+07	9.75E+07	5.79E+07	5.50E+07	1.12E+08	8.51E+07	8.79E+07	5.28E+08
4	9.29E+05	6.21E+05	3.86E+05	4.91E+04	1.06E+05	8.80E+05		2.97E+06
Grand Total	5.09E+07	1.47E+08	1.28E+08	9.89E+07	1.58E+08	1.77E+08	1.50E+08	9.10E+08

Life Stages: 1 = eggs; 2 = yolk-sac larvae; 3 = post yolk-sac larvae; 4 = juveniles

Table 2. Total number killed by entrainment based on in-plant sampling at Indian Point 2 & 3 during 1981-1987

American Shad

Sum of Number Entrained	Year					
Lifestage	1981	1983	1984	1985	1986	Grand Total
1		3.75E+04	6.49E+04	1.70E+04		1.19E+05
2	3.30E+06	1.51E+06	9.87E+05			5.80E+06
3	3.81E+05	5.60E+05	4.57E+07		1.86E+05	4.69E+07
4	2.19E+05	1.05E+05	4.19E+03		1.00E+05	4.28E+05
Grand Total	3.90E+06	2.21E+06	4.68E+07	1.70E+04	2.86E+05	5.32E+07

Bay Anchovy

Sum of Number Entrained	Year						
Lifestage	1981	1983	1984	1985	1986	1987	Grand Total
1	1.17E+08	7.55E+06	4.43E+07	8.74E+07	3.22E+07	2.13E+07	3.10E+08
2	1.77E+07		1.40E+08			2.38E+06	1.60E+08
3	2.51E+08	6.87E+07	7.57E+08	1.09E+08	9.38E+07	2.03E+08	1.48E+09
4	1.34E+06	1.34E+06	7.87E+05	9.92E+04	5.03E+05	1.73E+06	5.79E+06
Grand Total	3.87E+08	7.76E+07	9.42E+08	1.97E+08	1.26E+08	2.29E+08	1.96E+09

River Herring

Sum of Number Entrained	Year						
Lifestage	1981	1983	1984	1985	1986	1987	Grand Total
1	7.16E+04	2.46E+05	7.87E+05	8.42E+05	4.95E+03	4.17E+03	1.96E+06
2		7.32E+06	7.35E+08				7.42E+08
3	8.72E+07	4.27E+08	8.47E+08	1.23E+06	1.16E+08	1.66E+06	1.48E+09
4	9.45E+05	8.57E+05	1.25E+05		1.23E+05		2.05E+06
Grand Total	8.83E+07	4.36E+08	1.58E+09	2.07E+06	1.16E+08	1.67E+06	2.23E+09

Striped Bass

Sum of Number Entrained	Year						
Lifestage	1981	1983	1984	1985	1986	1987	Grand Total
1	2.08E+05	6.92E+04	1.11E+06	7.55E+04	4.21E+04	1.37E+04	1.52E+06
2	1.32E+07	3.94E+06	4.48E+06	1.28E+06	4.90E+06	4.50E+04	2.79E+07
3	5.11E+07	2.63E+07	5.46E+07	1.93E+07	7.18E+07	2.52E+07	2.48E+08
4	9.09E+05	1.60E+05	1.24E+05	2.80E+04	6.23E+04	3.17E+05	1.60E+06
Grand Total	6.55E+07	3.05E+07	6.03E+07	2.07E+07	7.68E+07	2.56E+07	2.79E+08

White Perch

Sum of Number Entrained	Year						
Lifestage	1981	1983	1984	1985	1986	1987	Grand Total
1	8.37E+05	4.84E+06	2.33E+06	1.29E+05	6.24E+03	9.35E+04	8.24E+06
2	7.18E+06	6.36E+06	9.38E+06	1.13E+06	2.31E+06	2.26E+05	2.66E+07
3	1.76E+08	2.40E+08	2.01E+08	3.49E+07	1.29E+08	1.21E+07	7.93E+08
4	3.20E+06	3.73E+05	1.35E+05	4.53E+04	5.05E+05	4.31E+04	4.31E+06
Grand Total	1.88E+08	2.52E+08	2.13E+08	3.62E+07	1.31E+08	1.25E+07	8.32E+08

Life Stages: 1 = eggs; 2 = yolk-sac larvae; 3 = post yolk-sac larvae; 4 = juveniles

Table 3. Total number killed by entrainment based on in-plant sampling at Bowline Point 1 & 2 during 1981-1987

American Shad

Sum of Number Entrained	Year						
Lifestage	1981	1982	1983	1984	1986	1987	Grand Total
1		1.20E+05					1.20E+05
3	4.13E+04	8.68E+05	5.48E+04	3.94E+05	1.32E+04	2.21E+04	1.39E+06
4	7.88E+04	2.76E+04	2.95E+04		1.55E+04	2.92E+04	1.81E+05
Grand Total	1.20E+05	1.02E+06	8.43E+04	3.94E+05	2.87E+04	5.13E+04	1.69E+06

Bay Anchovy

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1			3.25E+04	1.73E+05	3.82E+06	1.30E+05	8.05E+05	4.96E+06
2			8.59E+04			3.33E+05	4.25E+04	4.61E+05
3	5.21E+07	2.21E+05	2.38E+07	2.88E+08	3.07E+07	4.66E+07	9.46E+07	5.36E+08
4	1.35E+06	5.20E+04	1.14E+06	2.18E+06	7.17E+05	2.08E+05	7.78E+05	6.42E+06
Grand Total	5.35E+07	2.73E+05	2.51E+07	2.90E+08	3.52E+07	4.73E+07	9.62E+07	5.48E+08

River Herring

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1	3.91E+04	1.12E+04	1.80E+04	1.47E+05	1.09E+04	1.23E+04		2.38E+05
2			2.33E+04		2.64E+05			2.87E+05
3	2.02E+06	6.78E+06	2.44E+07	4.25E+07	4.00E+04	8.64E+05	1.52E+05	7.67E+07
4	1.39E+05	3.49E+04	7.69E+04	1.45E+04		4.51E+04	5.46E+03	3.16E+05
Grand Total	2.20E+06	6.82E+06	2.45E+07	4.27E+07	3.15E+05	9.21E+05	1.57E+05	7.76E+07

Striped Bass

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1			1.53E+03	2.17E+04	2.01E+03		1.02E+03	2.62E+04
2	1.92E+05	1.69E+06	1.26E+06	5.11E+05	2.50E+04	5.35E+06	2.44E+04	9.05E+06
3	3.36E+06	1.16E+06	1.78E+06	4.27E+06	3.28E+05	9.64E+06	2.32E+06	2.29E+07
4	1.32E+05	8.69E+04	1.17E+05	3.60E+04		3.18E+04	3.10E+05	7.13E+05
Grand Total	3.69E+06	2.94E+06	3.16E+06	4.84E+06	3.55E+05	1.50E+07	2.65E+06	3.27E+07

White Perch

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1	1.36E+06	3.73E+06	3.84E+06	3.75E+06	1.90E+05	1.67E+05	1.12E+03	1.30E+07
2		6.95E+04	9.03E+05	6.97E+05	2.87E+05	4.52E+05		2.41E+06
3	8.76E+06	3.63E+06	1.15E+07	1.01E+07	7.26E+05	5.56E+06	1.71E+05	4.05E+07
4	2.50E+05	4.95E+04	5.84E+04	1.14E+04	4.72E+04	6.70E+04	2.46E+04	5.08E+05
Grand Total	1.04E+07	7.48E+06	1.63E+07	1.46E+07	1.25E+06	6.25E+06	1.96E+05	5.65E+07

Life Stages: 1 = eggs; 2 = yolk-sac larvae; 3 = post yolk-sac larvae; 4 = juveniles

APPENDIX VI-1-D-2

ESTIMATED TOTAL NUMBER OF FISH ENTRAINED

Table 1. Total numbers entrained based on in-plant abundance sampling at Roseton 1 & 2 during 1981-1987.

American Shad

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1		2.48E+03	8.80E+04	2.84E+04	2.98E+03	2.75E+03	9.67E+03	1.34E+05
2		1.19E+05	2.17E+05	3.17E+06	5.75E+04			3.56E+06
3	2.32E+06	1.67E+06	2.92E+06	8.19E+06	1.13E+06	8.57E+05	4.67E+05	1.76E+07
4	5.92E+04	1.37E+05	1.74E+05		1.24E+05	1.53E+05		6.47E+05
Grand Total	2.38E+06	1.93E+06	3.40E+06	1.14E+07	1.31E+06	1.01E+06	4.77E+05	2.19E+07

Bay Anchovy

Sum of Number Entrained	Year				
Lifestage	1981	1982	1985	1986	Grand Total
3	5.09E+05		1.80E+06	3.14E+06	5.45E+06
4	1.09E+06	1.02E+06			2.11E+06
Grand Total	1.60E+06	1.02E+06	1.80E+06	3.14E+06	7.57E+06

River Herring

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1	1.47E+07	8.43E+06	1.56E+07	4.37E+06	7.54E+06	1.00E+07	2.10E+06	6.27E+07
2	3.53E+06	8.66E+06	1.34E+07	7.42E+07	1.11E+07	1.29E+06	1.33E+05	1.12E+08
3	4.64E+08	2.71E+08	5.18E+08	5.76E+08	1.12E+08	1.71E+08	1.31E+08	2.24E+09
4	3.03E+06	6.30E+05	2.05E+06	5.31E+04	2.94E+05	5.49E+05		6.60E+06
Grand Total	4.85E+08	2.89E+08	5.49E+08	6.54E+08	1.31E+08	1.83E+08	1.33E+08	2.42E+09

Striped Bass

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1		2.77E+05	1.73E+05	2.19E+05	1.55E+05	1.64E+05	4.59E+06	5.57E+06
2	1.37E+07	6.63E+07	8.53E+06	9.31E+06	8.64E+06	9.60E+07	2.77E+08	4.80E+08
3	1.66E+07	7.47E+07	2.50E+07	3.76E+07	4.11E+07	3.97E+07	2.68E+08	5.03E+08
4	1.20E+06	1.31E+05	1.70E+05	1.27E+05	8.99E+04	4.48E+04		1.76E+06
Grand Total	3.15E+07	1.41E+08	3.39E+07	4.73E+07	5.00E+07	1.36E+08	5.50E+08	9.90E+08

White Perch

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1	1.27E+07	2.06E+07	2.63E+07	1.30E+07	2.99E+07	3.61E+07	2.54E+07	1.64E+08
2	8.35E+06	4.97E+07	7.75E+07	5.44E+07	2.78E+07	9.72E+07	6.50E+07	3.80E+08
3	5.74E+07	1.72E+08	1.02E+08	9.69E+07	1.98E+08	1.50E+08	1.55E+08	9.33E+08
4	2.00E+06	1.34E+06	8.31E+05	1.06E+05	2.28E+05	1.90E+06		6.40E+06
Grand Total	8.05E+07	2.44E+08	2.07E+08	1.64E+08	2.56E+08	2.85E+08	2.46E+08	1.48E+09

Life Stages: 1 = eggs; 2 = yolk-sac larvae; 3 = post yolk-sac larvae; 4 = juveniles

Table 2. Total numbers entrained based on in-plant abundance sampling at Indian Point 2 & 3 during 1981-1987.

American Shad

Sum of Number Entrained	Year					
Lifestage	1981	1983	1984	1985	1986	Grand Total
1		3.75E+04	6.49E+04	1.70E+04		1.19E+05
2	4.15E+06	1.90E+06	1.24E+06			7.30E+06
3	4.63E+05	7.04E+05	5.76E+07		2.33E+05	5.90E+07
4	2.19E+05	1.18E+05	4.19E+03		1.24E+05	4.65E+05
Grand Total	4.83E+06	2.76E+06	5.89E+07	1.70E+04	3.57E+05	6.69E+07

Bay Anchovy

Sum of Number Entrained	Year						
Lifestage	1.98E+03	1.98E+03	1.98E+03	1.99E+03	1.99E+03	1.99E+03	Grand Total
1.00E+00	1.17E+08	7.55E+06	4.43E+07	8.74E+07	3.22E+07	2.13E+07	3.10E+08
2.00E+00	1.77E+07		1.40E+08			2.38E+06	1.60E+08
3.00E+00	2.51E+08	6.87E+07	7.57E+08	1.09E+08	9.38E+07	2.03E+08	1.48E+09
4.00E+00	1.34E+06	1.34E+06	7.87E+05	9.92E+04	5.03E+05	1.73E+06	5.79E+06
Grand Total	3.87E+08	7.76E+07	9.42E+08	1.97E+08	1.26E+08	2.29E+08	1.96E+09

River Herring

Sum of Number Entrained	Year						
Lifestage	1981	1983	1984	1985	1986	1987	Grand Total
1	7.16E+04	2.46E+05	7.87E+05	8.42E+05	4.95E+03	4.17E+03	1.96E+06
2		9.22E+06	9.26E+08				9.35E+08
3	1.09E+08	5.37E+08	1.07E+09	1.38E+06	1.46E+08	2.04E+06	1.86E+09
4	9.45E+05	8.65E+05	1.31E+05		1.42E+05		2.08E+06
Grand Total	1.10E+08	5.47E+08	1.99E+09	2.23E+06	1.46E+08	2.05E+06	2.80E+09

Striped Bass

Sum of Number Entrained	Year						
Lifestage	1981	1983	1984	1985	1986	1987	Grand Total
1	2.08E+05	6.92E+04	1.11E+06	7.55E+04	4.21E+04	1.37E+04	1.52E+06
2	4.50E+07	1.18E+07	1.31E+07	3.04E+06	1.68E+07	1.26E+05	9.00E+07
3	1.72E+08	9.16E+07	1.85E+08	6.70E+07	2.50E+08	8.44E+07	8.50E+08
4	3.58E+06	6.26E+05	4.88E+05	1.10E+05	2.45E+05	1.18E+06	6.23E+06
Grand Total	2.21E+08	1.04E+08	2.00E+08	7.02E+07	2.67E+08	8.58E+07	9.48E+08

White Perch

Sum of Number Entrained	Year						
Lifestage	1981	1983	1984	1985	1986	1987	Grand Total
1	8.37E+05	4.84E+06	2.33E+06	1.29E+05	6.24E+03	9.35E+04	8.24E+06
2	1.27E+07	1.12E+07	1.66E+07	2.00E+06	4.08E+06	3.99E+05	4.70E+07
3	3.10E+08	4.24E+08	3.55E+08	6.17E+07	2.27E+08	2.07E+07	1.40E+09
4	6.91E+06	8.03E+05	2.91E+05	9.76E+04	1.09E+06	9.29E+04	9.28E+06
Grand Total	3.31E+08	4.41E+08	3.74E+08	6.39E+07	2.32E+08	2.12E+07	1.46E+09

Life Stages: 1 = eggs; 2 = yolk-sac larvae; 3 = post yolk-sac larvae; 4 = juveniles

Table 3. Total numbers entrained based on in-plant abundance sampling at Bowline Point 1 & 2 during 1981-1987.

American Shad

Sum of Number Entrained	Year						
Lifestage	1981	1982	1983	1984	1986	1987	Grand Total
1		1.20E+05					1.20E+05
3	5.16E+04	1.09E+06	6.73E+04	4.96E+05	1.66E+04	2.78E+04	1.75E+06
4	8.87E+04	3.47E+04	3.15E+04		1.91E+04	3.68E+04	2.11E+05
Grand Total	1.40E+05	1.25E+06	9.88E+04	4.96E+05	3.57E+04	6.46E+04	2.08E+06

Bay Anchovy

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1			3.25E+04	1.73E+05	3.85E+06	1.30E+05	8.05E+05	4.99E+06
2			3.48E+05			3.33E+05	4.25E+04	7.23E+05
3	5.21E+07	2.21E+05	4.16E+07	2.88E+08	3.21E+07	4.66E+07	9.46E+07	5.55E+08
4	1.35E+06	5.20E+04	1.14E+06	2.18E+06	7.17E+05	2.08E+05	7.78E+05	6.42E+06
Grand Total	5.35E+07	2.73E+05	4.32E+07	2.90E+08	3.67E+07	4.73E+07	9.62E+07	5.67E+08

River Herring

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1	3.91E+04	1.12E+04	1.80E+04	1.73E+05	1.42E+04	1.23E+04		2.68E+05
2			2.93E+04		3.32E+05			3.61E+05
3	2.54E+06	8.54E+06	2.97E+07	5.36E+07	5.03E+04	1.09E+06	1.91E+05	9.57E+07
4	1.47E+05	3.70E+04	7.95E+04	1.50E+04		5.68E+04	6.88E+03	3.43E+05
Grand Total	2.73E+06	8.58E+06	2.98E+07	5.38E+07	3.97E+05	1.16E+06	1.98E+05	9.67E+07

Striped Bass

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1			1.53E+03	2.43E+04	2.01E+03		1.02E+03	2.88E+04
2	5.46E+05	6.25E+06	2.84E+06	1.57E+06	6.77E+04	1.42E+07	9.17E+04	2.56E+07
3	1.17E+07	4.04E+06	6.26E+06	1.57E+07	1.15E+06	3.36E+07	8.08E+06	8.06E+07
4	5.20E+05	3.42E+05	4.78E+05	1.42E+05		1.25E+05	1.22E+06	2.83E+06
Grand Total	1.28E+07	1.06E+07	9.58E+06	1.74E+07	1.22E+06	4.79E+07	9.39E+06	1.09E+08

White Perch

Sum of Number Entrained	Year							
Lifestage	1981	1982	1983	1984	1985	1986	1987	Grand Total
1	1.36E+06	3.73E+06	3.84E+06	4.10E+06	1.98E+05	1.67E+05	1.12E+03	1.34E+07
2		1.23E+05	1.60E+06	1.28E+06	5.07E+05	7.98E+05		4.31E+06
3	1.55E+07	6.41E+06	2.04E+07	2.02E+07	1.29E+06	9.83E+06	3.02E+05	7.40E+07
4	5.38E+05	1.07E+05	1.42E+05	2.45E+04	1.02E+05	1.44E+05	5.29E+04	1.11E+06
Grand Total	1.74E+07	1.04E+07	2.60E+07	2.56E+07	2.10E+06	1.09E+07	3.56E+05	9.28E+07

Life Stages: 1 = eggs; 2 = yolk-sac larvae; 3 = post yolk-sac larvae; 4 = juveniles

Appendix VI-2-A

Impingement Process and Sampling

APPENDIX VI-2-A

IMPINGEMENT PROCESS AND SAMPLING

A.. Description of the Process

To keep condensers from clogging with solid materials and biota, power plant cooling water intake systems use a combination of large- and finer-mesh screens. Typically, the large-mesh screens or bar racks are fixed in place while the finer-mesh screens can move to facilitate cleaning. The movable screens are called traveling screens. As the water passes through these screens, organisms larger than the mesh openings, juvenile and in some instances adult fish, can be pressed (impinged) against the screens. The number impinged relative to those entrained is a function of the mesh size on the traveling screens. Various screenwash systems are employed for periodically removing impinged fish from the screens and either disposing of them or returning them to the water body from which they came.

Some impinged fish die immediately (short-term mortality), some at a later time (latent or long-term mortality). The actual cause of mortality in impinged fish seems to be 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. 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.

The survival rate for impinged fish also depends on several other plant-related factors, such as intake velocity, plant design, and operating conditions. To a large degree, impingement survival is species specific, and also varies with size and season. Soft-bodied fish such as alewives, which possess easily lost scales, generally suffer higher impingement mortality than do hardier fish such as hogchokers.

B. Data to Estimate Impingement Effects

Sampling programs and studies concerned with the aquatic effects of impingement have been conducted at the Roseton, Indian Point, and Bowline Point generating stations. The following section provides a brief overview of studies at each plant.

Roseton

An ongoing impingement monitoring program was initiated at the Roseton Generating Station in 1973. Studies at Roseton have monitored species composition, total numbers, and total weight of fish and invertebrates impinged on the traveling screens of both units. Length frequency distributions, seasonal and diel abundance patterns, and long-term trends in impingement have been conducted for selected species. Plant operating conditions such as circulating pump operation, flow rates, and screenwash operation during sampling were

recorded. Details of annual impingement monitoring programs are found in the series of reports listed in Appendix V-1.

Studies at Roseton have also evaluated impingement mitigation and post-impingement survival. Studies conducted from 1975 through 1977 (EA 1979) were designed to estimate the survival rates of impinged fish under various screenwash and plant operating conditions during different seasons of the year.

Section VII-B-1 provides a detailed description of the conventional and dual-flow traveling screens operated at the Roseton Generating Station.

Indian Point

Impingement sampling at the Indian Point Generating Station began in June 1972. Sampling was conducted at Unit 1, Unit 2, and occasionally at Unit 3. Full sampling did not occur at Unit 3 until it began commercial operation in 1976. The monitoring program at Indian Point has concentrated on quantifying the species of fish impinged at both the traveling and/or fixed screens at each unit. Impingement data included total count and weight of species impinged, water quality and plant operating conditions (circulating pump operation, flow rates, and screenwash operation). In 1983 crabs were also included in the annual monitoring program. Further details of impingement studies are described in the annual reports listed in Appendix V-1.

Impingement sampling procedures have remained similar to those of early sampling programs. In July 1981 a seasonally stratified sampling scheme was initiated to reduce monitoring to 110 sampling days. Sampling days were reduced further in October 1990 with the adoption of a weekly sampling schedule (EA 1991). Studies were interrupted following the installation of modified Ristroph screens at both units in 1991 and 1992 until the installations, including the fish return system and any refinements desired by the parties to the 1980 Settlement, have been completed. A description of the Ristroph screen systems is provided in Section VII-B-2.

Bowline Point

Impingement sampling was initiated at the Bowline Point Generating Station in December 1972. This continuing program has monitored species composition, total numbers, and total weights of fish impinged at both units. Length frequency distributions, seasonal and diel abundance patterns, and long-term trends in impingement have also been examined for select species and age classes.

Special studies at Bowline Point have included impingement mitigation, estimates of initial and long- term postimpingement survival, and screen collection efficiency studies. A series of postimpingement survival studies was conducted at Bowline Point between 1975 and 1981 (EA 1979, 1982). Survival studies investigated both initial and extended survival of selected species and life stages after exposure to impingement. Impingement mitigation studies were conducted at Bowline Point during 1976 and 1977 (LMS 1978). The

effectiveness of a barrier net to reduce impingement was evaluated during the winter and spring months, historically higher periods of impingement at Bowline Point compared to the remainder of the year (LMS 1978). A detailed description and results of the barrier net installation are reported in Section IV.

C.. Qualitative Description of Impingement Effects

As discussed above, sampling for impingement abundance has been conducted at the Roseton, Indian Point, and Bowline Point stations for 26, 20, and 25 years, respectively. The number of species identified in these sampling efforts was 64 at Roseton, 88 at Indian Point, and 65 at Bowline Point. However, for most of these species the numbers caught were relatively small, and some represented incidental catches. The species lists shown in Table 1 indicate that 95% of the catch at the three stations discussed here was composed of nine species. These and certain other species were selected by DEC for more analysis.

D. Quantitative Description of Impingement Effects

Quantitative estimates of impingement losses were developed using the Conditional Impingement Mortality Rate (CIMR) model that is very similar to the Empirical Impingement Model (EIM) used in prior studies. The CIMR (described in Appendix VI-2) uses monthly estimates of numbers of fish lost due to impingement in conjunction with estimates of the river population during the same time period to estimate the fraction of the population lost due to impingement. The river population estimates for each month are derived from sampling data, estimates of gear efficiency, and estimated survival rates as determined from the literature or catch curve data. Conditional impingement mortality rates expected under the utilities' operating plan were estimated as they were for entrainment, discussed previously. Details of the modeling approach and results for each year appear in Appendix VI-2-B.

TABLE 1 (Page 1 of 3)

SPECIES COMPOSITION OF IMPINGEMENT ABUNDANCE SAMPLES AT ROSETON, BOWLINE, AND INDIAN POINT GENERATING STATIONS, 1981 - 1990

TAXON	BOWLINE %	ROSETON %	INDIAN POINT %
White perch	59.09	33.91	74.01
Striped bass	17.41	0.92	3.63
Blueback herring	2.86	34.12	3.83
Alewife	2.10	4.01	0.32
Atlantic tomcod	1.24	0.88	5.97
Hogchoker	3.50	1.26	2.51
Rainbow smelt	3.88	0.52	0.20
American shad	0.68	2.44	0.73
Bluefish	0.65	<0.01	0.20
Bay anchovy	2.15	14.92	5.14
Weakfish	1.00	<0.01	1.00
Threespine stickleback	1.78	<0.01	0.04
White catfish	<0.01	<0.01	0.42
Tessellated darter	<0.01	<0.01	0.02
American eel	<0.01	<0.01	0.14
Spottail shiner	<0.01	2.49	0.18
Pumpkinseed	<0.01	1.75	0.37
Gizzard shad	0.61	1.92	0.66
Atlantic menhaden	<0.01	<0.01	0.06
Mummichog	<0.01	<0.01	<0.01
Banded killifish	1.00	<0.01	0.10
Northern pipefish	<0.01	<0.01	0.05
Goldfish	<0.01	<0.01	0.05
Crevalle jack	<0.01	<0.01	0.01
Brown bullhead	<0.01	<0.01	0.02
Atlantic silverside	<0.01	<0.01	<0.01
Bluegill	<0.01	<0.01	0.08
Golden shiner	<0.01	<0.01	0.01
Redbreast sunfish	<0.01	<0.01	0.01
Atlantic sturgeon	<0.01	<0.01	<0.01
Yellow perch	<0.01	<0.01	0.04
Carp	<0.01	<0.01	<0.01
Atlantic needlefish	<0.01	<0.01	<0.01
Black crappie	<0.01	<0.01	<0.01
Tautog	<0.01	—	<0.01
Largemouth bass	<0.01	<0.01	0.01
Sa lamprey	<0.01	<0.01	<0.01
Shortnose sturgeon	—	<0.01	<0.01
Summer flounder	<0.01	<0.01	0.01
White crappie	—	<0.01	<0.01
White flounder	<0.01	—	<0.01

TABLE 1 (Page 2 of 3)

SPECIES COMPOSITION OF IMPINGEMENT ABUNDANCE SAMPLES AT ROSETON, BOWLINE, AND INDIAN POINT GENERATING STATIONS, 1981 - 1990

TAXON	BOWLINE %	ROSETON %	INDIAN POINT %
Red hake squirrel	<0.01	—	0.02
Rock bass	—	<0.01	<0.01
Spot	<0.01	—	<0.01
Tidewater silverside	<0.01	—	<0.01
Fourspine stickleback	<0.01	<0.01	<0.01
Whit bass	—	<0.01	<0.01
White sucker	—	<0.01	<0.01
Silvery minnow	—	<0.01	<0.01
Rough silverside	<0.01	—	<0.01
Warmouth	<0.01	—	<0.01
Central mudminnow	—	<0.01	<0.01
Lookdown	<0.01	—	0.01
Silver hake	<0.01	—	0.01
Butterfish	<0.01	—	0.05
Striped searobin	<0.01	<0.01	0.05
Atlantic croaker	<0.01	—	<0.01
Eastern mudminnow	—	<0.01	<0.01
Grubby	<0.01	—	<0.01
Windowpane flounder	<0.01	—	0.01
Chain pickerel	<0.01	<0.01	<0.01
Hickory shad	<0.01	<0.01	<0.01
Spotfin butterflyfish	<0.01	—	<0.01
Redfin pickerel	<0.01	<0.01	<0.01
Striped mullet	<0.01	—	<0.01
Atlantic moonfish	<0.01	—	<0.01
Lined seahorse	<0.01	—	<0.01
Naked goby	<0.01	—	<0.01
Spotted hake	<0.01	—	0.01
American sand lance	<0.01	—	<0.01
Longnose dace	<0.01	—	<0.01
Bluntnose minnow	<0.01	<0.01	<0.01
Black bullhead	—	<0.01	<0.01
Channel catfish	—	<0.01	<0.01
Creek chub	—	<0.01	<0.01
Fathead minnow	—	<0.01	<0.01
Freshwater drum	—	<0.01	<0.01
Kokanee	—	<0.01	<0.01
Longnose gar	—	<0.01	<0.01
Smallmouth bass	—	<0.01	<0.01
White mullet	—	<0.01	<0.01
Yellow bullhead	—	<0.01	<0.01

TABLE 1 (Page 3 of 3)

SPECIES COMPOSITION OF IMPINGEMENT ABUNDANCE SAMPLES AT
ROSETON, BOWLINE, AND INDIAN POINT GENERATING STATIONS, 1981 - 1990

TAXON	BOWLINE %	ROSETON %	INDIAN POINT %
Winter flounder	—	—	<0.01
Northern searobin	—	—	<0.01
Northern stargazer	—	—	<0.01
Gray snapper	—	—	<0.01
Margined madtom	—	—	<0.01
Sharptail goby	—	—	<0.01
Four-bearded rockling	—	—	<0.01
Northern puffer	—	—	<0.01
Inshore lizardfish	—	—	<0.01
King mackeral	—	—	<0.01
Seahorse	—	—	<0.01
Striped cuskeel	—	—	<0.01
Scup	—	—	<0.01
Inland silverside	—	—	<0.01
Longear sunfish	—	—	<0.01
Fourspot flounder	—	—	<0.01
Black sea bass	—	—	<0.01
Cunner	—	—	<0.01
Satinfin shiner	—	—	<0.01
Smallmouth flounder	—	—	<0.01
Atlantic mackeral	—	—	<0.01
Big eye scad	—	—	<0.01
Emerald shiner	—	—	<0.01
Longhorn sculpin	—	—	<0.01
Striped burrfish	—	—	<0.01
Logperch	—	—	<0.01
Northern pike	—	—	<0.01
Oyster toadfish	—	—	<0.01
Silver lamprey	—	—	<0.01
Atlantic cutlassfish	—	—	<0.01
Common shiner	—	—	<0.01
Conger eel	—	—	<0.01
Freckled blenny	—	—	<0.01
Green sunfish	—	—	<0.01
Mackeral scad	—	—	<0.01
Pigfish	—	—	<0.01
Planehead filefish	—	—	<0.01
Rock gunnel	—	—	<0.01
Silver perch	—	—	<0.01

Note: Some individuals could only be identified to genus and species, and were not included in the percent composition. These unidentified species represent less than one percent of the total.

Appendix VI-2-B

Methods for Estimating Conditional Impingement Mortality Rates

Methods for Estimating Conditional Impingement Mortality Rates

Overview and Approach

The conditional impingement mortality rate (CIMR) is the fractional reduction in abundance of a cohort at the end of a period of impingement vulnerability due to impingement:

$$CIMR = \frac{N_{end} - N^{*}_{end}}{N_{end}} \tag{1}$$

where,

N_{end} = cohort abundance at the end of the period in the absence of impingement mortality, and

N^{*}_{end} = cohort abundance at the end of the period in the presence of impingement mortality.

Empirical estimates of abundance under both conditions (i.e., with and without impingement mortality) cannot be obtained because both conditions cannot occur concurrently. Therefore, the formulation above, equation (1), cannot be used as the basis for estimating CIMR. An alternative formulation for CIMR, on which CIMR estimates can be based, is required. The alternative formulation defines CIMR in terms of instantaneous rates:

$$CIMR = 1 - \frac{N_0 \prod_{month=0}^{t} \exp[-IIR_{month} - M_{month}]}{N_0 \prod_{month=0}^{t} \exp[-M_{month}]}$$

$$= 1 - \prod_{month=0}^{t} \exp[-IIR_{month}] \tag{2}$$

where

N_0 = cohort abundance at the beginning of the period,

IIR_{month} = instantaneous impingement mortality rate (per month) in the specified month, and

M_{month} = instantaneous natural mortality rate (per month) in the specified month.

Month-specific values for IIR can be estimated from riverwide abundance estimates and estimates of numbers of fish that die from impingement. The ratio of the number of fish (from a cohort) that die from impingement during a month to the average abundance of the cohort during a month is the IIR for the month. By definition (e.g., Ricker 1975), the number that die (during a specified period) from a source of mortality

is the product of the average abundance during the period and the instantaneous mortality rate:

$$I_{month} = IIR_{month} \times \overline{N}_{month}$$

where

I_{month} = number (of the cohort) that die from impingement during the month, and
$\overline{N}_{month}$ = average abundance of the cohort during the month.

Therefore,

$$IIR_{month} = \frac{I_{month}}{\overline{N}_{month}}. \tag{3}$$

The estimator for CIMR is based on combining equations (2) and (3) as follows:

$$\hat{CIMR} = 1 - \prod_{month=0}^{t} \exp\left[-\frac{\hat{I}_{month}}{\hat{\overline{N}}_{month}}\right].$$

Riverwide Abundance Estimates

As noted above, estimates of abundance are needed for each annual cohort for each month during which the cohort is vulnerable to impingement. For each taxon and cohort, the month-specific abundance estimates are based on assumed survival rates from the juvenile stage to the last age of impingement vulnerability and on an estimate of juvenile abundance:

$$\hat{\overline{N}}_T = \frac{\hat{N}_T(1-\exp[-z_T])}{z_T}$$

$$\hat{N}_T = \hat{N}_J \prod_{t=J}^{T-1} S_t, \tag{4}$$

where

$\hat{\overline{N}}_T$ = estimate of the average abundance during month T, which corresponds to the age of the fish in months;
$\hat{N}_T$ = estimate of abundance at the beginning of month T;
$z_T = -\ln[S_T]$;
$\hat{N}_J$ = estimate of juvenile abundance at the beginning of month J (generally September); and
S_t = survival fraction from the beginning of month t to the end of month t.

Values for the survival fractions that are used in the CIMR calculations are summarized in Table 1 along with the source of information.

Two types of juvenile abundance estimates are used, depending on the availability of data for each taxon. For striped bass and Atlantic tomcod, the juvenile abundance estimates are based on mark-recapture estimates of age-1 and age-2 fish. The juvenile abundance estimates for these species are computed using a modification to equation (4):

$$\hat{N}_J = \frac{\hat{N}_R}{\prod_{t=J}^{R-1} S_t},$$

where

$\hat{N}_R$ = mark-recapture estimate of abundance at the beginning of month R.

For all other species, a combined standing crop estimate of juvenile abundance is used. The combined standing crop estimates are based on catch-per-unit-effort (CPUE) data from the Utilities' Fall Shoals and Beach Seine Programs. The CPUE data are scaled-up by the ratio of the volume of the river to the average volume swept per sample as described in the 1985 Year Class Report (Versar 1987). The combined standing crop estimates are also adjusted to account for gear efficiencies being less than 100%. Using this approach, the average juvenile abundance ($\overline{N}_J$) over weeks 33 through 40 (8 weeks) is estimated as

$$\overline{N}_J = \frac{1}{8}\sum_{wk=33}^{40}\left[\frac{\overline{CPUE}_{BS,wk} \times V_{BS}}{Q_{BS}} + \frac{\overline{CPUE}_{FSB,wk} \times V_{FSB}}{Q_{FSB}} + \frac{\overline{CPUE}_{FSC,wk} \times V_{FSC}}{Q_{FSC}}\right] \quad (5)$$

where

$\overline{CPUE}_{BS,wk}$ = riverwide average CPUE for the shore zone (sampled by the Beach Seine Survey) in week wk,

$\overline{CPUE}_{FSB,wk}$ = riverwide average CPUE for the Fall Shoals program bottom stratum (sampled by the beam trawl) in week wk,

$\overline{CPUE}_{FSC,wk}$ = riverwide average CPUE for the Fall Shoals program channel stratum (sampled by the tucker trawl) in week wk,

V_{BS} = riverwide volume of the shore zone,

V_{FSB} = riverwide volume of the bottom stratum (including the shoals stratum sampled by the beam trawl),

V_{FSC} = riverwide volume of the channel stratum,

Q_{BS} = assumed gear efficiency (probability of capture for the shore zone) of the beach seine,

Q_{FSB} = assumed gear efficiency of the beam trawl, and

Q_{FSC} = assumed gear efficiency of the tucker trawl.

Region and stratum volumes for the river were taken from Table II-12 of the 1985 Year Class Report (Versar 1987). Assumed gear efficiencies for the beam trawl, Tucker trawl and beach seine are discussed in the following section.

The juvenile abundance at the beginning of September was derived from the average abundance using the following relationships:

$$\hat{N}_J = \hat{N}_{35} = \left(\frac{z \times \overline{N}_J}{1 - \exp[-z]} \right) \times \left(\prod_{wk=33}^{34} S_{wk} \right) \tag{6}$$

where

$\hat{N}_{35}$ = juvenile abundance at the beginning of week 35 (1st week of September),

S_{wk} = survival fraction from the beginning to the end of week *wk*, and

$z = -\ln\left[\prod_{wk=33}^{40} S_{wk} \right]$.

Gear Efficiency Assumptions

Gear efficiency assumptions for the epibenthic sled and beam trawl are based on the following considerations:

1. The average ratio of catch rates (epibenthic sled to beam trawl) from gear efficiency studies conducted in 1980, 1983 and 1984 studies as reported by NAI in 1986 is 0.17:1 (see Table 2);

2. NAI (1984) reported that the high-rise 6.2-m trawl has nearly 2 m of vertical lift in comparison to the beam trawl with 1 m of lift. Accordingly, the ratio of catches in terms of volumetric density between the beam trawl and 6.2-m trawl would be 0.7:1 (0.35 x 2);

3. Kjelson and Colby (1977) reported the catch efficiency of a 6.1-m otter trawl (night sampling) to be 23% for juvenile pinfish and 16% for juvenile spot (an average of 19.5%); and

4. Loesch et al. (1976) reported the catch efficiency of a 4.9-m otter trawl to be 25% for Atlantic croaker and 6% for spot (an average of 16%).

For these analyses, the gear efficiency of the 3-m beam trawl is assumed to be similar to that reported by Loesch et al. of the 4.9-m otter trawl, i.e., 16%. A similar value can be derived from the gear efficiency of the 6.1-m otter trawl reported by Kjelson and Colby (1977). Assuming the 6.2-m high-rise trawl had an efficiency similar to the 6.1-m otter trawl, then the efficiency of the beam trawl would be roughly 14% (i.e., 0.7 x 0.195). Based on these observations, the beam trawl gear efficiency is assumed to be approximately 15%.

The gear efficiency of the epibenthic sled is derived from the assumed gear efficiency of the beam trawl and the ratio of catch rates between the epibenthic sled and beam trawl. Based on this approach the assumed gear efficiency for the epibenthic sled is 2.7% (i.e., 0.17 x 0.15). The 1-m Tucker trawl (which has the same net dimensions as the 1-m epibenthic sled) is assumed to have the same gear efficiency as the 1-m epibenthic sled.

The probability of capture for the beach seine is derived from abundance estimates of YOY striped bass. The approach has 4 steps:

1. Estimation of the riverwide abundance of YOY striped bass from the estimate of age-1 abundance from the Utilities' mark-recapture program and age-specific mortality rates (see Figure 1);

2. Estimation of the abundance of YOY within the channel, bottom and shoal strata of the river using the assumed gear efficiencies described above and CPUE data from the Utilities' Fall Shoals program;

3. Estimation of the fraction of the riverwide YOY abundance that is within the channel, bottom (and shoal) strata, and assume that the remaining fraction inhabits the shore zone; and

4. Derivation of the probability of capture for the beach seine within the shore zone as the ratio of

    a. the unadjusted shore zone abundance estimate from the beach seine survey (i.e., the average CPH divided by the fraction of the shore zone sampled by one haul), to

    b. the riverwide YOY abundance estimate times the estimated fraction inhabiting the shore zone.

Application of the methods described above to data for the 1985 through 1994 year classes of striped bass produced an estimate of probability of capture for the beach seine of 4%. All scale-up factors (1/Q) for gear efficiency and probability of capture are summarized in Table 3.

Estimates of Numbers that Die from Impingement

The estimated number that died due to impingement was calculated as the product of the estimated number impinged and the screen mortality rate.

Estimates of Numbers Impinged

For Indian Point, impingement data from 1980-1990 were obtained from Con Edison in computer files consisting of numbers impinged in impingement samples, length frequency information of numbers impinged, and length divisions for allocation to age classes. For white perch, American shad, and striped bass at Indian Point, estimates of the monthly number impinged by age were calculated from these data. For the other species, estimates of numbers impinged were only calculated by life stages (YOY, yearling, adult).

For Roseton, Danskammer, Lovett, Bowline Point, and Albany Steam, impingement data were obtained from impingement reports (see Literature Cited). For most species, the reports provided estimates of the monthly number impinged by life stage. For some species and years, only the monthly number collected (not by life stage) in impingement samples was provided. In these instances, the monthly number impinged by life stage was estimated using the sampled length frequencies, and the length divisions from the Indian Point data. If a length frequency for a particular species and month was not available, a length frequency from a proximate plant was used. If no length frequency distribution was available, the average length frequency distribution for that species, month and plant from all years of available data was used.

Estimates of numbers impinged were not available for all plants in all months and years. The availability of estimates of numbers impinged at each of the facilities is summarized in Table 4. Due to the very limited number of years with impingement estimates for Albany Steam, and the requirement for multiple years of estimates for taxa impinged over multiple ages, CIMR estimates were not calculated for this facility.

If an estimate of the number impinged was not available for a month in a particular year, but estimates were available for other years for that plant and month, the following substitution rule was used. The estimated monthly impingement mortality rate (IIR_{month}) for each available year was divided by the plant withdrawal volume for that month and year to give an estimated impingement-rate-per-unit-volume. These impingement-rates-per-unit-volume were averaged over all years of available data (for that plant). The average impingement-rate-per-unit-volume then was multiplied by the withdrawal volume in the month and year with the missing estimate of numbers impinged. The resulting value was used as the estimated impingement mortality rate for the month. If estimates of numbers impinged were not available in any year for a particular month and plant, the average impingement-rate-per-unit-volume, over all available months and years (for that plant), was used.

Monthly data on withdrawal volumes for Roseton, Lovett, Danskammer, Bowline Point, and Albany Steam were obtained from annual impingement reports (see Literature Cited). Flow data for Indian Point were in computer files provided by Con Edison.

Screen Mortality Rate

Background.—The Utilities have monitored impingement mortality at Hudson River power plants through the use of survival studies. These studies are similar to standard toxicological studies in that the stressed organisms are held and observed, and mortality is observed at set time intervals. Observation periods were of various lengths up to 96 hours.

Fletcher (1990) reported 8-hr mortality rates for fish impinged on Ristroph screens at Indian Point. Ristroph screens are designed to reduce impingement mortality. For the period before installation of Ristroph screens at Indian Point, the impingement mortality rate was assumed to be 100%, a conservative (worst-case) assumption. For the period after installation of the screens (January 1991 through 1997 for Unit 3 and July 1991 through 1997 for Unit 2), impingement mortality rates (Table 5) were taken from Fletcher's (1990) Table 4 (cumulative dead and injured) except for American shad and spottail shiner, for which no data were reported. The inpingement mortality rate for American shad was taken from Fletcher's Table 6 (opportunistic field collections, screen version 2), the rate for spottail shiner was estimated as the average rate of all species on his Table 4.

To order to have a comparable basis for expressing mortality at all Hudson River plants, the operators of Roseton, Danskammer Point, Bowline Point and Lovett Generating Stations directed that impingement mortality be estimated at 8 hours for all species at these plants. These plants have conventional screens rather than Ristroph screens, and so mortality estimates are not compatible with estimates made at Indian Point: Because the effects on fish survival from conventional and Ristroph screens may be different, mortality rates from Indian Point can not be used to predict mortality at the other plants, and data from the other plants can not be used to predict mortality at Indian Point. Therefore, 8-hr mortality rate was estimated separately for the plants with conventional screens. For Albany Steam Station, which is not one of the plants considered in the DEIS and for which no impingement mortality data were available, the impingement mortality rate was assumed to be 100% for all species in all years.

Where 8-hr mortality is directly available from study data for the plants with conventional screens, estimates were made from the data. The only experimental data now available for some plants and species are the initial mortality and cumulative mortality at 96 hours. In order to predict mortality at any other time, the shape of the time-response curve must be known. The following method was developed to estimate 8-hr mortality from three pieces of information: the initial mortality at a plant of interest, the 96-hr mortality at that plant, and time-response curves for the species and life stage at another plant.

In standard toxicological experiments, the stress is applied continuously, usually as a dose, and the gradual accumulation of the stressor induces the response (e.g., mortality). Because the experiment begins at $t = 0$, initial mortality is usually zero. In impingement studies, the stress occurs at time zero and then is removed, often resulting in initial mortality M_0. As a result, cumulative mortality (time-response) curves for impingement (Figure 2) differ from standard toxicological time-response curves. The following approach was takes this difference into account.

Methods.— The approach to characterizing the shape of the time-response curve is to transform it into relative units (Figure 3) such that the initial mortality (M_0 at $t = 0$ hrs) and the 96-hr mortality (M_{96} at $t = 96$ hrs) are assigned values of 0 and 1.0, respectively. The time-response curve in transformed units is represented by

$$\frac{M_t - M_0}{M_{96} - M_0} \text{ vs. } t.$$

Shape parameters are then estimated from the transformed curve.

One form of curve that appears to fit the data well is

$$\frac{M_t - M_0}{M_{96} - M_0} = \frac{t}{a + bt}, \tag{7}$$

where a and b are shaping parameters. This equation is structurally similar to the Beverton-Holt stock-recruitment relationship (Ricker 1975). When $t = 0$, both sides of the equation (7) equal 0.

At $t = 96$ hours, equation (1) becomes

$$1 = \frac{96}{a + 96 \cdot b} \tag{8}$$

from which

$$a = 96 \cdot (1 - b). \tag{9}$$

Substituting into equation (9) into equation (7) yields

$$\frac{M_t - M_0}{M_{96} - M_0} = \frac{t}{96 \cdot (1 - b) + b \cdot t}, \tag{10}$$

which is a one-parameter model that that can be used to describe the cumulative impingement mortality curves. Equation (10) can be rearranged as

$$\hat{b} = \frac{\left[t \cdot \frac{(M_{96} - M_0)}{(M_t - M_0)} - 96 \right]}{(t - 96)}, \tag{11}$$

from which a separate estimate $\hat{b}$ for the same curve can be calculated from each observation of cumulative mortality rate at each time t. Then the $\hat{b}$ estimates for the curve can be averaged and used to predict the 8-hr mortality, M_8, by rearranging equation (10) as

$$M_t = M_0 + t \cdot \left[\frac{M_{96} - M_0}{96 \cdot (1 - b) + b \cdot t} \right]. \tag{12}$$

Time-response impingement mortality data to estimate $\hat{b}$ values were available from studies conducted at Roseton Generating Station in 1990 and 1994 (LMS 1991c, NAI 1995). Mortality or survival was reported at 0, 2.5, 8, 12, 24, 48, and 96 hrs (Table 6). Mortality data for studies with a total of less than 30 fish were excluded from the present analyses. Fish recorded as "stunned " at 96 hrs were considered dead. The 1990 studies were performed separately for both the conventional and dual-flow screens. This distinction was retained throughout the analysis, so that separate estimate of $\hat{b}$ were made for the two screen types. The 1994 studies at Roseton assessed mortality only from dual-flow screens (Table 7).

Initial and 96-hr mortality only were available from studies at Bowline Point (EAI 1982a) and Danskammer Point (EAI 1982b) Generating Stations (Tables 8 and 9). At Bowline Point, mortality was reported for "river herring," a designation that did not occur in the time-response studies at Roseton. Mortality of river herring at each time t was calculated as the weighted average of mortality for alewife and blueback herring, with number of fish in the experiment as the weighting factor. Experiments from different time periods were reported from Bowline Point, and so multiple mortality data could be available for each species and life stage. Where multiple data were available, the 96-hr mortality for any species and life stage was calculated as a weighted average across periods using number of fish in each period as the weighting factor. To predict the 8-hr mortality rate at Bowline Point and Daskammer Point, only values of $\hat{b}$ calculated from studies of conventional screens at Roseton were used.

For Roseton, 8-hr mortality rates were estimated directly from the observations of mortality at $t = 8$ hrs. Estimates are a weighted average of observed mortality rates with a weight of 6 (the number of conventional screens) or 2 (the number of dual-flow screens) for results from conventional and dual-flow screens, respectively.

Results.—Values of the shaping parameter $\hat{b}$ for the nine species of concern are shown in Table 10. R-square values for the fit of the impingement mortality predicted by the model show that the fit is typically very good (Table 11). R-squared values do not include initial mortality and mortality at 96 hrs, which are fixed points in the model. The poor fits (including one case of a negative R^2) typically correspond to cases in which the initial mortality is very high and for which an 8-hr mortality rate equal to 100% would be a reasonable approximation.

After the 8-hr mortality rate analysis, combinations of plants, species, and life stages still existed for which there were no estimated 8-mortality rates. For example, there are no rates for Lovett for any species. Choosing substitution mortality rates is somewhat complicated by the fact that some tests were done by life stage and or season, while in other tests life stages or seasons were not differentiated. The following summarizes substitutions:

(1) There are complete data for Roseton, and no substitutions were made.

(2a) For any species at Danskammer for which there is a missing mortality rate for at least one life stage and season and for which there is at least one mortality rate measured for that species at Danskammer, the highest Danskammer mortality rate for any season for that species and life stage was substituted for the missing life stage and season. For white perch yearlings and adults during March and summer, the maximum of "yearling and older" rates from immediately previous and following seasons was applied.

(2b) For any species at Danskammer for which there was no mortality rate after applying (2a), the mortality rate at Roseton was applied.

(3a) For any species at Bowline Point for which there was a missing mortality rate for any life stage and for which there was at least one mortality rate measured for that species at Bowline, the highest Bowline mortality rate for that species was substituted for the missing life stages for that species. Data from Bowline studies are not differentiated by season.

(3b) For any species at Bowline Point for which there was no mortality rate after applying (3a), the highest mortality rate across all plants (not including Indian Point) was substituted for that species.

(4) For all species, life stages, and seasons at Lovett, values for Bowline Point were substituted.

Estimated and predicted impingement mortality rates for Bowline Point, Danskammer Point, and Roseton Generating Stations are shown in Tables 12, 13, and 14, respectively.

CIMR Estimates

For each taxon, two sets of CIMR estimates are produced. The first set represents the cumulative CIMR for an annual cohort from the juvenile life stage through the last age of impingement vulnerability (Tables 15 through 22). These results are presented for each plant and for the combined effects of the plants (i.e., riverwide). The second set (Tables 23 through 30) represents the annual riverwide CIMRs, by age class, that were used to compute the cumulative CIMRs for annual cohorts.

For both types of CIMR estimates, the availability of data limited the number of years for which CIMR estimates could be computed. The striped bass mark-recapture program produced abundance estimates only for the 1984 through 1996 cohorts, the Atlantic tomcod mark-recapture program produced abundance estimates only for the 1986 through 1994 cohorts, and riverwide abundance estimates based on bottom sampling with the beam trawl are available only from 1985 through 1997.

In addition to the year-specific data availability noted above, the number of cohorts for which cumulative CIMR estimates could be computed depends on the maximum age of impingement vulnerability. For example, for bay anchovy, which are vulnerable to impingement through age 2, cumulative CIMR estimates could be computed for the 1985 through 1995 cohorts. Whereas for white perch, which are vulnerable to impingement through age 8, cumulative CIMR estimates could be computed only for the 1985 through 1990 cohorts.

Literature Cited

EAI (Ecological Analysts, Inc.). 1982a. Bowline Point Generating Station Entrainment Abundance and Impingement Survival Studies: 1981 Annual Report. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

EAI (Ecological Analysts, Inc.). 1982b. Estimate of Impingement Mortality for Selected Fish Species at the Danskammer Point Generating Station, 1975-1980. Prepared for Central Hudson Gas and Electric Corporation, Poughkeepsie, New York.

EA (Ecological Analysts, Inc.). 1985 Roseton and Damskammer Point Generating Station Impingement Monitoring Program: 1984 Annual Report. Prepared for Central Hudson Gas & Electric, New York, New York.

EA (Ecological Analysts, Inc.). 1986 Roseton and Damskammer Point Generating Station Impingement Monitoring Program: 1985 Annual Report. Prepared for Central Hudson Gas & Electric, New York, New York.

Fletcher, R.I. 1990. Flow dynamics and fish recovery experiments: Water intake systems. Transactions of the American Fisheries Society 119:393-415.

Houde, E.D., and C.E. Zastrow. 1991. Bay anchovy *Anchoa mitchilli.* Pages 8-1 to 8-14 *in* S.L. Funderburk, J.A. Mihursky, S.J. Jordan, and D. Riley (eds.), Habitat Requirements for Chesapeake Bay Living resources, Second Edition. Chesapeake Research Consortium, Inc., Solomons, Maryland.

Kjelson, M.A., and D.R. Colby. 1977. The evaluation and use of gear efficiencies in the estimation of estuarine fish abundance. *In* M. Wiley (ed.) Estuarine Processes, Vol. II, Circulation, Sediments, and Transfer of Material in the Estuary, p. 416-424, Academic Press, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1981. 1980 Hudson River Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1982a. 1981 Impingement Abundance Sampling at Roseton and Danskammer Point Generating Station: Annual Progress Report. Prepared for Central Hudson Gas & Electric, New York, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1982b. 1981 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1982c. 1981 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1983a. White Perch *(Morone americans):* A Synthesis of Information on Natural History, with Reference to Occurrence in the Delaware River and Estuary Involvement with the Salem Nuclear Generating Station. Prepared for Public Service Gas and Electric Company, Newark, New Jersey.

LMS (Lawler, Matusky & Skelly Engineers). 1983b. 1982 Impingement Abundance Sampling at Roseton and Danskammer Point Generating Station: Annual Progress Report. Prepared for Central Hudson Gas & Electric. New York, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1983c. 1982 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1983d. 1982 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities. Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1984a. Albany Steam Generating Station SPDES Aquatic Monitoring Program (October 1982 - September 1983). Prepared for Niagara Mohawk Power Corporation. Syracuse, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1984b. 1983 Impingement Monitoring Program at Roseton and Danskammer Point Generating Station: Annual Progress Report. Prepared for Central Hudson Gas & Electric, New York, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1984c. 1983 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1984d. 1983 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1985a. Albany Steam Generating Station SPDES Aquatic Monitoring Program (April 1984 - April 1985). Prepared for Niagara Mohawk Power Corporation, Syracuse, New York.

LMS (Lawler, Matusky & Skelly Erigineers). 1985b. 1984 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1985c. 1984 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1986a. Hudson River Estuary White Perch Adult and Subadult Stock Assessment Study: Fall 1985. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1986b. 1985 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1986c. 1985 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1987a. Impingement Monitoring Program at the Roseton and Danskammer Point Generating Station. 1986 Annual Report, Prepared for Central Hudson Gas & Electric. New York, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1987b. 1986 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1987c. 1986 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1988a. Impingement Monitoring Program at the Roseton and Danskammer Point Generating Station. 1987 Annual Progress Report. Prepared for Central Hudson Gas & Electric, New York, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1988b. 1987 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1988c. 1987 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1989. Impingement Monitoring Program at the Roseton and Danskammer Point Generating Station. 1988 Annual Progress Report. Prepared for Central Hudson Gas & Electric, New York, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1989. 1988 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1989. 1988 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1990a. Impingement Monitoring Program at the Roseton and Danskammer Point Generating Station: 1989 Annual Progress Report. Prepared for Central Hudson Gas & Electric, New York, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1990b. 1989 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1990c. 1989 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1991a. 1990 Impingement Studies at the Bowline Point Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1991b. 1990 Impingement Studies at the Lovett Generating Station. Prepared for Orange and Rockland Utilities, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1991c. Intake Debris Screen Postimpingement Survival Study: Roseton Generating Station 1990. Prepared for Central Hudson Gas & Electric Corporation, Poughkeepsie, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1994. Impingement Monitoring Program at the Roseton and Danskammer Point Generating Stations:1992 Annual Progress Report. Prepared for Central Hudson Gas & Electric, New York, New York.

Loesch, H., J. Bishop, A. Crowe, R. Kuckyr, and P. Wagner. 1976. Technique for estimating trawl efficiency in catching brown shrimp (*Penaeus aztecus*), Atlantic croaker (*Micropogon undulatus*), and spot (*Leiostomus xanthurus*). Gulf Research Reports 2:29-33.

McLaren, J.B., T.H. Peck., W.P. Dey, and M. Gardinier. 1988. Biology of Atlantic tomcod in the Hudson River Estuary. American Fisheries Society Monograph 4: 102-112.

NAI (Normandeau Associates, Inc.). 1982. Optimum Deployment and Relative Catch Efficiency of a 3 m Beam Trawl for Quantitative Fisheries Sampling in the Hudson River. Prepared for PASNY. November 1982.

NAI (Normandeau Associates, Inc.). 1984. Relative Catch Efficiency of a 3 m Beam Trawl and a 6.2 m High-Rise Trawl for Sampling Young of the Year Fishes in the Hudson River Estuary. Prepared for New York Power Authority, White Plains, New York.

NAI (Normandeau Associates, Inc.). 1995. Roseton Generating Station 1994 Evaluation of Postimpingement Survival and Impingement Abundance.. Draft: March 1995. Prepared for Central Hudson Gas & Electric Corporation, Poughkeepsie, New York.

NAI (Normandeau Associates, Inc.). 1986. Size Selectivity and Relative Catch Efficiency of a 3 m Beam Trawl and a 1.0 m^2 Epibenthic Sled for Sampling Young of the Year Striped Bass and other Fishes in the Hudson River Estuary. Prepared for New York Power Authority, White Plains, New York.

NAI (Normandeau Associates, Inc.). 1990. Roseton and Danskammer Point Generating Station Impingement Monitoring Program. 1989 Annual Progress Report. Prepared for Central Hudson Gas & Electric, New York, New York.

NAI (Normandeau Associates, Inc.). 1992a. Bowline Point Generating Station 1991 Impingement Studies. Prepared for Orange and Rockland Utilities, Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1992b. Lovett Generating Station 1991 Impingement Studies. Prepared for Orange and Rockland Utilities, Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1992c. Roseton and Danskammer Point Generating Station Impingement Monitoring Program. 1991 Annual Progress Report. Prepared for Central Hudson Gas & Electric, New York, New York.

NAI (Normandeau Associates, Inc.). 1993. Bowline Point Generating Station 1992 Impingement Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1993. Lovett Generating Station 1992 Impingement Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1994. Bowline Point Generating Station 1993 Impingement Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1994. Lovett Generating Station 1993 Impingement Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1995. Bowline Point Generating Station 1994 Impingement Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1995. Lovett Generating Station 1994 Impingement Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1996. Bowline Point Generating Station 1995 Impingement Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1996. Lovett Generating Station 1995 Impingement Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1996. Roseton and Danskammer Point Generating Stations Impingement Monitoring Program 1993 Annual Progress Report. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1996. Roseton and Danskammer Point Generating Stations Impingement Monitoring Program 1994 Annual Progress Report. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1997. Bowline Point Generating Station 1996 Impingement Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1997. Lovett Generating Station 1996 Impingement Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1997. Roseton and Danskammer Point Generating Stations Impingement Monitoring Program 1995 Annual Progress Report. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1997. Roseton and Danskammer Point Generating Stations Impingement Monitoring Program 1996 Annual Progress Report. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1998. Bowline Point Generating Station 1997 Impingement Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1998. Lovett Generating Station 1997 Impingement Studies. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

NAI (Normandeau Associates, Inc.). 1998. Roseton and Danskammer Point Generating Stations Impingement Monitoring Program 1997 Annual Progress Report. Prepared for Orange and Rockland Utilities, Inc., Pearl River, New York.

Ricker, W.E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations. Bulletin of the Fisheries Research. Board of Canada 191. 382 p.

Sandler, R. and D. Schoenbrod (Editors). 1981. The Hudson River Power Plant Settlement. New York University School of Law, New York, New York.

Smith, L.L, Jr., and R.H. Kramer. 1964. The spottail shiner in Lower Red Lake, Minnesota. Transactions of the American Fisheries Society 93:35-45.

Stagg, C. 1985. An Evaluation of the Information Available for Managing Chesapeake Bay Fisheries: Preliminary Stock Assessments. Chesapeake Bay Commission: UMCEES[CBL] 85-29.

TI (Texas Instruments). 1980. Report on 1978-1979 Studies to Evaluate Catch Efficiency of the 1.0 m^2 Epibenthic Sled. Prepared for Con Edison Co. of New York, Inc., New York, New York.

Versar, Inc. 1987. 1985 Year Class Report for the Hudson River Estuary Monitoring Program. Prepared for Consolidated Edison Company of New York, Inc., New York, New York.

Table 1.—Survival fractions used in CIMR calculations.

Taxon	Annual Survival Fraction	Period	Source
Alewife	0.032	YOY Sep 1 – Age 1 Sep 15	Analysis of age 0 vs. age 1 standing crop estimates
	0.410	Age 1 Sep 16 – Age 4 Apr 30	Average of adjacent estimates
	0.787	Age 4 May 1 – Age 5 Apr 30	Average from Stagg 1986
	0.554	Age 5 May 1 – Age 6 Apr 30	Average from Stagg 1986
	0.379	Age 6 May 1 – Age 7 Apr 30	Average from Stagg 1986
	0.310	Age 7 May 1 – Age 9 Apr 30	Average from Stagg 1986
American Shad	0.00075	YOY Sep 1 – YOY Oct 17	Analysis of BSS weekly catch
	0.30363	YOY Oct 17 – Age 1 Dec 31	Average of adjacent estimates
	0.60653	Age 2 Jan 1 – Age 2 Dec 31	exp(-0.5)
Atlantic Tomcod	0.005	YOY Apr 1 – YOY Dec 31	Taken from data in Atlantic tomcod assessment reports
	0.15	Age 1 Jan 1 – Age 3 Dec 31	Taken from data in Atlantic tomcod assessment reports
Bay Anchovy	0.031	YOY Sep 1 – Age 1 Sep 15	Analysis of age 0 vs. age 1 standing crop estimates
	0.08	Age 1 Sep 15 – Age 3 Dec 31	Houde and Zastrow 1991
Blueback Herring	0.002	Age 0 Sep 1 – Age 1 Sep 15	Analysis of age 0 vs. age 1 standing crop estimates
	0.347	Age 1 Sep 16 – Age 4 Apr 30	Blueback herring average of adjacent estimates
	0.691	Age 4 May 1 – Age 5 Apr 30	Average from Stagg 1986
	0.221	Age 5 May 1 – Age 6 Apr 30	Average from Stagg 1986
	0.228	Age 6 May 1 – Age 9 Dec 31	Average from Stagg 1986

Table 1 (continued).—Survival fractions used in CIMR calculations.

Taxon	Annual Survival Fraction	Period	Source
Spottail Shiner	0.43	YOY Sep 1 – Age 1 Sep 15	Analysis of age 0 vs. age 1 standing crop estimates
	0.14	Age 1 Sep 15 – Age 3 Dec 31	Analysis of catch-at-age data in Smith and Kramer 1964
Striped Bass	[see Figure 1]		
White Perch	0.53	YOY Sep 1 – Age 1 Sep 15	Analysis of age 0 vs. age 1 standing crop estimates
	0.69	Age 1 Sep 16 – Age 2 Apr 30	Average of adjacent estimates
	0.85	Age 2 May 1 – Age 3 Apr 30	Median of literature rates LMS 1983a, LMS 1986a
	0.45	Age 3 May 1 – Age 4 Apr 30	Median of literature rates LMS 1983a, LMS 1986a
	0.44	Age 4 May 1 – Age 5 Apr 30	Median of literature rates LMS 1983a, LMS 1986a
	0.51	Age 5 May 1 – Age 6 Apr 30	Median of literature rates LMS 1983a, LMS 1986a
	0.41	Age 6 May 1 – Age 7 Apr 30	Median of literature rates LMS 1983a, LMS 1986a
	0.36	Age 7 May 1 – Age 7 Dec 31	Median of literature rates LMS 1983a, LMS 1986a

Table 2.—Summary of relative catch efficiency of Fall Shoals sampling gears for YOY striped bass.

1-m^2 Epi-benthic Sled	1-m^2 Tucker Trawl	3-m Beam Trawl	6.2-m High-Rise Trawl	Basis for Estimates	Years of Study	Reference
<0.1	NA	NA	NA	literature	1978 and 1979 (fall)	TI 1980
0.11	A	1	NA	volume density	1980 September	NAI 1982
0.09	NA	0.35	1	area density	1983 October	NAI 1984 (draft)
0.11	NA	1	NA	NA	1980	NAI 1986
0.17	NA	1	NA	NA	1983	
0.25	NA	1	NA	volume density	1984	

NA = not applicable.

Table 3.—Summary of scale-up factors (1/Q) for converting CPUE data into estimates of abundance for CIMR calculations.

Sampling Gear	Scale-up Factor
Beach Seine	22.06
Epibenthic Sled	37.04
Beam Trawl	6.67
Tucker Trawl	37.04

Table 4. —Summary of years with available impingement data.

Year	Indian Point	Roseton	Dans-kammer	Lovett	Bowline Point	Albany Steam
1980					●	
1981	●	●	●	●	●	
1982	●	●	●	●	●	
1983	●	●	●	●	●	
1984	●	●	●	●	●	●
1985	●	●	●	●	●	●
1986	●	●	●	●	●	
1987	●	●	●	●	●	
1988	●	●	●	●	●	
1989	●	●	●	●	●	
1990	●	●	●	●	●	
1991		●	●	●	●	
1992		●	●	●	●	
1993		●	●	●	●	
1994		●	●	●	●	
1995		●	●	●	●	
1996		●	●	●	●	
1997		●	●	●	●	

Table 5. —Ristroph screen mortality rates for Indian Point (from Fletcher 1990).

Taxon	Screen Mortality Rate (%)
Bay anchovy	23
American shad	35
Blueback herring	26
Striped bass	9
White perch	14
Atlantic tomcod	17
Alewife	62
Spottail shiner	15.5[a]

a Average of all taxon-specific values in Fletcher's (1990) Table 4.

Table 6. —Data from 1990 impingement mortality studies at Roseton Generating Station (data from LMS 1991c).

Species	Stunned	Dead							Stunned	Live
	0 hr	0 hr	2.5 hr	8 hr	12 hr	24 hr	48 hr	96 hr	96 hr	96 hr
				Conventional Screens						
American shad	5	569	19	11	0	0	1	0	0	1
Atlantic tomcod	15	26	12	5	3	5	2	3	0	5
Alewife	9	681	32	15	0	0	0	7	0	1
Bay anchovy	1	2073	3	0	0	0	0	0	0	0
Blueback herring	134	5307	835	133	11	7	4	5	1	2
Striped bass	6	104	46	38	8	14	9	15	0	73
Spottail shiner	6	63	5	5	1	5	3	9	0	66
White perch	288	633	135	212	116	275	152	182	6	652
				Dual Flow Screens						
American shad	2	2302	126	61	22	1	4	2	0	12
Atlantic tomcod	16	16	7	10	10	3	4	13	0	16
Alewife	6	2289	162	43	6	6	3	4	0	7
Bay anchovy	3	5097	58	6	0	0	0	0	0	0
Blueback herring	358	24759	3049	352	56	34	44	27	0	17
Striped bass	26	370	275	266	92	47	72	100	0	928
Spottail shiner	10	55	8	11	11	20	21	53	6	376
White perch	503	682	155	296	201	496	418	562	36	2376

Table 7. —Data from 1994 impingement mortality studies at Roseton (dual-flow screens) (data from NAI 1995).

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

a Presented as survival rather than mortality to be consistent with the original source.

Table 8. —Impingement survival at Bowline Point Generating Station (data from EAI 1982a).

Species	Life Stage	Number	Survival Rate	
			0 hr	96 hr
Atlantic tomcod	yoy	63	0.86	0.59
	adu	114	0.97	0.88
Alewife	yoy	33	0.73	0.03
	yoy	32	0.72	0.09
Bay anchovy	all	62	0.64	0.05
Blueback herring	yoy	158	0.71	0.00
	yoy	244	0.77	0.11
River herring	yoy	219	0.75	0.02
	yrl	63	0.94	0.02
	adu	65	0.89	0.01
	yoy	296	0.75	0.11
Striped bass	yoy	208	0.99	0.54
	yrl	843	0.91	0.25
	yrl	648	0.91	0.42
White perch	adu	499	0.89	0.33
	adu	36	0.92	0.5
	adu	47	0.94	0.68
	yoy	2764	0.97	0.54
	yoy	271	0.93	0.63
	yoy	238	0.91	0.72
	yrl	3196	0.89	0.31
	yrl	747	0.93	0.51
	yrl	2003	0.92	0.53

[a] adu = adult, yoy = young-of-the-year, yrl = yearling.

Table 9.—Impingement mortality studies at Danskammer Point Generating Station (EAI 1982b)

Species	Life Stage[a]	Season	Number	Mortality Rate	
				0 hr	96 hr
American shad	yoy	fall	34	0.265	1.000
Atlantic tomcod	yoy	fall	39	0.077	0.270
	yrl	winter	301	0.123	0.301
Alewife	yoy	fall	223	0.300	0.991
Blueback herring	yoy	fall	240	0.338	0.992
Spottail shiner	yrl	winter	54	0.130	0.600
White perch	yoy	spring	122	0.123	0.623
	yoy	fall	965	0.094	0.520
	yrl	winter	53	0.094	0.755
	yrl	spring	1067	0.030	0.452
	yrl	fall	192	0.047	0.323

[a] yoy = young of the year, yrl = yearling and older.

Table 10. —Estimated values of the time-response curve shaping parameter $\hat{b}$ for impingement mortality studies at Roseton Generating Station.

Species	Study (Year and Screen)		
	1990		1994
	Conventional	Dual Flow	Dual Flow
Alewife	0.94964	0.98872	0.98253
American shad	0.99284	0.98863	0.99212
Atlantic tomcod	0.92823	0.80194	NA
Bay anchovy	1.00000	0.99945	0.95757
Blueback herring	0.99606	0.99449	0.97805
River herring	0.99397	0.99416	0.97879
Spottail shiner	0.75378	0.44413	0.71715
Striped bass	0.92730	0.92498	0.90283
White perch	0.81343	0.66000	0.79359

NA Not available.

Table 11.—R-squared value for fit of impingement mortality predicted by the model compared to estimated mortality rates at each observed time *t*.

Species	Study (Year and Screen)		
	1990		1994
	Conventional	Dual Flow	Dual Flow
Alewife	-1.20	0.97	0.67
American shad	0.69	0.86	0.91
Atlantic tomcod	0.89	0.82	NA
Bay anchovy	NC	0.22	0.98
Blueback herring	0.92	0.92	0.95
River herring	0.93	0.93	0.93
Spottail shiner	0.80	0.93	0.65
Striped bass	0.88	0.89	0.93
White perch	0.99	0.99	1.00

NA Not available

NC Could not be calculated due to a zero sum of squares.

Table 12.—Estimated and predicted impingement mortality rates for Bowline Point Generating Station.

Species	Life Stage[a]	M_0	M_8	M_{96}
Alewife	yoy	0.27492	0.70322	0.94046
Atlantic tomcod	adu	0.03000	0.08030	0.12000
	yoy	0.14000	0.29089	0.41000
Bay anchovy	all	0.36000	0.95000	0.95000
Blueback herring	yoy	0.25358	0.90499	0.93323
River herring	adu	0.11000	0.93527	0.99000
	yoy	0.25000	0.88609	0.92827
	yrl	0.06000	0.92279	0.98000
Striped bass	yoy	0.01000	0.26003	0.46000
	yrl	0.09000	0.41567	0.67612
White perch	adu	0.10411	0.27680	0.63122
	yoy	0.03767	0.16931	0.43946
	yrl	0.09487	0.25734	0.59076

[a] adu = adult, yoy = young-of-the-year, yrl = yearling.

Table 13. —Estimated and predicted impingement mortality rates for Danskammer Point Power Plant.

Species	Life Stage[a]	Season	M_0	M_8	M_{96}
Alewife	yoy	fall	0.300	0.74468	0.991
American shad	yoy	fall	0.265	0.94635	1.000
Atlantic tomcod	yoy	fall	0.077	0.18486	0.270
	yrl	winter	0.123	0.22247	0.301
Blueback herring	yoy	fall	0.338	0.96482	0.992
Spottail shiner	yrl	winter	0.130	0.25674	0.600
White perch	yoy	fall	0.094	0.23357	0.520
	yoy	spring	0.123	0.28681	0.623
	yrl	fall	0.047	0.13743	0.323
	yrl	spring	0.030	0.16826	0.452
	yrl	winter	0.094	0.31056	0.755

[a] yoy = young-of-the-year, yrl = yearling and older.

Table 14.—Estimated and predicted impingement mortality rates for Roseton Power Plant.

Species	M_0	M_8	M_{96}
Alewife	0.84975	0.97168	0.99113
American shad	0.86268	0.98010	0.98966
Atlantic tomcod	0.37031	0.63312	0.88789
Bay anchovy	0.96212	0.98625	0.99950
Blueback herring	0.77137	0.97015	0.99081
River herring	0.78021	0.97075	0.99094
Spottail shiner	0.31846	0.37584	0.49706
Striped bass	0.28946	0.56500	0.72458
White perch	0.22349	0.35967	0.66331

Table 15. —Alewife cumulative CIMR estimates by year class and plant.

Plant	1985	1986	1987	1988	1989
Bowline Point	0.000	0.000	0.000	0.000	0.000
Danskammer	0.012	0.015	0.011	0.008	0.009
Indian Point	0.002	0.002	0.001	0.001	0.001
Lovett	0.000	0.000	0.000	0.000	0.000
Roseton	0.002	0.002	0.002	0.002	0.002
Riverwide	0.016	0.020	0.015	0.011	0.010

Table 16. —American shad CIMR estimates by year class and plant.

Plant	1985	1986	1987	1988	1989	1990	1991	1992	1993
Bowline Point	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Danskammer	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Indian Point	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lovett	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Roseton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Riverwide	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000

Table 17.—Atlantic tomcod cumulative CIMR estimates by year class and plant.

Plant	1986	1987	1988	1989	1990	1991	1992	1993	1994
Bowline Point	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Danskammer	0.001	0.001	0.000	0.000	0.001	0.001	0.001	0.000	0.004
Indian Point	0.008	0.030	0.005	0.003	0.004	0.002	0.002	0.002	0.002
Lovett	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Roseton	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000
Riverwide	0.010	0.031	0.006	0.004	0.005	0.006	0.003	0.003	0.005

[Note: 0.000 indicates that CIMR < 0.0005]

Table 18. —Bay anchovy cumulative CIMR estimates by year class and plant.

Plant	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Bowline Point	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Danskammer	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Indian Point	0.002	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lovett	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Roseton	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Riverwide	0.002	0.004	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000

Table 19. —Blueback herring cumulative CIMR estimates by year class and plant.

Plant	1985	1986	1987	1988	1989
Bowline Point	0.000	0.000	0.000	0.000	0.000
Danskammer	0.001	0.002	0.001	0.001	0.001
Indian Point	0.003	0.004	0.002	0.001	0.001
Lovett	0.000	0.000	0.000	0.000	0.000
Roseton	0.000	0.001	0.000	0.000	0.000
Riverwide	0.005	0.007	0.004	0.002	0.002

Table 20. —Spottail shiner cumulative CIMR estimates by yearclass and plant.

Plant	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Bowline Point	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Danskammer	0.004	0.001	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Indian Point	0.002	0.001	0.007	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Lovett	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Roseton	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Riverwide	0.007	0.002	0.009	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.002

[Note: 0.000 indicates that CIMR < 0.0005]

Table 21. —Striped bass cumulative CIMR estimates by year class and plant.

Plant	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Bowline Point	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Danskammer	0.001	0.002	0.002	0.001	0.001	0.001	0.003	0.001	0.001	0.001	0.001
Indian Point	0.008	0.003	0.005	0.005	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Lovett	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Roseton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Riverwide	0.010	0.005	0.007	0.007	0.001	0.001	0.005	0.002	0.002	0.001	0.002

Table 22. —White perch cumulative CIMR estimates by year class and plant.

Plant	1985	1986	1987	1988	1989	1990
Bowline Point	0.001	0.000	0.000	0.000	0.000	0.000
Danskammer	0.003	0.003	0.003	0.003	0.004	0.004
Indian Point	0.026	0.032	0.012	0.011	0.014	0.007
Lovett	0.000	0.000	0.000	0.000	0.000	0.000
Roseton	0.001	0.001	0.001	0.001	0.001	0.002
Riverwide	0.031	0.037	0.017	0.016	0.020	0.013

[Note: 0.000 indicates that CIMR < 0.0005]

Table 23. —Alewife CIMR estimates by calendar year and life stage.

Year	YOY	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
1985	0.001	NA	NA	NA	NA	NA	NA	NA
1986	0.000	0.003	NA	NA	NA	NA	NA	NA
1987	0.001	0.009	0.004	NA	NA	NA	NA	NA
1988	0.001	0.005	0.002	0.002	NA	NA	NA	NA
1989	0.000	0.001	0.002	0.002	0.002	NA	NA	NA
1990	NA	0.002	0.002	0.002	0.002	0.002	NA	NA
1991	NA	NA	0.002	0.002	0.002	0.002	0.002	NA
1992	NA	NA	NA	0.002	0.002	0.002	0.002	0.002
1993	NA	NA	NA	NA	0.001	0.001	0.001	0.001
1994	NA	NA	NA	NA	NAA	0.001	0.001	0.001
1995	NA	NA	NA	NA	NA	NA	0.001	0.001
1996	NA	NA	NA	NA	NA	NA	NA	0.002

NA = Not applicable

Table 24. —American shad CIMR estimates by calendar year and life stage.

Year	YOY	Age 1	Age 2	Age 3	Age 4
1985	0.001	NA	NA	NA	NA
1986	0.000	0.000	NA	NA	NA
1987	0.000	0.000	0.000	NA	NA
1988	0.000	0.000	0.000	0.000	NA
1989	0.000	0.000	0.000	0.000	0.000
1990	0.000	0.000	0.000	0.000	0.000
1991	0.001	0.000	0.000	0.000	0.000
1992	0.000	0.000	0.000	0.000	0.000
1993	0.000	0.000	0.000	0.000	0.000
1994	NA	0.000	0.000	0.000	0.000
1995	NA	NA	0.000	0.000	0.000
1996	NA	NA	NA	0.000	0.000
1997	NA	NA	NA	NA	0.000

NA = Not applicable

[Note: 0.000 indicates that CIMR < 0.0005]

Table 25. —Atlantic tomcod CIMR estimates by calendar year and life stage.

Year	YOY	Age 1	Age 2	Age 3
1986	0.003	NA	NA	NA
1987	0.026	0.003	NA	NA
1988	0.001	0.001	0.003	NA
1989	0.001	0.002	0.001	0.001
1990	0.003	0.002	0.003	0.003
1991	0.005	0.001	0.000	0.000
1992	0.001	0.001	0.000	0.000
1993	0.001	0.001	0.000	0.000
1994	0.001	0.001	0.000	0.000
1995	NA	0.000	0.000	0.000
1996	NA	NA	0.001	0.001
1997	NA	NA	NA	0.014

NA = Not applicable

Table 26. —Bay anchovy CIMR estimates by calendar year and life stage.

Year	YOY	Age 1	Age 2
1985	0.000	NA	NA
1986	0.000	0.000	NA
1987	0.000	0.000	0.001
1988	0.000	0.000	0.004
1989	0.000	0.000	0.000
1990	0.000	0.000	0.000
1991	0.000	0.001	0.000
1992	0.000	0.000	0.000
1993	0.000	0.000	0.000
1994	0.000	0.000	0.000
1995	0.000	0.000	0.000
1996	NA	0.000	0.000
1997	NA	NA	0.000

NA = Not applicable

[Note: 0.000 indicates that CIMR < 0.0005]

Table 27. —Blueback herring CIMR estimates by calendar year and life stage.

Year	YOY	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
1985	0.000	NA	NA	NA	NA	NA	NA	NA
1986	0.000	0.001	NA	NA	NA	NA	NA	NA
1987	0.000	0.004	0.001	NA	NA	NA	NA	NA
1988	0.000	0.001	0.001	0.001	NA	NA	NA	NA
1989	0.000	0.000	0.001	0.001	0.001	NA	NA	NA
1990	NA	0.000	0.001	0.001	0.001	0.001	NA	NA
1991	NA	NA	0.000	0.000	0.000	0.000	0.000	NA
1992	NA	NA	NA	0.000	0.000	0.000	0.000	0.000
1993	NA	NA	NA	NA	0.000	0.000	0.000	0.000
1994	NA	NA	NA	NA	NA	0.000	0.000	0.000
1995	NA	NA	NA	NA	NA	NA	0.000	0.000
1996	NA	NA	NA	NA	NA	NA	NA	0.000

NA = Not applicable

Table 28. —Spottail shiner CIMR estimates by calendar year and life stage.

Year	YOY	Age 1	Age 2
1985	0.000	NA	NA
1986	0.000	0.001	NA
1987	0.000	0.001	0.007
1988	0.000	0.000	0.001
1989	0.000	0.000	0.009
1990	0.000	0.000	0.002
1991	0.000	0.000	0.001
1992	0.000	0.000	0.001
1993	0.000	0.000	0.000
1994	0.000	0.000	0.000
1995	0.000	0.000	0.000
1996	NA	0.001	0.000
1997	NA	NA	0.000

NA = Not applicable

[Note: 0.000 indicates that CIMR < 0.0005]

Table 29. —Striped bass CIMR estimates by calendar year and life stage.

Year	YOY	Age 1	Age 2	Age 3
1984	0.000	NA	NA	NA
1985	0.000	0.007	NA	NA
1986	0.000	0.001	0.001	NA
1987	0.001	0.004	0.001	0.001
1988	0.000	0.005	0.002	0.002
1989	0.000	0.001	0.001	0.001
1990	0.000	0.000	0.000	0.000
1991	0.001	0.004	0.000	0.000
1992	0.000	0.001	0.000	0.000
1993	0.000	0.001	0.000	0.000
1994	0.000	0.001	0.000	0.000
1995	NA	0.002	0.000	0.000
1996	NA	NA	0.000	0.000
1997	NA	NA	NA	0.000

NA = Not applicable

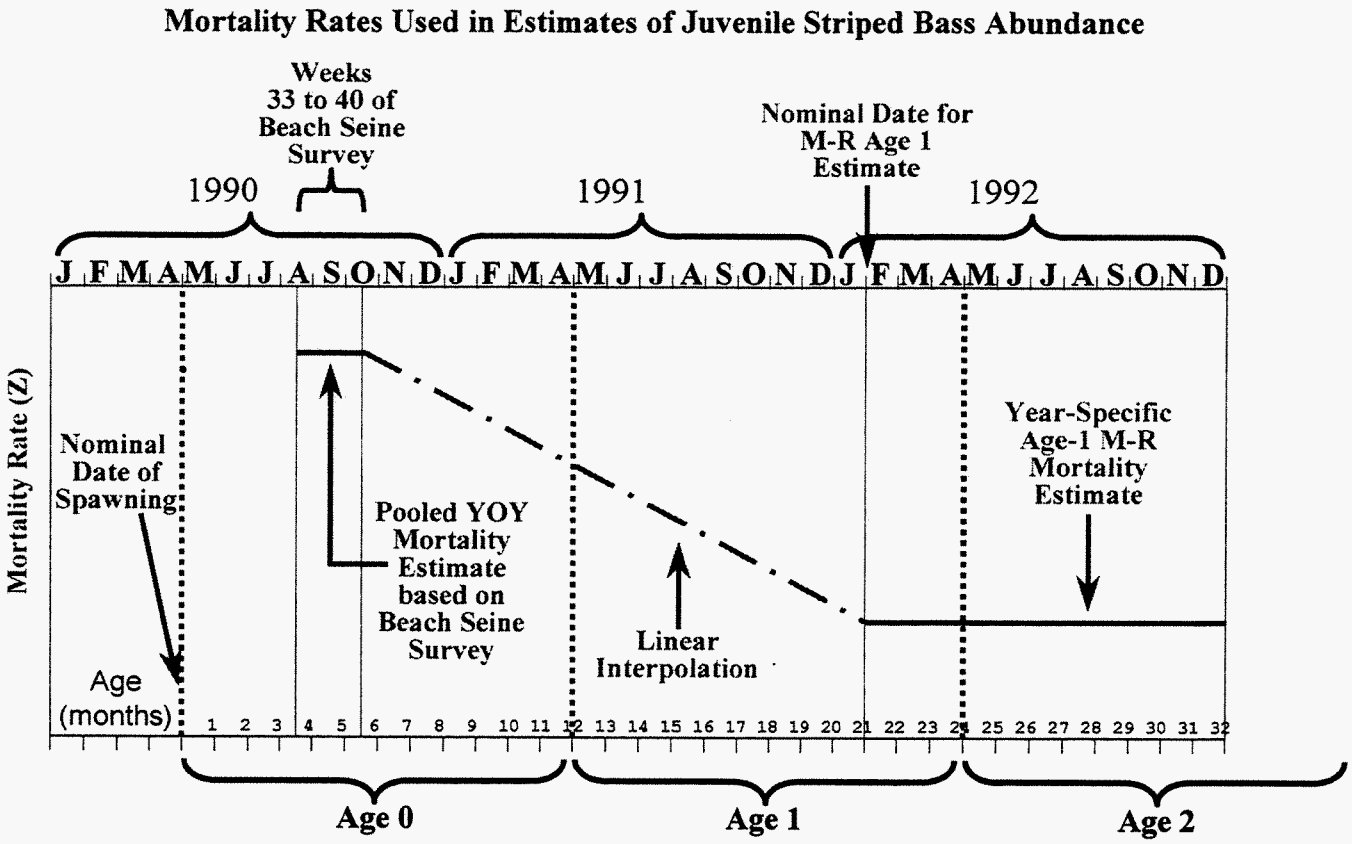
Table 30. —White perch CIMR estimates by calendar year and life stage.

Year	YOY	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7
1985	0.009	NA	NA	NA	NA	NA	NA	NA
1986	0.011	0.015	NA	NA	NA	NA	NA	NA
1987	0.002	0.021	0.002	NA	NA	NA	NA	NA
1988	0.004	0.011	0.001	0.001	NA	NA	NA	NA
1989	0.006	0.007	0.001	0.001	0.001	NA	NA	NA
1990	0.003	0.009	0.001	0.001	0.001	0.001	NA	NA
1991	NA	0.016	0.000	0.000	0.000	0.000	0.000	NA
1992	NA	NA	0.001	0.001	0.001	0.001	0.001	0.001
1993	NA	NA	NA	0.001	0.001	0.001	0.001	0.001
1994	NA	NA	NA	NA	0.001	0.001	0.001	0.001
1995	NA	NA	NA	NA	NA	0.001	0.001	0.001
1996	NA	NA	NA	NA	NA	NA	0.002	0.002
1997	NA	NA	NA	NA	NA	NA	NA	0.000

NA = Not applicable

[Note: 0.000 indicates that CIMR < 0.0005]

Figure 1.


Mortality Rates Used in Estimates of Juvenile Striped Bass Abundance
Weeks 33 to 40 of Beach Seine Survey
Nominal Date for M-R Age 1 Estimate
1990
1991
1992
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
Mortality Rate (Z)
Nominal Date of Spawning
Pooled YOY Mortality Estimate based on Beach Seine Survey
Linear Interpolation
Year-Specific Age-1 M-R Mortality Estimate
Age (months)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
Age 0
Age 1
Age 2

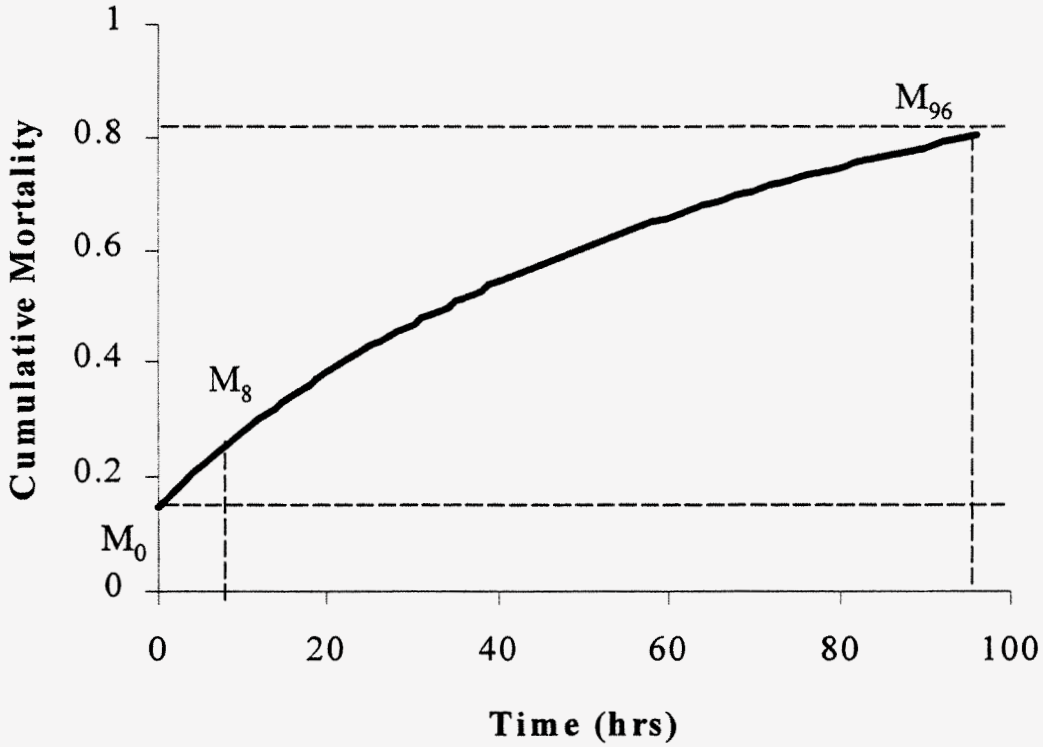


Figure 2. —Typical time-response curve for impingement mortality studies showing initial (M_0), 8-hr (M_8), and 96-hr (M_{96}) mortality rates.

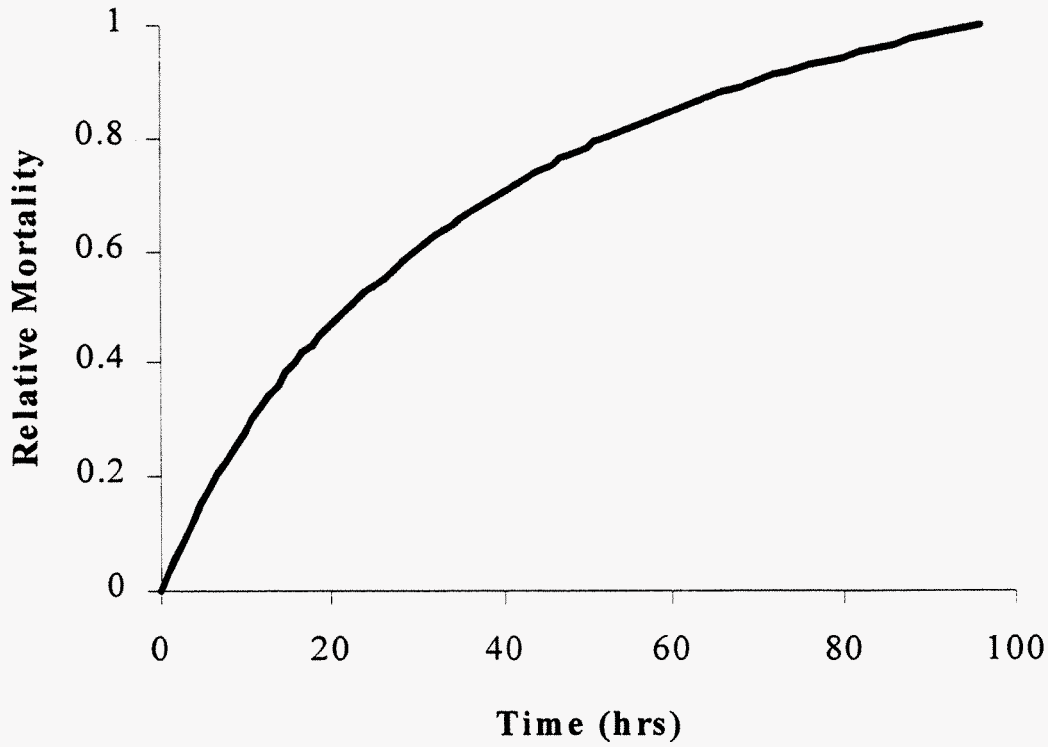


Figure 3. —Time response curve of impingement mortality studies after adjusting for initial (M_0) and 96-hr (M_{96}) mortality rates.

Appendix VI-2-C

Mark-Recapture Methods

Abundance and Survival Estimates for Hudson River Striped Bass

Introduction

Starting in 1984, striped bass in the Hudson River have been captured, tagged, and released alive. Recaptures of these striped bass have been used to estimate abundance at age 1+ and age 2+ and survival from age 1+ to age 2+ and from age 2+ to age 3+. This report describes how these estimates were calculated.

Abundance Estimators

Age Designation

A convention in fisheries biology is to regard January 1 as the date on which the age designation changes annually, i.e., the date on which a fish becomes a year older. The striped bass used to estimate abundance (and survival) in the Hudson River typically were tagged and/or recaptured between the fall season of one year and the spring season of the next year, i.e., spanning the January 1 date. To avoid having fish of the same cohort designated as two different ages depending on whether they were caught before or after January 1, an alternative convention was used. The alternative convention designates the annual age change at the time of spawning. Additionally, to indicate that the estimates of abundance (and survival) of Hudson River striped bass are for fish that have survived beyond the annual age change, a "+" was added after the age.

Basis and Time Frame

Mark-recapture abundance estimators for both age-1+ and age-2+ striped bass are based on the Petersen method (Ricker 1975, Coastal 1992). Two years of marking and recapture results are required for measures of abundance of both age-1+ and age-2+ striped bass. To accommodate the two-year time frame, the following convention is used. The year for which abundance estimates of age-2+ fish apply is denoted as year $y+1$. Year $y+1$ is the second of the two years. Abundance estimates are made for age-1+ striped bass in the previous year. That year is the first of the two years and is denoted as year y. The following development of the estimators begins with age-1+ fish (in year y) and proceeds to age-2+ fish (in year $y+1$).

Age 1+

The Petersen method is used to estimate the abundance of fish based on their recapture rate after being marked and released. The abundance of age-1+ striped bass is estimated as

$$\hat{N1}_y = \frac{M_y \hat{C}_{y+1}}{R_{y+1}} \quad , \qquad (1)$$

where

$\hat{N1}_y$ = the abundance estimate for age-1+ striped bass in year y;

$\hat{C}_{y+1}$ = the estimate of the number of age-2+ striped bass that were collected in year $y + 1$ (This is an estimated quantity because scales from a subsample of fish in each length category were aged and the age frequency distribution for each length category coupled with the length frequency distribution for the whole sample were used to estimate the number of age-2+ fish in the whole sample);

M_y = the number of age-1+ striped bass that were tagged and released in the previous year, y; and

R_{y+1} = the number of striped bass tagged in year y at age 1+ that were recaptured at age 2+ in year y +1.

Data on number of striped bass tagged (M_y), number recaptured (R_{y+1}), and total number collected ($\hat{C}_{y+1}$) were from the Utilities' in-river sampling program (see following section on Data).

This estimate is a measure of absolute abundance if the survival rate of tagged fish (or the retention rate of tags in fish) and the survival rate of untagged fish from the time of tagging to the time of recapture is the same. Where survival of tagged fish (or tags themselves) is different from survival of untagged fish, equation (1) produces a biased estimate of the number of age-1+ striped bass in year y.

Assumptions to be satisfied with the Petersen method (Seber 1982, White et al. 1982, reviewed in Martin Marietta 1986) are that

1. mortality rates of tagged and untagged fish are equal,

2. tags are not lost during the experiment,

3. marking does not affect the vulnerability of fish to capture,

4. all recaptures are recognized and reported,

5. the ratio of tagged to untagged fish within the area sampled equals the ratio for the population as a whole, and

6. all fish are of Hudson River origin.

Age 2+

The abundance of age-2+ striped bass is estimated from the abundance estimate of age-1+ striped bass ($\hat{N1}_y$) adjusted for survival of tagged fish from age 1+ to age 2+ as follows:

$$\hat{N2}_{y+1} = \hat{N1}_y \, \hat{S}_y, \tag{2}$$

where

$\hat{N2}_{y+1}$ = the abundance estimate for age-2+ striped bass in year $y + 1$ and

$\hat{S}_y$ = the estimated fraction of tagged striped bass that survive between tagging in year y when fish are age 1+ and the beginning of the sampling season when the fish are age 2+; this survival term can be partitioned into the survival of the fish $\hat{S}_{F_y}$ and the survival (retention) of legible tags on the fish $\hat{S}_{T_y}$ to the time of recapture, i.e., $\hat{S}_y = \hat{S}_{F_y} \hat{S}_{T_y}$.

In addition to the requirements for the age 1+ abundance estimates, the age 2+ estimator requires an unbiased estimate of survival for tagged fish ($\hat{S}_y$).

Survival

The survival estimator is "Model H_2" (Robson and Youngs 1971, Brownie et al. 1985), one of a series of such estimators. It is a variation developed for bird banding in the case where reporting rate by hunters near the banding sites is different than the reporting rate of hunters farther away. For example, reporting rates of nearby hunters might be increased by solicitation of returns or be decreased where hunters recognize and avoid bands. This situation is somewhat similar to Hudson River mark-recapture programs in which fish are more likely to be recaptured soon after being released than they are in subsequent years when they have mixed more thoroughly with the population at large. In the context of the striped bass program, survival is the survival of tags from the time of tagging to the time of recapture, and it includes survival of the tagged fish, tag retention, and tag legibility. All data on tag returns used here are from the Hudson River Foundation's Tag Return Program and represent tag returns from fishers. Year-specific rates of tag retention were not estimated from the in-river sampling program because the number of recaptures was too small to produce reliable estimates.

The survival rate from age 1+ (yearling) to age 2+ is given by

$$S_i' = \left(\frac{Q_{i\bullet} - Q_{ii}}{M_i}\right)\left(\frac{N_{i+1}+1}{R_{i+1,\bullet} - R_{i+1,i+1}+1}\right)\left(\frac{T_{i+1}+U_{i+1}-Q_{i+1,\bullet}-R_{i+1,\bullet}-W_{i+1}+R_{i+1,i+1}}{T_{i+1}+U_{i+1}-Q_{i+1,\bullet}-R_{i+1,\bullet}}\right) \quad (3)$$

where

S_i'	=	the survival rate of yearlings from age 1+ to age 2+;
i	=	$1,\ldots,k-2$ if $l = k$ and $1,\ldots,k-1$ if $l > k$;
k	=	the number of years in which tagged striped bass were released;
l	=	the number of years in which recaptures were recorded; $l \geq k$, which is sometimes written as $l = k + s$ where s = the number of years in which recaptures were recorded but no fish were tagged;
M_i	=	the number of age-1+ striped bass tagged in year i;
N_{i+1}	=	the number of age 2+ and older striped bass tagged in year $i+1$;
Q_{ii}	=	the number of tags recovered in year i from the age-1+ striped bass released in year i (i.e., yearlings recaptured in same year as they were tagged) ;
$Q_{i\bullet}$	=	the number of tags recovered in all years from the age-1+ striped bass released in year i ;
$Q_{i+1,\bullet}$	=	the number of tags recovered in all years from the age-1+ striped bass released in year $i+1$;
$R_{i+1,\bullet}$	=	the number of tags recovered in all years from age 2+ and older striped bass released in year $i+1$;
$R_{i+1,i+1}$	=	the number of tags recovered in year $i+1$ from age 2+ and older striped bass released in year $i+1$(i.e., adults recaptured in same year as they were tagged) ;
T_{i+1}	=	the total number of tag recoveries from striped bass tagged in year $i+1$ that were age 2+ and older in year $i+1$;
U_{i+1}	=	the total number of tag recoveries from striped bass tagged in year $i+1$ that were age 1+ in year $i+1$; and
W_{i+1}	=	the total number of tags recovered in year $i+1$ from age 2+ and older striped bass ($= R_{.,i+1} + Q_{.,i+1} - Q_{i+1,i+1}$).

The notation describing the estimator is from Brownie et al. (1985), and some symbols differ from those used for striped bass abundance estimators. The variance of survival is estimated from the following formula:

$$\mathrm{var}(S_i') = (S_i')^2 \cdot \left[\left(\frac{1}{Q_{i\bullet} - Q_{ii}}\right) - \left(\frac{1}{M_i}\right) + \left(\frac{1}{R_{i+1\bullet} - R_{i+1,i+1}}\right) - \left(\frac{1}{N_{i+1}}\right)\right.$$

$$\left. + \left(\frac{1}{T_{i+1}+U_{i+1}-Q_{i+1}-R_{i+1}-W_{i+1}+R_{i+1,i+1}}\right) - \left(\frac{1}{T_{i+1}+U_{i+1}-Q_{i+1\bullet}-R_{i+1\bullet}}\right)\right]. \quad (4)$$

The quantity $T_{i+1} + U_{i+1} - Q_{i+1}$. (sometimes referred to as A_{i+1}) in equations (3) and (4) is the total number of recoveries in year i+1 and later of fish that were age 2+ or older with tags before year i+1 (whether tagged as yearlings or older). These equations may be better understood in the context of a symbolic representation of the mark-recapture data used for the estimates (Table 1).

Model H_2 allows for the following conditions:

1. annual survival, harvest and reporting rates are year-specific,

2. the annual survival and harvest rates are age-dependent only for the first year after tagging, and,

3. in any year, the reporting rate for newly released fish is different from that of the reporting rate for fish from previous releases.

Because this estimator is appropriate for such general conditions (including year-specific reporting rates, and different reporting rates for fish caught in the year of release and fish caught in subsequent years) tag return data from anglers can be used to estimate survival rates. Using tag returns from anglers (e.g., rather than recaptures from limited fisheries-independent sampling) provides a means for characterizing survival rates for the population over its entire geographic range.

Data

In-River Sampling Program (Tagging and Recapturing)

Overview.—Striped bass stock assessment reports (e.g., NAI 1988) provide yearly descriptions of the in-river sampling program, and a typical overview is provided here. The 1984 striped bass program was conducted in spring. Subsequent programs starting with the 1985-1986 program were conducted in winter (NAI 1986). Winter sampling with trawls was performed in the Battery and Upper Harbor regions of the lower Hudson River, typically from November through April. The months with cold water temperatures were selected to reduce handling stress, which tends to be higher at elevated water temperatures. Sampling locations were not chosen with randomization but were selected to maximize the catch per unit effort based on previous study results. Procedures for handling striped bass and inserting tags were designed to minimize handling stress.

From the winter 1984 program through the 1987-1988 program, striped bass not previously tagged, in good condition, and of length greater than 200 mmTL were tagged with internal anchor tags before release (NAI 1986,1987, and 1988). Starting with the 1988-1989 program, the length criterion was reduced to 150 mmTL (NAI 1990). A scale sample was taken for subsequent age determination. All scales were not analyzed to determine fish age. A stratified sampling was applied to determine age and mean length at age. About 16% of scales from striped bass captured were analyzed. Therefore, the

number of age-2+ striped bass that were tagged in any year was an estimated rather than a known quantity. Striped bass were classified as age 1+ if the total length was between 170 mm and 250 mm.

All captured striped bass were examined for external tags and tagging scars. Tag numbers appear on the external streamer of anchor tags and were recorded. In the 1987-1988 program, for example, a total of 143 striped bass were recovered that had tags or tag scars (NAI 1988, Table 4-25). Of these, 129 or 90% had legible tags. Some of the tag scars may be due to fishers removing the tags before returning fish to the water. In that case, the data (for the purpose of estimating survival) are not lost. Also, tag abrasion increases with time, and although striped bass may retain the tags for years, the period used between mark and recapture for abundance estimates is only about 1 year. Therefore, some of the illegible tags may not be those needed to estimate abundance.

Extent of Sampling.—In 1984 sampling was confined to the Hudson River and included the area from the lower Tappan Zee (River Mile 24, km 38) to north of Poughkeepsie (River Mile 76, km 122) (Table 2). Exploratory sampling of the East River, Harlem River, and Lower New York Harbor in the 1985-1986 Program indicated that CPUEs were much lower there than in the Battery and Upper New York Harbor Regions (NAI 1986). Starting with the 1986-1987 program, sampling was confined to the Battery Region where the CPUE was the highest in order to maximize striped bass catches (Table 2). The period of sampling changed from spring sampling in 1984 to winter sampling thereafter. Dates have varied somewhat but were standardized to the first week in November to mid-April starting with the 1992-1993 sampling Program (Table 2).

Collection Gear.—Early studies compared the characteristics of various fishing gear with respect to marking and recapturing striped bass in the Hudson River. As a result, fishing gear changed during the early program years but quickly became standardized (Table 3). Attributes initially investigated included initial mortality of captured fish, efficiency (size selectivity), and reliability and productiveness (number of fish that could be caught per day). The 1984 program demonstrated that an average initial mortality rate of less than 18% could be achieved with the Scottish seines and 12-m trawl when water temperatures ranged from 8 to 16 °C and that striped bass could be tagged without significantly increasing 24-hr mortality (NAI 1987).

The 1985-1986 program found that although the mean catch per unit effort of the 12-m trawl was higher than the 9-m trawl, the mean catch per day of the two gear were almost identical because the 9-m trawl could be deployed more often (NAI 1987). Sampling with these trawls in the lower Hudson, Harlem, and East Rivers in the winter and spring of 1985-1986 had also indicated that the greatest catch of striped bass occurred in the Battery and Upper Harbor regions between mid-December and mid-April (NAI 1987). These findings provided the basis for focusing the subsequent sampling effort to the area and time when the striped bass population was most concentrated.

The 1985-1986 program also identified the relative size-selectivity of the fishing gear (NAI 1987). The 12-m trawl was most efficient for striped bass in the age-1+ through age-3+ size range. The Scottish seine, which was fished in the Tappan Zee and Croton-Haverstraw regions in April and May, was most efficient for striped bass of sizes that would be older than age 3+. The 9-m trawl was the most efficient at capturing striped bass in the age-0+ to age-1+ size range. Starting with the 1988-1989 program, only the 9-m trawl was used (Table 3).

Tags.—Tag types used since the beginning of the program are summarized in Table 4. The changes in tag type were adopted to improve tag legibility and to reduce tag loss and tagging mortality. In the 1984 program, fish were double tagged with both Floy FD-688 Anchor Tags and Floy Internal Anchor-External Streamer Tags. Double tagging allowed estimates to be made of the rate of tag loss for each type of tag relative to the other, and only the latter tags were used in the 1985-1986 program. In 1987 a modified Floy Internal Anchor-External Streamer Tag was introduced that had a clear vinyl tube protecting the external streamer (NAI 1988). Unfortunately, the tubing was not watertight, and algal and bacterial growth between the tube and the legend rendered most of the external streamer legends unreadable (NAI 1991). Information on the streamer was reproduced on the anchor, so that if the external streamer was lost or the if the number on the streamer had become illegible, the tag number could still be recovered by sacrificing the fish.

In the 1987-1988 mark-recapture program, Hallprint Internal Anchor-External Streamer Tags (with exposed streamers) were used in addition to the Floy internal anchor and modified internal anchor tags (NAI 1988). The Hallprint tags have the advantage of having the tag number on the anchor, so that the tag number can still be recovered by sacrificing the fish. These tags also have the advantage that the legend is sealed between layers of polyethylene, and so these tags showed no abrasion or loss of information due to abrasion. An exposed section of monofilament, however, cut the fish's ventral body wall and caused some tags to be shed (NAI 1991). A modified Hallprint Internal Anchor-External Streamer Tag with a covered streamer was introduced in 1988 (NAI 1990), and this change almost eliminated tag loss due to shedding (NAI 1991). The modified Hallprint Internal Anchor-External Streamer Tag became the standard tag and has been used by the program since 1998.

Hudson River Foundation Tag Return Program

In addition to recaptures from the in-river sampling program, data on tag returns from commercial and recreational fishers were available and were used for estimating survival rates. Each tag contained a written offer for a monetary reward ($5.00 to $10.00) to the individual returning the tag, and the address of The Hudson River Foundation, where the tags were to be sent (Waldman 1989). As an additional incentive to anglers to return tags, each returned tag was entered into a drawing with prizes of up to $1000.00 to the anglers who returned the winning tags. The Hudson River Foundation maintained a publicity campaign to create angler awareness, and developed a database of

tag returns from anglers. The database contains records of tag returns from the beginning of the Hudson River striped bass tagging program in 1984.

Numbers Marked and Recaptured

Mark-recapture data from the in-river sampling program were available to estimate abundances of the 1984 through 1994 year classes of Hudson River striped bass (Table 5). Between 2,373 and 15,250 age-1+ striped bass were marked annually. Between 1,484 and 11,865 age-2+ striped bass were captured annually, and between 4 and 158 of these (per year) had been tagged the previous year as age-1+ fish. Of 75,136 fish were tagged at age 1+, 435 were recaptured at age 2+ among a total of 43,795 age-2+ fish recaptured regardless of age at tagging. For estimating survival rates, the mark-recapture data from the utilities' sampling program were combined with the data from The Hudson River Foundation tag return program. These data are displayed in the manner of Table 1 for the estimation of survival rates (Table 6). The Hudson River Foundation data contained tag returns from 12,619 striped bass tagged at age 1+ through age 4+ from 1984 through 1998.

Results

Estimates of survival rates of Hudson River striped bass calculated using equation (3) and data on Table 6 were used in equation (2) to estimate age 2+ abundance (Table 7). The time between tagging of fish as yearlings (age 1+) and their subsequent recapture as age 2+ varies by a few days between year classes due to differences in the starting date of sampling. Rates were standardized to one year (365 days) to compare survival estimates between year classes (Table 7). The standardized rates varied with year class and age. The standardized survival rate from age 1+ to age 2+ ranges from 0.201 to 0.510 (Table 7) and has a mean value of 0.360. Age 2+ to age 3+ survival is higher and has a mean value of 0.618 and a range of 0.474 to 0.890. Abundance estimates (Table 8) were calculated from data in Tables 5 and 7.

Discussion

The validity of the estimates of abundance depends on the extent to which assumptions that underlie the estimators are satisfied. In this section, each of the key assumptions is addressed.

Equal Mortality Rates for Tagged and Untagged Fish

Results from field and experimental studies of tagging mortality indicate that tagging and handling induced mortality has been small, and that the mortality rates of tagged and untagged fish are indistinguishable.

Dunning et al. (1987) found no statistically significant differences in 24-hour mortality between striped bass tagged with anchor tags, tagged with internal anchors tags, double tagged, and not tagged. These conclusions were based on a 1984 study of 736 striped bass captured by an otter trawl, a Jackson 280 modified box trawl, and a Kosalt 360 plaice seine between April 12 and June 2. Twenty-four-hour mortality was determined for a random subsample of 247 striped bass that were held in cages suspended in the Hudson River at a salinity of less than 1 ‰. Although no effects of tagging on mortality were noted, mortality was positively related to temperature between 8 and 16.5 °C.

After 1984, the Utilities' mark-recapture programs were conducted in the lower part of the Hudson River estuary in winter when mortality rates should be minimal due to high salinity and low temperature. Also, in the mark-recapture programs after 1984, trawl catches were transferred to a partially-submerged holding tank to lessen handling and tagging stress of captured striped bass. Use of the holding tank decreased the immediate mortality of striped bass to below 1.2% (Dunning et al. 1989) and eliminated the relationship of mortality and temperature found in the original tagging mortality study (Dunning et al. 1987)

Dunning et al. (1987) also reported no significant difference in 180-day mortality between tagged and untagged fish held in pools. In this study, striped bass were held after tagging for 180 days in pools containing either fresh water (at 18 °C) or salt water (28 - 39 ‰ at 9 to 25°C). Fish were randomly assigned to 5 tagging treatments: tagged with an anchor tag, tagged with an internal anchor, tagged with both, tagged with a dart tag, or not tagged (control). Initial (24-hr) mortality in the holding pools was less than 2% for all tagged and untagged striped bass. Due to a protozoan infection, none of the striped bass held in freshwater pools survived beyond 28 days. At the end of the study (180 days), mortality rates ranged from 73% for controls to 80% for fish with both internal anchors and fish with both internal anchors and anchor tags.

Tags Not Lost During the Experiment

Results from field and experimental studies of tag loss indicate that some tags are lost between the time of tagging and the time of recapture, one year later.

Rates of tag retention were evaluated during the tagging mortality experiments described above. The 24-hr tag retention rate (based on 247 striped bass) was 100% (Dunning et al. 1987). For striped bass held in pools for 180 days, the retention rates for internal anchor tags was 98.1% (Dunning et al. 1987). No internal anchor tags were lost after day 18 of the experiment.

In the 1984 mark-recapture program, striped bass were double-tagged with anchor tags and internal anchor tags. The retention rate of each tag relative to the other (Dunning et al. 1987) were calculated as the numbers of fish captured with each type of tag divided by the total number of recaptured fish with either tag attached. Within the 1984-1985 mark-recapture program, the relative retention rates were 98.0% for internal

anchor tags and 42.0% for anchor tags. For fish tagged in the 1984 program and recaptured in the 1985-1986 program, the relative retention rate was 92% for internal anchor tags and 8% for anchor tags (Waldman et al. 1991). Those data are unusual in that one striped bass was recovered that had an anchor tag but no internal anchor tag.

In addition to tag retention, tags must be legible for use in abundance estimates. Loss of legibility is a second form of tag loss that needs to be considered. Estimates of "tag survival" based on legibility were computed as the ratio of the number of tags with legible data divided by the total number of tags recovered. Estimates of this type of tag survival were computed for each year of recaptures (Table 9). These are minimum estimates of annual tag survival because some of the fish could have been tagged more that one year prior to recapture. Estimates of tag survival (based on tag legibility) ranged from 72% for recaptures reported between 1991 and 1993 to 100% for recaptures reported between 1995 and 1997.

Estimates of age 2+ abundance are not biased by tagging mortality and tag loss (see Attachment 1); however, tag loss may produce overestimates of age 1+ abundance (see Attachment 2). The age-2+ abundance estimator is not affected by tag loss because it explicitly includes an empirical estimate of year-specific survival of tags, including tag retention and legibility. The age-1+ estimates would be biased high by a factor equal to the reciprocal of the combined (i.e., tag loss and legibility) survival rate for tags. Based on the estimated tag survival rates discussed above (92% to 98% for tag loss for internal anchor tags and 72% to 100% for legibility), age-1+ abundance may be overestimated by 2% to 51%.

Equal Catchability for Tagged and Untagged Fish

Concern over this assumption may arise when recapture is done using gear such as gill nets in which tags can become entangled. Because recaptures are performed with trawls, catchability of tagged striped bass would not be affected by entanglement or like processes. Concern over this assumption also may arise when fish of several ages are marked and fish of those ages have different patterns of movement and behavior that affect the probability of recapture. Because recaptures of only age-2+ striped bass are used in the population estimates, effects on catchability due to differential behavior are likely to be minimal.

All Recaptures Reported

Field, laboratory, and quality control procedures were directed toward assuring that field crews recognized and reported recaptured striped bass. These protocols included reporting illegible tags, use of labeled internal anchor tags, and examination by crews for tagging scars.

Ratio of Tagged to Untagged Fish Within the Area Sampled Equal to the Ratio for the Population as a Whole

Some degree of mixing of marked and unmarked fish occurs naturally between tagging at age 1+ and recapture at age 2+. This extended period between tagging and recapture was selected with the intention of allowing for thorough mixing of marked fish into the population. Use of recapture information after a year of mixing of marked and unmarked fish reduces the chance of bias in the population estimates.

All Striped Bass Collected are of Hudson River Origin

Stock discrimination studies and mark-recapture studies conducted in the Hudson River estuary and the New York Bight support the conclusion that most age-1+ and age-2+ striped bass in the Lower Hudson River during the winter are of Hudson River origin.

Berggren and Lieberman (1978) suggested that striped bass overwintering in the Hudson River were primarily of Hudson River origin. This conclusion was based on a discriminant analysis of morphological characters to determine the relative contribution of Hudson River striped bass to the Atlantic coast population. Earlier, investigators in the 1950s suggested that striped bass from the Chesapeake might overwinter in the Hudson River (Vladykov and Wallace 1952, Raney 1952). Subsequent tagging studies (McLaren et al. 1981, Boreman and Lewis 1987) did not support that conclusion. Van Winkle et al. (1988) suggested that few age-2+ or age-3+ striped bass move from the Hudson River estuary, based on the low number of recaptures of age-2+ and age-3+ male, and age-2+ through age-5+ female, striped bass in ocean waters.

More recently, Waldman et al. (1990) suggested that age 1+ and age 2+ in the lower Hudson River in winter are of Hudson River origin, and that the population is relatively closed. This conclusion was based on an examination of distribution patterns of recaptured Hudson River striped bass from the utilities 1984-1987 mark-recapture studies and additional information compiled by the Hudson River Foundation. The majority of recaptured striped bass were found within a 50-km radius of the river mouth. Also, smaller striped bass tended to be recaptured closer to the river than larger striped bass.

References

Berggren, T.J., and J.T. Lieberman. 1978. Relative contribution of Hudson, Chesapeake, and Roanoke striped bass, *Morone saxatilis*, stocks to the Atlantic east coast fishery. Fishery Bulletin 76(2):335-345.

Boreman, J., and R.R. Lewis. 1987. Atlantic coastal migration of striped bass. American Fisheries Society Symposium 1:331-339.

Brownie, C., D.R. Anderson, K.P. Burnham, and D.S. Robson. 1985. Statistical inference from band recovery data--A handbook. 2nd edition. U.S. Department of the Interior, Fish and Wildlife Service, Resource Publication 156, Washington, DC

Coastal (Coastal Environmental Services, Inc.). 1992. 1991 Supplement to the Hudson River Striped Bass Stock Assessment. Final Report. Prepared for New York Power Authority, White Plains, New York. Coastal Environmental Services, Inc., Linthicum, Maryland.

Dunning, D.J., Q.E. Ross, J.R. Waldman, and M.T. Mattson. 1987. Tag retention by, and tagging mortality of, Hudson River striped bass. North American Journal of Fisheries Management 7:535-538.

Dunning, D.J., Q.E. Ross, M.T. Mattson, P. Geoghegan, and J.R. Waldman. 1989. Reducing mortality of striped bass captured in seines and trawls. North American Journal of Fisheries Management 9:171-176.

LMS (Lawler, Matusky & Skelly Engineers). 1999a. Hudson River Striped Bass Stock Assessment Program November 1994 - April 1995. Prepared for New York Power Authority, White Plains, New York. Lawler, Matusky & Skelly Engineers, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1999b. Hudson River Striped Bass Stock Assessment Program November 1995 - April 1996. Prepared for New York Power Authority, White Plains, New York. Lawler, Matusky & Skelly Engineers, Pearl River, New York.

LMS (Lawler, Matusky & Skelly Engineers). 1999c. Hudson River Striped Bass Stock Assessment Program November 1996 - April 1997. Prepared for New York Power Authority, White Plains, New York. Lawler, Matusky & Skelly Engineers, Pearl River, New York.

Martin Marietta Environmental Systems. 1986. An Overall Study Design for a Hatchery Evaluation and Population Assessment for Hudson River Striped Bass. Prepared for New York Power Authority, White Plains, New York. Martin Marietta Environmental Systems, Columbia, Maryland.

McLaren, J.B., J.C. Cooper, T.B. Hoff, and V. Lander. 1981. Movements of Hudson River striped bass. Transactions of the American Fisheries Society110:167-168.

NAI (Normandeau Associates Inc.). 1986. 1985-86 Hudson River Striped Bass Program. R-503-2. Prepared for New York Power Authority, White Plains, New York. Normandeau Associates, Inc., Bedford, New Hampshire.

NAI (Normandeau Associates Inc.). 1987. 1986-87 Hudson River Striped Bass Hatchery Evaluation. R-0012. Prepared for New York Power Authority, White Plains, New York. Normandeau Associates Inc., Bedford, New Hampshire.

NAI (Normandeau Associates Inc.). 1988. 1987-88 Hudson River Striped Bass Hatchery Evaluation. R-1163-3. Prepared for New York Power Authority, White Plains, New York. Normandeau Associates Inc., Bedford, New Hampshire.

NAI (Normandeau Associates Inc.). 1990. 1988-89 Hudson River Striped Bass Hatchery Evaluation. R-1250.00. Prepared for New York Power Authority, White Plains, New York. Normandeau Associates Inc., Bedford, New Hampshire.

NAI (Normandeau Associates Inc.). 1991. 1990-91 Hudson River Striped Bass Stock Assessment. R-1250.02-189, Draft. Prepared for New York Power Authority, White Plains, New York. Normandeau Associates, Inc., Bedford, New Hampshire.

NAI (Normandeau Associates Inc.). 1995a. Hudson River Striped Bass Stock Assessment Program November 1992 - April 1993. Prepared for New York Power Authority, White Plains, New York. Normandeau Associates, Inc., Bedford, New Hampshire.

NAI (Normandeau Associates Inc.). 1995b. Hudson River Striped Bass Stock Assessment program November 1993 - April 1994. Prepared for New York Power Authority, White Plains, New York. Normandeau Associates, Inc., Bedford, New Hampshire.

NAI (Normandeau Associates Inc.). 1999. Hudson River Striped Bass Stock Assessment Program November 1997 - April 1998. Prepared for New York Power Authority, White Plains, New York. Normandeau Associates, Inc., Bedford, New Hampshire.

Raney, E.C. 1952. The life history of striped bass *Roccus saxatilis* (Walbaum). Bulletin of the Bingham Oceanographic Collection, Yale University 14(1):5-97. Cited in Boreman and Lewis (1987).

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Department of Fisheries and Oceans, Bulletin 191, Ottawa, Canada.

Robson, D.S., and W.D. Youngs. 1971. Statistical analysis of reported tag-recaptures in the harvest from an exploited population. Biometrics Unit, Cornell University, BU-369-M, Ithaca, New York.

Seber, G.A.F. 1982. The estimation of animal abundance, 2nd edition. MacMillan Publishing Co., Inc., New York.

Van Winkle, W., K.D. Kumar, and D.S. Vaughan. 1988. Relative contributions of Hudson River and Chesapeake Bay striped bass stocks to the Atlantic coast population. American Fisheries Society Monograph 4:255-266.

Vladykov, V.D., and D.H. Wallace. 1952. Studies of striped bass, *Roccus saxatilis* (Walbaum), with special reference to the Chesapeake Bay region during 1936-1938. Bulletin of the Bingham Oceanographic Collection, Yale University14(1):132-172. Cited in Boreman and Lewis (1987).

Waldman, J.R. 1989. Hudson River Striped Bass Tag Recovery Program, March 1987-February 1988. Prepared for the New York Power Authority, White Plains, NY.

Waldman, J.R., D.J. Dunning, Q.E. Ross, and M.T. Mattson. 1990. Range dynamics of Hudson River striped bass along the Atlantic coast. Transactions of the American Fisheries Society 119:910-919.

Waldman, J.R., D.J. Dunning, and M.T. Mattson. 1991. Long term retention of anchor tags and internal anchor tags by striped bass. North American Journal of Fisheries Management 11:232-234.

White, G.C., D.R. Anderson, K.P. Burnham, and D.L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory, LA-8787-NERP, New Mexico.

Table 1.— Symbolic representation of the data for a tagging study in which yearling and nonharvestable adult fish are tagged and released each year (after Brownie et al. 1985, Table 4.1). In this example table $k = 3$, $l = 5$, and $s = l - k = 2$.

Year Tagged	Number Tagged	Year of Recovery 1	2	3	4	$l = 5$	Row Totals
Fish tagged as nonharvestable adults							
1	N_1	R_{11}	R_{12}	R_{13}	R_{14}	R_{15}	$R_{1\cdot} = T_1$
2	N_2	T_1	R_{22}	R_{23}	R_{24}	R_{25}	$R_{2\cdot}$
$k = 3$	N_3		T_2	R_{33}	R_{34}	R_{35}	$R_{3\cdot}$
				T_3	T_4		
Column Totals		$R_{\cdot 1}$	$R_{\cdot 2}$	$R_{\cdot 3}$	$R_{\cdot 4}$	$R_{\cdot 5} = T_5$	
Fish tagged as yearlings							
1	M_1	Q_{11}	Q_{12}	Q_{13}	Q_{14}	Q_{15}	$Q_{1\cdot} = U_1$
2	M_2	U_1	Q_{22}	Q_{23}	Q_{24}	Q_{25}	$Q_{2\cdot}$
$k = 3$	M_3		U_2	Q_{33}	Q_{34}	Q_{35}	$Q_{3\cdot}$
				U_3	U_4		
Column Totals		$Q_{\cdot 1}$	$Q_{\cdot 2}$	$Q_{\cdot 3}$	$Q_{\cdot 4}$	$Q_{\cdot 5} = U_5$	

Note that:

$$T_i = \begin{cases} R_{i\bullet} & ; i = 1 \\ R_{i\bullet} + T_{i-1} - R_{\bullet,i-1} & ; i = 2,\ldots,k \\ T_{i-1} - R_{\bullet,i-1} & ; i = k+1,\ldots,l \quad if \quad l > k. \end{cases}$$

and

$$U_i = \begin{cases} Q_{i\bullet} & ; i = 1 \\ Q_{i\bullet} + U_{i-1} - Q_{\bullet,i-1} & ; i = 2,\ldots,k \\ U_{i-1} - Q_{\bullet,i-1} & ; i = k+1,\ldots,l \quad if \quad l > k. \end{cases}$$

Table 2.—Extent of sampling for mark-recapture studies on the Hudson River from 1984 through 1997.

Program	Date		Number of Tows	Region			
	Start	End		IP, WP, CW, PK	TZ, CH	HR, ER, LH	BT, UH
1984	Apr. 9	Jun 7	339	X	X		
1985-1986	Nov 11	May 18	1,472		X	X	X
1986-1987	Dec 21	May 9	1,064				X
1987-1988	Nov 9	Apr 22	1,192				X
1988-1989	Oct. 15	Apr 15	1,151				X
1989-1990	Oct 31	Apr 15	891				X
1990-1991	Nov 12	Apr 20	971				X
1991-1992	Nov 4	May 7	1,169				X
1992-1993	Nov 6	Apr 16	818				X
1993-1994	Nov 1	Apr 20	794				X
1994-1995	Nov 2	Apr 14	819				X
1995-1996	Nov 6	Apr 15	806				X
1996-1997	Nov 4	Apr 13	954				X

UH = Upper Harbor, Hudson River Miles -6-0 (km -9-0);
BT = Battery, Hudson River Miles 0-11 (km 0-18);
TZ = Tappan Zee, Hudson River Miles 24-33 (km 38-53);
CH = Croton-Haverstraw, Hudson River Miles 34-38 (km 54-61);
IP = Indian Point, Hudson River Miles 39-46 (km 62-74);
CW = Cornwall, Hudson River Miles 56-61 (km 90-98);
PK = Poughkeepsie, Hudson River Miles 62-76 (km 99-122);
ER = East River;
LH = Lower New York Harbor; and
HR = Harlem River.

Table 3.—Primary fishing gear for the Hudson River striped bass adult stock assessment.

Program Year	Gear Type						Ref.
	Scottish Seine	12-m Trawl Without Cod End Liner	12-m Trawl With 2.5-cm Cod End Liner	12-m Trawl With 9-m Cod End	9-m Trawl Without Cod End Liner	9-m Trawl With 2.5-cm Cod End Liner	
1984	X	X					NAI 99
1985-1986	X	X			X		NAI 86
1986-1987		X	X		X	X	NAI 87
1987-1988				X	X		NAI 88
1988-1989					X		NAI 90
1989-1990					X		LMS 99a
1990-1991					X		NAI 91
1991-1992					X		LMS 99a
1992-1993					X		LMS 99a
1993-1994					X		LMS 99a
1994-1995					X		LMS 99a
1995-1996					X		LMS 99b
1996-1997					X		LMS 99c
1997-1998					X		NAI 99

Table 4.—Tag type and number of striped bass tagged and released for the Hudson River Striped bass adult stock assessment.

Program Year	Number Tagged	Tag Type					
		Anchor	Internal Anchor (Floy)	Internal Anchor W/Tube (Floy)	Internal Anchor (Hall)	Modified Internal Anchor (Hall)	Small Dart (Hall)
1984	737	737*	737				
1985-1986	18,448		18,448				
1986-1987	9,437		7,258	2,215			
1987-1988	12,433		1,598	2,360	8,475		
1988-1989	24,393				7,927	16,466	819*
1989-1990	24,362					24,362	659*
1990-1991	22,406					22,406	
1991-1992	24,307					24,307	
1992-1993	21,746					21,746	
1993-1994	18,310					18,310	
1994-1995	6,838					6,838	
1995-1996	11,015					11,015	
1996-1997	13,011					13,011	
1997-1998	14,986					14,986	
Totals	222,465	737	28,041	4.575	16,402	173,447	1,478

Data from NAI (1999, Hudson River Striped Bass Stock Assessment Program November 1997 - April 1998, Appendix Table D-6)
* Not included in row total because fish were double-tagged.
Hall = Hallprint

Table 5.—Mark-recapture data used to estimate abundance of Hudson River striped bass using equations (1) and (5).

Year Class	Marked and Released at Age 1 (M_y)	Marked at Age 1 and Recaptured at Age 2 (R_{y+1})	Estimated[a] Total Number of Age 2 Captured ($\hat{C}_{y+1}$)
1984	4,248	29	5,606
1985	2,373	21	3,025
1986	3,605	19	1,484
1987	15,250	47	4,118
1988	15,024	158	11,865
1989	7,332	35	4,337
1990	10,164	56	4,504
1991	9,565	53	5,633
1992	7,371	13	1,571
1993	2,411	4	1,652
1994	5,125	17	3,781
1995	4,261	35	7,026

[a] Estimated from length frequency of catch and age-length keys.

Table 6.— Mark-recapture data arranged to estimate survival rates as in Table 1 with $k = 13$, $l = 14$, and $s = l - k = 1$.

Winter Marked	i	Number Marked	Winter of Recovery / i													
			84-85	85-86	86-87	87-88	88-89	89-90	90-91	91-92	92-93	93-94	94-95	95-96	96-97	97-98
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Marked as Age 2+ to Age 4+ ($R_{i+1,j+1}$)																
	(i)	(N_i)														
84	1	543	0	0	8	4	0	2	1	0	0	0	0	0	0	0
85-86	2	13912		485	311	163	88	63	48	34	28	14	2	6	4	0
86-87	3	6989			270	136	101	47	24	28	19	7	4	3	1	0
87-88	4	8799				232	247	122	74	42	24	18	16	9	7	1
88-89	5	7471					302	210	130	70	55	29	25	13	13	2
89-90	6	7262						307	195	121	57	31	23	24	11	2
90-91	7	14723							520	305	155	88	41	29	28	3
91-92	8	12342								426	294	137	57	50	33	3
92-93	9	11034									398	213	82	60	46	4
93-94	10	9777										368	104	63	36	7
94-95	11	4270											128	67	37	4
95-96	12	5218												164	94	10
96-97	13	8486													216	32
Marked as Yearling (Age 1+) ($Q_{i,i}$)																
	(i)	(M_i)														
84	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85-86	2	4248		91	44	25	11	8	1	3	4	3	1	0	0	0
86-87	3	2373			55	31	19	4	8	6	3	1	1	1	0	0
87-88	4	3605				67	72	41	18	18	6	8	3	3	1	1
88-89	5	15250					237	257	153	107	64	42	29	33	21	1
89-90	6	15024						243	237	123	65	49	25	27	11	1
90-91	7	7332							147	104	55	40	9	7	6	0
91-92	8	10164								158	166	70	20	29	5	0
92-93	9	9565									169	116	38	29	15	0
93-94	10	7371										164	59	22	9	0
94-95	11	2411											32	20	5	0
95-96	12	5125												77	51	10
96-97	13	4261													70	19

Subtotals

Winter Marked	i	$R_{i\cdot}$	$R_{\cdot i}$	$Q_{i\cdot}$	$Q_{\cdot i}$	T_i	U_i	$W_i = R_{\cdot i}+Q_{\cdot i}-Q_{ii}$	$A_i = T_i+U_i-Q_i$
84-85	1	15	0	0	0	15	0	0	15
85-86	2	1,246	485	191	91	1,261	191	485	1,261
86-87	3	640	589	129	99	1,416	229	633	1,516
87-88	4	792	535	238	123	1,619	368	591	1,749
88-89	5	849	738	944	339	1,933	1,189	840	2,178
89-90	6	771	751	781	553	1,966	1,631	1,061	2,816
90-91	7	1,169	992	368	564	2,384	1,446	1,409	3,462
91-92	8	1,000	1,026	448	519	2,392	1,330	1,387	3,274
92-93	9	803	1,030	367	532	2,169	1,178	1,393	2,980
93-94	10	578	905	254	493	1,717	900	1,234	2,363
94-95	11	236	482	57	217	1,048	464	667	1,455
95-96	12	268	488	138	248	834	385	659	1,081
96-97	13	248	526	89	194	594	226	650	731

Note on use of table: The 1990 year class, for example, was tagged at age 1+ in the winter program of 1991-1992, so that $i = 8$ and $i + 1 = 9$ in this table and equations (3) and (4).

Table 7.— Survival rate estimates (with standard error) for Hudson River striped bass used in equation (5) and annualized values for comparisons among year classes.

Year Class	Age 1 to Age 2				Age 2 to Age 3			
	Survival Rate ($\hat{S}_{t-1}$)		Annualized[a] Survival Rate		Survival Rate		Annualized[a] Survival Rate	
1984	0.260	(0.030)	0.293	(0.030)	0.519	(0.036)	0.476	(0.037)
1985	0.306	(0.038)	0.262	(0.037)	0.516	(0.032)	0.509	(0.032)
1986	0.385	(0.034)	0.377	(0.034)	0.722	(0.046)	0.721	(0.046)
1987	0.457	(0.028)	0.456	(0.028)	0.886	(0.054)	0.890	(0.053)
1988	0.497	(0.030)	0.510	(0.029)	0.546	(0.032)	0.538	(0.032)
1989	0.374	(0.030)	0.364	(0.030)	0.686	(0.046)	0.686	(0.046)
1990	0.421	(0.033)	0.420	(0.033)	0.876	(0.076)	0.876	(0.076)
1991	0.494	(0.050)	0.494	(0.050)	0.469	(0.056)	0.474	(0.056)
1992	0.267	(0.038)	0.272	(0.038)	0.492	(0.070)	0.491	(0.070)
1993	0.202	(0.045)	0.201	(0.045)	0.520	(0.126)	0.520	(0.126)
1994	0.311	(0.080)	0.310	(0.080)	NA	NA	NA	NA

[a] One year, February to February.
NA = Not available.

Table 8.—Estimates of abundance of age-1+ and age-2+ Hudson River striped bass based on mark-recapture data. Values are in thousands.

Year Class	Age 1+ Abundance		Age 2+ Abundance	
	Estimate	Std. Error	Estimate	Std. Error
1984	821	152	213	46
1985	342	74	104	26
1986	282	64	108	26
1987	1,336	194	611	96
1988	1,128	89	560	55
1989	908	153	339	63
1990	817	109	344	53
1991	1,017	139	502	85
1992	891	246	238	74
1993	996	497	201	110
1994	1,140	276	354	125
1995[a]	855	144	NA	NA

[a] = Preliminary estimate that has not undergone QC examination.
NA = Not available

Table 9.—Tag condition for Hudson River striped bass tagged and released in a program prior to capture.

Program Year	Tag No. Completely Legible	Tag No. Abraded But Legible	Tag No. Partly or Completely Missing: Not Legible	Suspected Tag Wound		Total	Reference	Percent of Tags Recovered With Useable Data From Previous Programs
				Tag and Anchor Missing	Only Anchor Present			
1984	-	-	-	-				
1985 - 1986	**0**	**0**	0	0	2	2	NAI 86	0%
1986 - 1987	96	17	10	4	0	127	NAI 87	Insuff. Data
1987 - 1988	118	11	5	9	0	143	NAI 88	Insuff. Data
1988 - 1989	**47**	**6**	**0**	4	**2**	59	NAI 92	55/59 = 93%
1989 - 1990	**69**	**3**	**0**	6	**0**	78	NAI 92	72/78 = 92%
1990 - 1991	**228**	**2**	**1**	72	**9**	312	NAI 92	240/312 = 77%
1991 - 1992	**117**	**1**	2	47	**10**	177	NAI 94	128/177 = 72%
1992 - 1993	**147**	**1**	0	64	**15**	227	NAI 95a	163/227 = 72%
1993 - 1994	**129**	**0**	0	31	**18**	178	NAI 95b	147/178 = 83%
1994 - 1995	**29**	**0**	1	0	**0**	30	LMS 99a	29/30 = 97%
1995 - 1996	**5**	**1**	0	0	**0**	6	LMS 99b	6/6 = 100%
1996 - 1997	**37**	**0**	0	0	**0**	37	LMS 99c	37/37 = 100%
1997 - 1998	**72**	**0**	0	25	**8**	105	NAI 99	80/105 = 76%
Totals	1,094	42	19	262	64	1481		

Bolding indicates tag conditions that yield useable data and that are counted in the last column.

Attachment
Relative and Absolute Estimators of Abundance

Age 1+

The Petersen estimator for age 1+ striped bass (ignoring subscripts) is

$$\hat{N1} = \frac{M \cdot C}{R}, \qquad \text{(A-1)}$$

where

$\hat{N1}$	=	the estimated abundance of age 1+ fish,
M	=	the number of fish marked and released,
C	=	the number of fish collected, and
R	=	the number of tagged fish that are recaptured.

If mortality occurs between tagging and recapture and the survival rates of tagged and untagged fish are equal, the expected values of R and C are

$$\mathrm{E}(R) = M \cdot S \cdot q \text{ and} \qquad \text{(A-2)}$$
$$\mathrm{E}(C) = N1 \cdot S \cdot q,$$

where

$N1$	=	the actual abundance of age 1+ fish at the time of tagging,
S	=	the survival rate, and
q	=	the proportion of the total population $N1$ that is captured.

Substituting the expected values (A-2) into equation (A-1) gives

$$\mathrm{E}(\hat{N1}) \cong \frac{M(N1 \cdot S \cdot q)}{(M \cdot S \cdot q)} \cong N1, \qquad \text{(A-3)}$$

which shows that the approximate expected value of $\hat{N1}$ is the absolute abundance $N1$ (see Seber 1982 for a discussion of the accuracy of this approximation)

Because the number of racaptured fish depends on the ability to recognize tags, the survival rate of tagged fish depends on both the survival rate of the fish and the rate at which the fish retain the tags. In studies such as the present one, where the period between tagging and recapture can be long (about a year in this study), fish may loose tags, and the rate at which the fish retain tags can become important. In practice, the survival rate S of recaptured fish in E(R) has two components:

$$S = S_F \cdot S_T, \qquad \text{(A-4)}$$

where

S_F = the survival rate of the fish and
S_T = the survival (retention and legibility) rate of the tags on the fish.

The survival rate of tags on the fish does not, however, affect the total survival rate for term C, the number of fish captured, and so for E(C),

$$S = S_F. \tag{A-5}$$

With these considerations and equations (A-3) through (A-5),

$$E(\hat{N}1) \cong \frac{M(N1 \cdot S_F \cdot q)}{M(S_F \cdot S_T)q} \cong \frac{N1}{S_T}. \tag{A-6}$$

From equation (A-6), $\hat{N}1$ estimates absolute abundance only when the retention rate of tags is 100%. At other retention rates, $\hat{N}1$ is an upwardly biased estimate that can be used to measure relative abundance if one assumes that the tag survival rate is constant among years.

Age 2+

The abundance estimator for age 2+ fish, $\hat{N}2$, is

$$\hat{N}2 = \hat{N}1 \cdot \hat{S}, \tag{A-7}$$

where

$\hat{S}$ = the estimated survival rate of tagged fish.

Here the survival estimate is based on recaptures of fish that have been at large for about a year or more, and it includes both survival of the fish and survival of tags on the fish. With this information, equation (A-6), and the assumption that $\mathrm{E}(\hat{S}) = S_F S_T$, equation (A-7) becomes

$$\mathrm{E}(\hat{N}2) \cong \frac{N1}{S_T}(S_F \cdot S_T) \cong N1 \cdot S_F, \tag{A-8}$$

and the approximate expected value of $\hat{N}2$ is the abundance of fish at age 2+ (i.e., $N2 = N1 \cdot S_F$).

APPENDIX VI-2-D

ESTIMATED TOTAL NUMBER OF FISH IMPINGED

Estimated number impinged : Alewife Roseton

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	7	4835	0
Jul	2722	426	2699	815	2023	1164	1467	942	198	1838	11953	254
Aug	16228	582	4861	794	1175	426	4307	2924	105	2837	5317	4183
Sep	4884	546	887	97	487	61	905	241	188	562	1609	3199
Oct	3362	169	1005	494	72	281	1680	586	233	115	920	1272
Nov	253	321	218	278	263	640	72	74	0	1290	166	134
Dec	0	15	0	0	0	32	0	0	0	0	0	0

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	8	0	0	0	0	0	0	0	0
Feb	0	0	0	0	11	0	0	0	0	0	0	0
Mar	19	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	8	30	0	0	0	0	0	0	0	0
May	0	15	8	490	0	0	87	0	0	0	27	20
Jun	0	0	0	9	6	0	9	26	19	0	65	107
Jul	45	7	68	39	974	24	33	26	8	9	40	12
Aug	225	97	167	55	16	16	131	258	36	4	140	52
Sep	69	66	31	11	19	46	68	10	53	12	38	46
Oct	0	18	11	24	0	37	20	0	0	0	20	5
Nov	0	0	0	11	0	62	4	0	0	0	0	8
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	6	0	0	0	0	0	0	0
Mar	0	0	4	0	0	0	0	0	8	16	0	17
Apr	0	10	8	0	16	0	31	0	30	8	0	45
May	34	8	86	0	15	17	33	8	16	7	47	72
Jun	0	0	10	8	9	0	17	24	18	14	16	0
Jul	0	0	0	0	21	14	6	9	0	0	25	0
Aug	50	5	24	0	13	8	60	20	0	8	70	10
Sep	23	14	6	0	19	0	21	0	0	0	32	18
Oct	0	8	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Estimated number impinged :

Alewife

Roseton

Young-of-Year

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	33	0
1015	19205	9787	0
1049	5259	2385	532
1431	794	8	82
2701	2401	294	116
332	853	144	255
4	7	0	362

Yearling

1993	1994	1995	1996
0	0	12	0
0	0	0	751
0	35	27	15
0	9	0	0
0	0	59	0
9	14	4	1
51	0	1385	0
17	42	445	47
97	0	8	1
29	0	8	1
0	0	0	0
0	0	0	40

Adults

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	35
0	0	15	8
0	15	7	6
9	22	0	4
0	0	31	0
0	0	12	2
0	0	0	0
0	11	0	0
0	0	0	6
0	0	0	0

Estimated number impinged : **American shad** **Roseton**

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	6	5	0	5	0	0	10245	0
Jul	4127	604	1425	0	535	1612	252	1452	411	2652	4850	304
Aug	8089	1171	2230	257	582	1248	877	1308	100	622	853	2612
Sep	2752	253	283	72	285	38	469	155	688	300	782	1167
Oct	2673	176	1159	1418	77	903	748	812	1119	226	256	401
Nov	235	429	52	384	231	189	46	0	41	1019	91	61
Dec	0	7	0	0	8	0	0	0	0	0	0	0

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	7	0	0
Jul	0	0	0	0	183	5	0	0	0	0	8	0
Aug	0	0	13	0	0	0	11	0	0	0	8	33
Sep	0	4	21	0	0	0	0	0	7	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	4	0	0	0	0	0	0	0	0	0
Apr	0	0	4	0	0	0	0	0	0	0	0	0
May	0	0	13	0	6	0	0	8	8	0	0	0
Jun	0	0	0	0	0	0	0	8	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0	0	0
Aug	0	0	5	0	11	8	0	0	0	0	14	11
Sep	23	0	0	0	3	0	0	0	0	0	0	8
Oct	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Estimated number impinged : **American shad** **Roseton**

Young-of-Year

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	210	16	0
.	5833	6344	10
.	669	929	150
.	100	15	15
.	257	62	35
.	219	74	39
0	7	0	0

Yearling

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	109	4	0
.	0	0	0
.	0	7	0
.	0	0	0
.	0	0	0
.	0	0	0
0	0	0	0

Adults

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
.	0	0	0
.	0	7	0
.	0	0	0
.	0	0	0
.	0	0	0
0	0	0	0

Estimated number impinged : **Atlantic tomcod** **Roseton**

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	0	8	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	50	32	73	63	46	8	971	38	24	45	24	42
Jun	32	135	23	976	180	9	1859	106	116	53	390	0
Jul	112	25	71	137	418	19	194	46	15	17	7038	8
Aug	851	75	307	1034	683	0	528	9	57	23	7235	75
Sep	344	77	63	108	430	0	71	0	113	6	38	90
Oct	20	235	36	54	0	0	0	15	6	7	0	16
Nov	253	106	0	30	0	17	7	8	45	48	0	0
Dec	3709	19	41	16	8	221	20	64	248	8	0	35

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	1064	167	8	172	132	243	170	55	358	275	24
Feb	0	51	42	36	88	22	0	0	0	119	7	0
Mar	0	18	32	0	36	0	0	7	0	62	0	0
Apr	0	22	7	0	8	0	0	7	8	0	0	0
May	0	0	0	37	0	0	0	0	0	0	0	0
Jun	0	0	0	98	0	0	0	0	0	15	0	0
Jul	0	0	0	0	0	0	8	8	0	17	0	0
Aug	0	0	0	0	53	0	0	0	0	0	0	0
Sep	0	19	6	0	113	0	10	0	0	0	0	0
Oct	0	0	3	0	0	0	0	0	0	0	0	0
Nov	18	0	0	0	0	7	0	0	16	0	0	0
Dec	204	0	6	0	0	4	4	0	8	0	0	0

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	19	7	101	47	0	11	0	0	8	7	0
Feb	0	0	0	0	9	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Estimated number impinged : **Atlantic tomcod** **Roseton**

Young-of-Year

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	115	179	0
20	63	400	11
55	15	1003	0
564	0	22	25
183	0	0	22
0	8	0	0
0	0	0	6
79	0	0	300

Yearling

1993	1994	1995	1996
156	164	6	8
7	7	0	4
0	11	0	0
0	0	0	0
0	0	22	0
0	0	6	0
0	0	19	0
65	0	0	0
24	0	0	0
0	0	0	0
0	0	0	0
0	0	0	4

Adults

1993	1994	1995	1996
0	16	0	0
0	7	0	0
0	5	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	1

Estimated number impinged :

Roseton

Bay anchovy

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	7
Jul	0	0	0	0	0	0	0	0	0	0	4687	0
Aug	1445	58	562	8	200	16	434	260	17	7001	142973	199
Sep	3889	1180	3176	255	566	183	666	519	264	61604	132537	7943
Oct	172	1007	2712	1128	86	24	73	2617	62	6707	58114	16660
Nov	0	40	77	34	0	0	0	0	0	0	8	0
Dec	0	0	0	0	0	0	0	0	0	0	0	7

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	8	8	10	8	0	0	0	0	0	0	7	20
Jun	8	0	18	26	2561	29	0	0	0	15	29	79
Jul	4495	539	9579	4664	6717	2151	784	297	0	76	23557	113
Aug	19505	41024	39433	22648	7049	3020	13133	2038	0	4810	36614	12265
Sep	4141	2369	6157	690	1920	648	755	285	159	1158	45164	7734
Oct	57	694	1444	1093	17	30	39	690	0	8	2396	708
Nov	0	45	20	23	8	0	0	0	0	0	7	0
Dec	0	0	0	0	0	0	0	0	0	0	7	0

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0	0	0
Aug	36	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Estimated number impinged :

Bay anchovy
Young-of-Year

Roseton

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	217	734 .	
634	2023	25417 .	
2636	4820	50 .	
1249	272	21543	0
0	60	0	0
0	0	0	0

Yearling

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
1644	0	3688 .	
4632	0	4575 .	
2247	0	61 .	
19	0	10077	0
0	0	0	0
0	0	0	0

Adults

1993	1994	1995	1996
0	8	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0 .	
0	0	0 .	
0	0	0 .	
0	0	0	0
0	0	0	0
0	0	0	0

Estimated number Impinged : Blueback herring Roseton

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	9110	569
Jul	1517	346	2254	22	628	179	488	285	0	4616	14487	3661
Aug	21337	2188	2011	257	2455	891	5543	1835	92	13519	6089	25991
Sep	35334	4808	2068	33	945	327	39529	1487	4503	23677	9408	32666
Oct	60255	7981	32702	298	6434	6523	89639	43170	15321	15831	17053	18385
Nov	7115	7936	3697	83	7973	1532	2586	4838	2512	16646	11989	474
Dec	19	90	54	39	8	0	0	0	0	8	88	0

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	8	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	7	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	17	0
Apr	0	0	0	0	8	0	0	46	53	0	84	20
May	0	15	126	45	0	39	159	54	119	0	624	255
Jun	16	0	53	0	0	0	19	92	16	7	531	130
Jul	22	0	0	8	0	55	0	106	0	8	3821	11
Aug	50	25	11	27	13	11	154	291	0	23	70	0
Sep	92	126	6	8	53	0	163	46	29	35	81	0
Oct	0	8	72	3	0	21	0	0	0	16	41	0
Nov	0	9	0	0	0	0	0	0	0	0	13	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	8	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	4	0	0	0	0	0	0	8	0	15
May	50	22	182	0	16	8	171	23	40	27	109	56
Jun	32	93	260	0	72	78	139	164	223	269	126	447
Jul	67	0	0	8	34	43	30	0	0	16	288	0
Aug	50	20	27	0	32	0	128	20	8	11	324	0
Sep	0	14	13	0	69	0	8	21	0	22	62	0
Oct	0	15	14	0	0	0	0	52	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	7	0	0	0	0	0	0	0	0	0	0

Estimated number impinged :

Blueback herring
Young-of-Year

Roseton

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
98	15817	9978	0
339	6558	7216	4511
4671	16525	67	23
7981	8543	14627	121
488	680	1709	374
8	15	0	0

Yearling

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	15	0
0	8	153	0
13	0	11	1
0	0	698	0
44	0	66	0
228	0	0	0
30	0	52	0
0	0	0	0
0	0	0	0

Adults

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	7	33
115	30	17	52
11	0	0	0
7	0	99	54
21	0	7	0
0	0	0	0
0	0	0	0
0	0	0	0

Estimated number impinged : Striped bass Roseton

Young-of-Year

	1981	1982	1983	1985	1986	1987	1988	1989	1990	1991	1992	1993
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	2705	0	0
Jul	781	12	162	78	45	69	94	38	2116	13293	325	530
Aug	1452	77	796	16	38	628	956	35	1202	11412	1741	1150
Sep	482	58	101	16	8	475	169	175	90	3036	814	2530
Oct	122	42	554	12	30	319	1289	120	258	475	83	350
Nov	831	27	90	0	38	262	74	64	293	413	33	377
Dec	352	11	397	23	54	212	377	39	62	523	97	1000

Yearling

	1981	1982	1983	1985	1986	1987	1988	1989	1990	1991	1992	1993
Jan	484	47	0	9	17	0	109	93	0	11	119	8
Feb	539	7	13	196	0	0	22	14	7	0	16	0
Mar	19	0	13	31	0	8	13	163	0	17	7	0
Apr	18	17	31	8	0	0	46	61	0	16	58	0
May	17	8	0	4	0	36	8	8	0	16	91	0
Jun	16	0	0	0	5	0	0	0	16	373	53	0
Jul	0	0	0	4	0	0	23	8	0	491	66	282
Aug	25	0	8	8	0	6	17	4	8	204	31	0
Sep	23	0	0	22	0	0	0	0	0	97	7	0
Oct	0	3	7	0	0	0	67	0	0	50	10	0
Nov	18	0	0	0	24	0	0	0	0	8	0	0
Dec	0	0	0	0	0	0	0	86	0	0	0	0

Older

	1981	1982	1983	1985	1986	1987	1988	1989	1990	1991	1992	1993
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	17	0	0	0	0	0	0	0	0	7	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	8	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	4	0	8	0	4	0	0
Jun	0	0	0	0	0	0	0	3	0	0	0	0
Jul	0	15	9	0	0	0	0	0	0	8	6	0
Aug	0	0	0	0	0	0	0	4	0	0	8	0
Sep	0	0	0	0	0	0	0	0	0	0	7	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	3	0	0	8	0
Dec	0	0	0	0	0	0	0	70	0	0	0	0

Estimated number impinged :

Striped bass

Roseton

Young-of-Year

1994	1995	1996	1997
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
9	473	0	0
9445	14818	21	2229
1010	8000	105	6942
285	90	23	466
903	597	4	2555
453	148	136	940
668	58	5	890

Yearling

1994	1995	1996	1997
54	148	4	0
0	30	0	5
15	14	9	0
0	38	0	0
23	250	0	3
5	132	0	22
539	976	3	171
12	222	2	34
0	7	0	0
0	0	0	0
0	5	27	0
0	0	1	0

Older

1994	1995	1996	1997
0	0	12	0
0	0	0	0
0	0	5	0
0	0	0	0
0	0	0	0
0	0	0	0
0	89	0	0
0	32	1	0
0	0	0	0
0	0	0	0
0	0	21	0
0	0	1	0

Estimated number impinged : Spottail shiner Roseton

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	5	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0
Jul	37	0	44	0	28	10	0	0	0	84	751	30
Aug	214	9	310	17	21	16	6	34	0	60	453	285
Sep	288	23	6	6	13	0	18	9	44	62	148	147
Oct	69	90	82	65	15	319	52	535	48	380	116	133
Nov	1415	134	479	64	666	774	167	224	633	804	166	237
Dec	344	211	425	16	476	427	156	1001	690	853	601	374

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	525	622	127	233	17	731	207	913	1115	1591	2289	481
Feb	3014	378	337	245	317	732	210	218	842	364	919	646
Mar	1381	639	920	717	191	728	310	259	1463	2416	2553	689
Apr	1254	2800	2313	1404	428	154	1647	757	2753	1300	1279	1306
May	40	304	345	144	23	0	2901	47	126	24	400	377
Jun	0	62	147	38	15	0	139	87	155	22	42	169
Jul	10	20	27	23	11	21	11	9	8	0	45	25
Aug	224	58	64	45	11	0	34	26	8	11	123	101
Sep	42	120	17	6	3	0	24	12	7	6	0	16
Oct	26	14	27	24	0	21	40	0	6	16	0	0
Nov	579	47	8	38	8	267	39	0	159	141	0	18
Dec	324	22	58	8	41	270	13	0	1435	209	0	26

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	85	25	110	54	0	203	1265	4	0
Feb	0	0	0	7	276	64	120	0	58	133	0	0
Mar	0	0	0	94	77	7	81	0	48	303	0	0
Apr	0	0	0	196	84	0	89	0	128	159	0	0
May	0	0	0	28	12	0	484	0	16	15	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Estimated number impinged :

Spottail shiner

Roseton

Young-of-Year

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
4	461	783	0
0	145	427	18
26	128	15	5
39	164	116	17
272	870	982	2332
961	371	951	676

Yearling

1993	1994	1995	1996
148	318	593	550
693	449	906	877
795	869	1824	1177
233	337	540	932
23	301	501	144
0	36	713	131
39	18	592	18
54	0	112	144
19	0	0	10
0	23	0	18
23	44	111	989
434	49	294	607

Adults

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

Estimated number impinged :

White perch

Roseton

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	756	0
Jul	5600	34	465	72	2007	1431	267	643	15	326	6735	291
Aug	22789	3122	11659	5089	8436	4533	14009	21134	1031	980	14225	9547
Sep	9149	4513	2048	1315	4723	1610	9993	5373	7052	1266	3295	6404
Oct	2471	5269	5589	8311	603	5363	4556	11050	5130	3582	1200	1165
Nov	30177	13914	3134	5613	2463	11243	7911	2055	12576	14446	1360	1979
Dec	6046	5269	5490	674	1421	5077	2184	4526	3994	3776	1542	3156

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	1955	2080	2500	845	40	2440	357	566	2021	474	155	176
Feb	1466	792	3618	850	528	433	206	656	684	420	104	470
Mar	1431	2017	4639	444	1001	62	352	1279	5348	5884	2487	1095
Apr	8581	2379	46993	4969	1773	358	2366	24847	13848	18472	4817	3943
May	755	2018	12913	4400	1472	430	31054	1489	5730	1035	5047	1219
Jun	65	572	888	692	161	48	915	1844	8333	1838	4547	982
Jul	424	40	285	353	254	179	171	806	130	291	2139	160
Aug	1152	22	367	442	39	133	337	647	15	94	1360	593
Sep	252	89	10	6	69	15	299	111	45	30	1124	272
Oct	182	112	254	163	0	245	199	865	28	142	819	71
Nov	5165	296	97	45	0	641	267	171	3057	4582	1228	102
Dec	260	63	230	16	47	94	73	188	956	1040	1494	453

Older

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Jan	447	106	34	109	13	214	52	50	172	629	194	274
Feb	6978	125	189	216	148	150	175	119	142	287	149	103
Mar	2714	212	746	50	150	187	180	125	593	4029	1378	328
Apr	1534	3040	5229	2741	226	110	2367	962	3677	2334	318	1503
May	84	174	327	481	70	15	2879	70	231	72	753	983
Jun	617	344	972	243	100	234	440	188	724	577	385	3296
Jul	156	62	165	54	157	110	221	71	114	100	1376	251
Aug	1077	130	660	102	177	108	548	392	74	113	1936	871
Sep	413	201	54	14	134	8	239	65	53	63	218	272
Oct	41	127	62	52	7	64	59	44	6	45	24	91
Nov	578	126	0	4	0	224	30	0	386	585	0	0
Dec	74	4	106	0	0	74	17	22	1392	217	58	276

Estimated number impinged :

White perch

Roseton

Young-of-Year

1993	1994	1995	1996
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
203	1247	7089	2
4356	711	9986	46
3910	394	342	13
1887	2485	1950	85
4119	3374	3721	4353
11523	1895	813	1016

Yearling

1993	1994	1995	1996
249	2116	64	648
126	194	175	168
124	707	266	101
27	259	413	1220
173	351	3028	789
310	257	2309	288
125	43	3761	21
231	8	1333	145
266	6	0	11
11	14	21	31
201	16	766	4558
10709	122	136	1585

Older

1993	1994	1995	1996
164	1339	0	1716
134	166	0	1188
62	476	55	478
125	348	53	1211
6	273	290	454
251	212	610	343
151	206	1423	28
779	99	482	100
452	17	15	6
64	68	52	9
73	16	167	2002
4622	20	63	915

Estimated number impinged : **American shad** **Indian Point**

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0
Aug	83600	1021	7965	50	41	3361	301	108	3862	0
Sep	2318	102	438	143	15	989	952	119	598	0
Oct	3849	0	137	471	678	2176	1823	197	2639	0
Nov	4743	0	126	83	1751	1176	50	43	2638	0
Dec	19	0	4	35	106	4	0	4	3	0

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	4	0	0	27	29	5	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0
Mar	0	4	0	0	4	2	3	0	15	0
Apr	0	0	0	0	5	9	52	8	0	32
May	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0

Estimated number impinged : Alewife Indian Point

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	9
Jun	0	799	0	0	0	263	12	0	0	551
Jul	20061	255	2166	163	212	81	188	27	349	458
Aug	2225	89	4373	1116	335	42	272	104	558	310
Sep	404	0	274	401	19	74	696	173	155	45
Oct	1243	0	113	2289	427	176	828	376	249	182
Nov	518	0	65	1620	614	154	16	79	126	128
Dec	20	0	0	547	23	0	0	0	68	0

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	13	0	0	25	127	0	4	8	0	87
Feb	16	0	0	28	219	13	53	37	0	24
Mar	0	0	0	0	58	9	23	35	0	0
Apr	7	0	0	14	0	18	21	2	0	0
May	165	0	40	450	194	96	93	211	0	0
Jun	320	67	332	247	197	171	83	223	0	21
Jul	266	9	2	176	11	58	0	19	25	16
Aug	88	35	0	96	14	70	12	95	46	74
Sep	0	7	11	74	0	356	237	73	37	16
Oct	10	0	0	77	17	65	95	36	7	23
Nov	5	0	2	0	5	13	0	0	0	0
Dec	0	0	0	0	0	0	0	0	8	0

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	14	0	0	0	10	0	0	0	0	12
Feb	0	0	0	0	21	6	0	3	0	0
Mar	0	0	0	7	10	118	2	30	5	0
Apr	49	2	0	11	23	210	39	1	0	21
May	568	159	143	581	2182	60	95	71	0	172
Jun	443	120	155	235	657	798	238	12	0	208
Jul	184	23	34	175	14	76	371	0	0	28
Aug	18	0	0	77	4	28	68	25	0	6
Sep	0	0	0	14	10	197	33	0	0	12
Oct	19	0	0	4	300	18	9	12	0	21
Nov	0	0	5	0	38	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0

Estimated number impinged : **Atlantic tomcod** **Indian Point**

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	170	0	3	12
May	43528	2712	14157	1652	14394	10312	182180	985	7	1071
Jun	212576	41568	24154	42395	31739	19326	440210	7879	100	50816
Jul	78630	6748	29902	57419	12040	19489	619273	2886	1043	6245
Aug	34439	25365	67835	35571	9636	4288	108393	4376	880	47569
Sep	2187	4986	630	803	187	3913	1116	387	3317	276
Oct	1940	85	12	318	167	2644	643	193	3258	107
Nov	164	3	16	65	202	163	179	65	283	0
Dec	2089	0	611	231	639	4587	83	216	3802	0

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	180	0	0	0	10755	402	1305	568	332	735
Feb	83	0	0	0	846	134	212	151	75	981
Mar	590	0	1	0	2663	92	169	166	90	28
Apr	66	0	38	0	150	26	21	0	0	11
May	9	0	0	0	45	0	0	7	0	276
Jun	331	0	3	0	19	12	144	0	0	1394
Jul	307	0	0	0	79	131	1112	29	3	468
Aug	17	0	0	0	709	172	213	47	69	254
Sep	0	0	0	0	20	41	336	14	180	39
Oct	0	0	0	0	11	28	96	20	54	23
Nov	14	0	0	0	2	3	54	32	363	0
Dec	45	0	4	0	6	62	33	4	573	0

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	11	1477	5148	188	191	0	25	17	43	11
Feb	0	304	31	43	31	4	0	4	0	8
Mar	3	103	129	88	11	0	30	0	0	0
Apr	0	0	34	29	0	0	0	0	0	0
May	2	110	12	4	9	0	67	0	0	52
Jun	9	133	0	32	0	0	12	0	0	1241
Jul	96	108	0	30	0	9	156	0	0	9
Aug	0	418	0	14	28	0	30	0	0	0
Sep	0	194	0	45	0	0	12	0	0	0
Oct	0	0	0	32	0	0	3	0	8	21
Nov	0	0	0	20	2	0	10	0	8	0
Dec	4	0	0	157	0	3	0	0	34	0

Estimated number impinged : Bay anchovy Indian Point

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0
Jun	93	0	3	0	0	0	0	0	0	0
Jul	14	0	613	1265	7	60	75	15	745	0
Aug	7277	352	22853	1801	345	419	401	294	2793	0
Sep	11746	678	4559	629	234	5929	7268	1351	608	0
Oct	13281	137	13662	2489	612	7407	8536	7913	946	0
Nov	81	0	1896	1950	271	1007	0	100	125	0
Dec	93	0	2	21	46	14	0	0	25	0

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	11	0	0	0	78	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0
Apr	14	0	0	0	4	0	0	0	0	0
May	913	0	288	0	1207	968	0	0	0	0
Jun	63468	0	595	0	8589	15927	0	0	0	0
Jul	464608	0	43501	0	3434	8602	0	0	0	0
Aug	22273	0	90242	0	2029	7195	0	0	0	0
Sep	13554	0	5398	0	362	8284	0	0	0	0
Oct	6368	0	1573	0	1766	3095	0	0	0	0
Nov	12	0	179	0	70	120	0	0	0	0
Dec	19	0	0	0	0	0	0	0	0	0

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	46	136	15	0	0	104	3	331	0
Feb	3	0	0	0	0	0	0	0	11	0
Mar	0	0	5	0	0	0	0	0	4	0
Apr	3	0	0	0	0	5	0	0	0	0
May	1330	800	0	7551	2280	645	155	10	0	0
Jun	2	419	0	5014	12	0	348	319	0	0
Jul	0	44272	0	33741	0	0	3464	962	238	0
Aug	0	56364	0	48142	0	0	834	1033	2389	0
Sep	0	8173	0	5901	0	0	4704	10995	1681	0
Oct	0	60	0	3592	0	0	2321	6144	510	0
Nov	0	0	0	685	0	0	0	165	0	0
Dec	0	0	0	2	0	0	0	5	2	0

Estimated number impinged : Blueback herring Indian Point

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	235	53	0	0	0
Jul	8066	105	26830	81	17	85	702	614	138	344
Aug	11230	564	32719	942	148	51	257	1776	2166	1968
Sep	13166	180	1288	275	173	288	9099	1273	492	829
Oct	181820	3	10697	1641	7391	5832	61268	16784	16980	6048
Nov	31876	50	5618	2246	15167	5395	2855	3552	38621	10012
Dec	540	0	117	527	203	6	30	9	110	0

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	96	7	13	44	20	34	5	104	51	0
Feb	3	2	0	34	19	0	11	64	13	0
Mar	2	0	16	4	0	5	4	11	41	0
Apr	7	0	0	1	33	77	14	159	0	0
May	76	10	100	394	120	776	145	161	0	9
Jun	216	53	3089	2511	38	187	492	91	0	578
Jul	152	0	2	879	7	25	138	52	27	13
Aug	47	10	0	27	3	0	30	137	72	192
Sep	0	40	0	0	8	44	119	72	36	50
Oct	3	0	15	12	76	129	298	40	27	1
Nov	0	0	0	0	0	0	0	5	0	0
Dec	0	0	0	0	0	0	0	2	0	0

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	0	0	0	58	0	0	0	2	0
Feb	0	0	0	0	47	4	0	0	0	4
Mar	0	0	0	0	8	0	9	1	7	0
Apr	22	0	0	1511	17	0	317	85	5	2
May	735	10	125	1479	3572	1326	359	207	11	18
Jun	1055	15	2427	2816	352	4042	526	696	175	676
Jul	302	0	152	259	54	342	323	96	107	66
Aug	139	35	138	78	135	99	568	106	38	258
Sep	6	7	72	98	83	24	356	34	358	159
Oct	0	0	32	7	255	124	14	10	0	21
Nov	4	0	0	6	46	16	0	0	0	0
Dec	3	0	0	0	0	0	0	0	0	0

Estimated number impinged :

Striped bass

Indian Point

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0
Aug	6694	103	5952	680	483	1326	1008	0	0	0
Sep	4590	127	214	643	59	401	3845	0	0	0
Oct	6194	0	1194	399	494	520	18646	0	0	0
Nov	4240	0	813	674	2194	548	847	0	0	0
Dec	26001	0	1793	1552	1407	1097	267	0	0	0

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	5518	13043	1187	51337	3403	1372	20370	0	0
Feb	0	27940	3118	2161	7803	187	1584	19711	0	0
Mar	0	6718	709	590	10228	200	2154	9569	0	0
Apr	0	203	15	1450	851	20	148	628	0	0
May	0	48	0	707	724	36	321	333	0	0
Jun	0	21	111	1327	432	39	28	312	0	0
Jul	0	46	89	1188	120	41	0	240	0	0
Aug	0	77	115	158	77	19	0	229	0	0
Sep	0	40	20	31	87	29	60	106	0	0
Oct	0	0	0	2	32	10	688	56	0	0
Nov	0	0	0	12	138	19	10	32	0	0
Dec	0	0	18	18	511	108	5	30	0	0

Older

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	0	671	3	256	526	16	3	79	0
Feb	0	0	19	20	365	67	0	132	2	0
Mar	0	0	17	27	99	92	0	37	12	0
Apr	0	0	0	548	57	61	21	0	0	0
May	0	0	0	357	39	36	0	3	0	0
Jun	0	0	19	27	1	0	0	20	0	0
Jul	0	0	27	26	14	12	0	0	30	0
Aug	0	0	26	56	13	0	13	0	7	0
Sep	0	0	14	0	13	12	20	0	0	0
Oct	0	0	12	5	20	12	247	0	3	0
Nov	0	0	0	0	19	0	2	9	28	0
Dec	0	0	2	0	80	12	0	9	165	0

Estimated number impinged :

Spottail shiner

Indian Point

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0
Jul	0	0	57	0	0	0	0	0	8	0
Aug	0	0	0	0	0	0	0	0	0	0
Sep	0	0	11	0	0	0	0	0	0	0
Oct	6	0	0	0	0	0	0	21	20	0
Nov	80	0	98	14	4	197	31	266	199	0
Dec	312	0	411	0	73	326	5	196	2554	0

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	93	0	0	0	223	84	0	0	0	0
Feb	83	0	0	0	69	42	0	0	0	0
Mar	242	0	1	0	36	179	0	0	0	0
Apr	153	0	7	0	32	39	0	0	0	0
May	15	0	69	0	12	0	0	0	0	0
Jun	14	0	50	0	0	0	0	0	0	0
Jul	4	0	59	0	4	0	0	0	0	0
Aug	20	0	0	0	3	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0
Nov	2	0	16	0	34	85	0	0	0	0
Dec	13	0	142	0	149	176	0	0	0	0

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	206	145	158	387	1075	136	359	444	2004	0
Feb	222	433	106	884	257	62	1602	439	103	0
Mar	689	330	52	755	144	231	1147	330	778	0
Apr	89	124	0	325	21	31	109	0	25	0
May	24	0	0	108	12	0	36	0	12	0
Jun	0	0	0	74	0	0	0	6	29	0
Jul	0	0	0	15	0	0	0	0	20	0
Aug	0	0	0	29	0	0	0	0	62	0
Sep	0	0	0	0	0	0	0	0	25	0
Oct	0	0	0	0	0	0	2	3	1	0
Nov	0	0	0	9	0	0	3	45	61	0
Dec	0	0	0	4	0	0	16	43	2005	0

Estimated number impinged : White perch Indian Point

Young-of-Year

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0
Aug	41793	23935	23457	1016	3603	14545	2078	20596	3406	3178
Sep	16951	1913	441	661	72	1284	6334	6782	8363	359
Oct	71849	15	2319	327	5130	17708	28378	13148	32309	4153
Nov	187147	0	10638	5183	135699	43955	33271	45138	44226	6268
Dec	997852	0	37001	29695	181525	260086	5128	192144	254980	37043

Yearling

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	437651	103751	97645	224326	293037	130239	84841	188048	268339
Feb	0	302961	80616	153177	49111	77941	144522	172454	71355	111052
Mar	0	305892	33319	48143	56560	26579	157287	145945	114830	2048
Apr	0	11023	18382	121907	23154	4457	31129	12008	10706	9328
May	0	24421	15729	58060	15842	33993	63614	19675	5193	3438
Jun	0	4804	11487	20907	3084	2299	11110	15615	12870	35284
Jul	0	567	740	12026	136	1696	1332	702	837	1904
Aug	0	303	603	1581	229	490	1112	1096	198	1164
Sep	0	127	45	468	61	79	2343	872	259	102
Oct	0	5	122	421	1982	405	1664	775	722	771
Nov	0	0	174	212	18357	3291	604	916	1168	554
Dec	0	0	2646	1721	11082	9499	139	1897	3259	4324

Adults

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Jan	0	0	3910	2724	4819	2716	4605	1863	2301	1805
Feb	0	0	1070	2153	2598	504	2156	4575	340	2003
Mar	0	0	1433	7459	10017	2422	4435	2971	1049	92
Apr	0	0	2314	31196	23779	8337	8165	883	54	346
May	0	0	2093	7479	1185	1243	764	862	44	309
Jun	0	0	8372	8660	854	18047	2353	1349	384	6529
Jul	0	0	537	3330	95	1024	3184	153	507	3128
Aug	0	0	785	1018	262	409	516	205	2	2002
Sep	0	0	203	180	114	127	0	19	257	599
Oct	0	0	25	87	0	102	613	0	268	3
Nov	0	0	86	0	5290	144	27	176	197	47
Dec	0	0	354	157	1579	0	9	0	910	365

Estimated number impinged : **American shad** **Bowline Point**

Young-of-Year

	1980	1981	1982	1983	1984	1985	1990	1991	1992	1993	1994	1995
Jan	0	0	0	0	0	0	0	0	0	0 .		0
Feb	0	0	0	0	0	0	0	0	0 .		0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0
Jul	628	5767	0	221	20	55	74	18	4	17	54	124
Aug	160	28	57	995	59	0	212	0	48	6	13	502
Sep	18	26	9	26	6	0	0	0	37	0	0	0
Oct	0	41	0	55	2	5	15	0	0	0	15	161
Nov	49	16	0	179	0	24	69	0	0	0	158	0
Dec	8	0	7	12	3	11	3	0	0	0	7	0

Yearling

	1980	1981	1982	1983	1984	1985	1990	1991	1992	1993	1994	1995
Jan	0	4	0	0	0	4	0	0	0	0 .		0
Feb	0	0	0	0	0	0	0	0	0 .		0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	3	0	0	0	1	0	0	0	0
Jun	0	6	0	0	0	0	0	3	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	0	0	2
Aug	15	0	28	90	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Adults

	1980	1981	1982	1983	1984	1985	1990	1991	1992	1993	1994	1995
Jan	0	0	0	0	0	0	0	0	0	0 .		0
Feb	0	0	0	0	0	0	0	0	0 .		0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	14	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0	0	0	9	0	2
Aug	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	6	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Estimated number impinged : **American shad** **Bowline Point**

Young-of-Year

1996	1997	0	0
0 .		0	0
0 .		0	0
0	0	0	0
. .		0	0
0	0	0	0
.	0	0	0
74	0	0	0
35	22	0	0
0	0	0	0
31	0	0	0
0	0	0	0
.	0	0	0

Yearling

1996	1997	0	0
0 .		0	0
0 .		0	0
0	0	0	0
. .		0	0
0	0	0	0
.	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
.	0	0	0

Adults

1996	1997	0	0
0 .		0	0
0 .		0	0
0	0	0	0
. .		0	0
0	0	0	0
.	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
.	0	0	0

Estimated number impinged : Alewife Bowline Point

Young-of-Year

	1980	1981	1982	1983	1984	1985	1988	1989	1990	1991	1992	1993
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	2	0	2	1	0	0
Jul	422	883	12	33	0	15	41	129	11	16	0	18
Aug	856	816	35	12098	45	0	38	0	261	0	14	76
Sep	72	56	4	25	5	26	0	24	0	0	0	0
Oct	4	49	0	10	0	5	0	8	17	0	0	25
Nov	87	8	0	113	0	8	0	0	80	0	0	0
Dec	164	0	7	22	0	3	7	0	5	0	6	0

Yearling

	1980	1981	1982	1983	1984	1985	1988	1989	1990	1991	1992	1993
Jan	20	10	21	6	39	7	5	0	0	0	0	0
Feb	34	0	3	0	7	101	17	2	0	1	0	
Mar	3	42	0	8	2	40	2	0	0	0	7	0
Apr	7	37	0	0	0	0	0	5	0	0	5	23
May	10	24	0	2	4	8	21	32	5	1	0	0
Jun	152	7	27	43	111	19	19	115	16	0	113	25
Jul	1265	0	3	0	25	0	12	0	3	1	0	49
Aug	0	19	0	0	0	0	38	6	0	0	0	18
Sep	8	0	0	1	0	0	0	1	0	0	0	4
Oct	0	0	12	0	0	0	0	0	0	0	0	6
Nov	4	0	0	4	0	0	0	0	0	0	0	0
Dec	35	0	0	1	0	0	0	0	0	0	0	0

Adults

	1980	1981	1982	1983	1984	1985	1988	1989	1990	1991	1992	1993
Jan	4	5	0	1	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	4	0	0	0	0	0	
Mar	0	1	0	0	0	3	0	0	0	0	0	0
Apr	0	0	0	0	0	13	0	0	2	0	0	0
May	7	15	0	6	4	84	2	27	0	3	0	0
Jun	46	50	0	20	42	0	8	0	7	1	38	4
Jul	422	177	2	1	8	0	5	0	1	0	0	0
Aug	0	9	69	0	0	0	0	0	0	0	0	0
Sep	8	0	0	0	0	9	0	2	0	0	0	0
Oct	0	0	0	0	0	0	13	0	0	0	0	0
Nov	0	0	0	9	0	3	0	0	4	0	0	0
Dec	0	0	0	2	0	0	0	0	3	0	0	0

Estimated number impinged :

Alewife

Bowline Point

Young-of-Year

1994	1995	1996	1997
.	0	0 .	
0	0	0 .	
0	0	0	0
0	0 .	.	
0	0	0	0
0	0 .		0
32	194	6	0
25	144	63	160
0	0	17	0
15	291	89	0
200	6	8	0
31	0 .		0

Yearling

1994	1995	1996	1997
.	0	0 .	
0	0	0 .	
0	0	0	0
0	0 .	.	
0	4	0	0
19	36 .		27
18	0	9	0
51	6	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0 .		0

Adults

1994	1995	1996	1997
.	0	0 .	
0	0	0 .	
0	0	0	0
0	0 .	.	
0	0	0	0
0	14 .		0
0	0	0	0
0	6	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0 .		0

Estimated number impinged : Blueback herring Bowline Point

Young-of-Year

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0
Jul	0	0	3	54	0	4	0	61	24	8	0	2
Aug	210	77	51	3	67	0	47	72	281	143	24	0
Sep	111	166	11	13	11	0	7	52	23	16	0	0
Oct	28	741	213	489	2	377	6	7895	167	18	250	0
Nov	1198	491	435	1793	136	568	738	845	42	86	1131	0
Dec	391	380	475	265	81	196	10	307	0	3	5	19

Yearling

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Jan	48	124	6	24	20	17	18	0	87	16	0	1
Feb	94	0	0	6	36	9	18	3	39	21	0	1
Mar	8	3	0	0	3	0	5	0	4	12	0	0
Apr	6	32	0	0	4	0	2	0	0	55	0	0
May	0	0	0	6	3	0	0	4	20	34	0	1
Jun	92	0	0	18	69	0	0	0	0	19	0	1
Jul	427	0	1	0	0	1	0	19	7	3	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0
Oct	7	0	13	1	0	0	0	62	10	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Adults

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Jan	10	0	0	0	0	6	0	0	0	0	0	0
Feb	6	0	0	0	0	14	0	0	0	0	0	0
Mar	0	1	0	0	0	14	0	0	0	0	0	0
Apr	5	28	0	0	0	13	2	0	0	36	0	0
May	22	22	0	8	6	56	21	16	8	25	13	1
Jun	35	58	3	14	243	6	0	6	0	19	39	2
Jul	427	129	4	0	0	5	0	68	27	9	0	1
Aug	368	26	51	0	34	59	47	0	0	0	24	0
Sep	18	0	4	1	4	24	2	0	7	5	0	0
Oct	0	0	0	1	0	0	0	0	0	0	0	0
Nov	8	0	0	0	0	7	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Estimated number impinged :

Blueback herring

Bowline Point

Young-of-Year

1992	1993	1994	1995
0	0 .		0
0 .		0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	16	7	69
62	29	42	37
40	0	0	0
8	43	39	14398
0	6	267	58
6	0	7	0

Yearling

1992	1993	1994	1995
11	0 .		0
0 .		0	0
0	0	0	0
0	0	0	0
0	0	0	0
22	0	0	40
0	5	7	19
0	0	0	11
0	0	0	0
0	6	0	0
0	0	0	0
0	0	0	0

Adults

1992	1993	1994	1995
0	0 .		0
0 .		0	0
0	0	0	0
0	0	0	0
0	0	0	0
6	0	8	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

Estimated number impinged :

Striped bass

Bowline Point

Young-of-Year

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	16	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	1	2	0	0	0	0	0	0	1
Jul	10	133	0	0	6	25	0	23	37	13	0	20
Aug	27	33	46	138	25	27	42	20	42	37	65	0
Sep	7	26	9	20	0	0	7	43	11	11	15	0
Oct	0	6	11	12	0	4	0	459	80	8	88	0
Nov	7	0	4	9	0	2	28	39	31	5	242	0
Dec	137	82	7	164	17	12	13	4029	51	5	128	6

Yearling

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Jan	266	107	52230	138	45	89	11	9	12755	137	0	91
Feb	150	1106	8782	218	222	203	835	0	11649	80	0	86
Mar	253	79252	1142	162	143	3470	711	5	1280	124	0	35
Apr	516	8400	1811	92	54	1323	27	3	18	937	5	3
May	12	0	8	0	0	0	0	3	2	19	0	1
Jun	8	16	0	4	14	0	0	0	12	0	0	1
Jul	10	56	0	0	2	25	0	0	14	5	0	5
Aug	2	0	7	9	2	2	0	1	0	0	22	0
Sep	0	9	9	7	0	5	0	0	4	4	0	0
Oct	0	0	6	1	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	0	0	0	0

Adults

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Jan	0	5	124	5	2	3	4	0	0	0	0	0
Feb	0	6	36	2	2	2	8	0	16	2	0	0
Mar	0	331	6	1	1	0	21	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	4	0	1	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0
Jul	29	0	0	0	1	0	0	0	7	2	0	0
Aug	0	0	0	0	0	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0	0	0
Dec	5	0	0	1	0	0	0	0	0	0	0	0

Estimated number impinged : **Striped bass** **Bowline Point**

Young-of-Year

1992	1993	1994	1995
0	0		0
0		0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
8	63	92	74
50	78	287	243
11	4	138	7
0	0	39	279
0	0	72	37
6	0	106	20

Yearling

1992	1993	1994	1995
35	6		239
6		0	129
33	0	22	2600
23	402	6	438
0	0	0	0
11	4	8	36
0	88	25	50
8	9	0	14
17	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

Adults

1992	1993	1994	1995
0	0		0
0		0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	6	8	0
0	0	0	7
6	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

Estimated number impinged :

White perch

Bowline Point

Young-of-Year

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Jan	0	0	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0	0	0	0
Jul	114	507	0	45	0	0	0	0	25	0	0	1
Aug	938	451	1933	309	0	0	186	0	39	14	310	0
Sep	19	36	8	39	0	9	9	17	0	10	8	0
Oct	0	25	16	53	5	0	19	419	6	8	94	0
Nov	23	78	12	30	0	0	93	301	41	15	1403	0
Dec	319	352	58	538	20	4	146	21627	995	284	1281	11

Yearling

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Jan	9170	236	191749	437	277	368	107	284	18694	1687	47	96
Feb	2685	2857	19962	1065	595	201	5274	125	15054	547	219	85
Mar	3452	238152	6764	1644	441	3885	10924	122	622	564	119	53
Apr	9208	44389	7992	1653	1750	2764	677	279	8	7219	85	2
May	653	161	337	321	22	33	136	62	223	673	31	47
Jun	851	556	33	375	2045	22	0	23	123	1747	249	28
Jul	135	220	25	182	104	20	0	44	0	39	218	5
Aug	156	20	91	162	20	17	247	0	52	0	546	0
Sep	10	9	0	20	0	9	0	17	0	0	0	1
Oct	0	0	16	7	5	6	0	88	0	0	0	0
Nov	9	0	0	8	0	7	24	23	3	0	65	0
Dec	113	7	6	100	12	37	3	2371	7	23	119	1

Adults

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Jan	988	217	5024	113	92	133	71	27	581	34	60	4
Feb	634	482	754	178	110	59	274	161	384	40	19	3
Mar	403	10896	130	103	17	85	630	6	32	0	23	7
Apr	63	830	45	225	10	55	66	22	8	474	22	1
May	29	40	0	53	8	11	8	18	21	112	8	4
Jun	498	221	98	256	169	22	143	46	16	610	76	7
Jul	456	110	147	262	38	30	93	67	101	0	97	13
Aug	840	131	235	632	168	78	263	48	78	54	207	9
Sep	78	72	117	195	67	80	19	26	10	29	40	2
Oct	12	12	144	53	26	26	14	18	6	0	7	0
Nov	23	0	37	12	2	0	7	0	7	0	39	0
Dec	42	39	32	79	0	37	10	231	4	12	27	1

Estimated number impinged :

White perch
Young-of-Year

Bowline Point

1992	1993	1994	1995
0	0 .		0
0 .		0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	9	0
0	36	42	0
39	7	83	84
7	0	0	0
0	0	0	69
0	7	8	297
12	12	97	648

Yearling

1992	1993	1994	1995
78	61 .		165
0 .		53	98
73	0	138	3273
34	3149	163	576
0	127	208	13
285	294	338	483
37	42	59	145
39	7	35	14
48	5	0	0
0	0	0	41
0	0	0	6
0	0	0	8

Adults

1992	1993	1994	1995
8	105 .		6
0 .		0	0
7	0	6	632
13	113	7	474
0	0	0	4
419	131	123	84
201	143	21	427
70	67	7	35
124	40	0	0
16	0	0	8
0	7	0	0
0	0	0	0