Bennett Harless

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Final

environmental statement

related to operation of

INDIAN POINT NUCLEAR GENERATING PLANT UNIT NO. 3

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

DOCKET NO. 50-286

February 1975

Volume II

UNITED STATES NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION

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Environmental Statement
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INDIAN POINT NUCLEAR GENERATING STATION UNIT NO. 3
Consolidated Edison Company of New York, Inc.
Docket No. 50-286
Volume II, February 1975

ADDENDUM

In Appendix B the results given for the Striped Bass Young-of-the-Year Model (Section 4.b) and for the Striped Bass Life-Cycle Population Model (Section 4.c) are intended as illustrative examples only. The results used in the staff's assessment are given in Chapters V and XI.

The various parameters given in Appendix B correspond to the results given in Appendix B. The parameters used to obtain the results in Chapters V and XI are given in the Tables in this Addendum. Only those Tables in which the parameters are different are included; parameters in other Tables are the same. An additional Table is attached which gives the values used to obtain the results in Chapters V and XI which differ from the corresponding values in the text and Figures in Appendix B.

Table B-24. Parameter values employed in the staff's model for population density dependent compensatory mechanism for survival percentages of life stage populations

Life stage	Maximum population density (number per 1,000 ft^3)	Effective survival percentage	Critical population density (number per 1,000 ft^3)	Optimum survival percentage
Egg	No population density dependent compensatory effect			36.0
Yolk-sac larva	7.08	40	0.354	58.0
Post yolk-sac larva	5.56	64	0.278	74.8
Juvenile I	1.84	90	0.092	93.0
Juvenile II	1.13	90	0.057	93.0
Juvenile III	0.45	95	0.022	96.5

Table B-26. Approximate data employed in the staff's model for the mobility characteristics of life stage age group populations

Life stage	Maximum swimming speed (fps)	Sustained duration (hour)	Intake avoidance parameter	Shoaling effect parameter	Crowding effect parameter
Juvenile I	0.50	2.00	0.00	0.4	0.2
Juvenile II	1.00	4.00	0.80	0.4	0.2
Juvenile III	1.00	6.00	1.00	0.4	0.2

Table B-28. Intake avoidance factor and optimum plant survival percentage values employed in the staff's model

Life stage	Intake avoidance factor	Optimum plant survival percentage
Egg	0.00	0.20
Yolk-sac larva	0.00	0.39
Post yolk-sac larva	0.00	0.39
Juvenile I	0.00	0.28
Juvenile II	0.80	0.00
Juvenile III	1.00	0.00

Table B-27. Hudson River power plant operating data

Power plant	Unit No.	Location; mile point above Battery	In-service date	Capacity (MWe)	Intake flow rate (cfs)	Condenser temperature rise (F°)	Plant thermal discharge (billion Btu/hr)	Intake velocity (fps)	Plant intake geometry factor	Plant discharge geometry factor
Albany		140		400	784	11.0	1.917	1.0	1.0	1.0
Danskammer	1	66	1951	64	89	14.5	2.250	2.5	1.0	1.0
	2		1954	64	89					
	3		1959	127	231					
	4		1967	253	277					
Roseton	1	65.4	1974	600	724	15.4	5.000	0.75	1.0	1.0
	2		1974	600	724					
Cornwall (pumped storage)		57	1980-83	2000	4000[c]			1.0	1.0	1.0
Indian Point	1	43	1962	265	709	12.6	15.755	0.7	1.0	1.0
	2		1973	873	1938[a]	14.9		1.0		[a]
	3		1975	1033	1938[b]	17.5		1.0		[b]
Lovett	1	42	1949	19	58	18.0	3.184	1.52	1.0	1.0
	2		1951	20	58	20.0		1.52		
	3		1955	68	96	22.0		1.83		
	4		1966	195	237	20.0		1.64		
	5		1969	202	272	22.0		2.0		
Bowline	1	37.5	1972	600	855.5	15	5.16	0.77	1.0	1.0
	2		1974	600	855.5	15		0.77		
59th Street		5		221	374	6.0	0.500	1.0	1.0	1.0

[a] With closed-cycle cooling, the intake flow rate is 125 cfs and the discharge geometry factor is 0.0.

[b] With closed-cycle cooling, the intake flow rate is 135 cfs and the discharge geometry factor is 0.0.

[c] Average value.

Additional changes in parameter values. The values given in this table, which differ from the corresponding values given in Appendix B, were used in the young-of-the-year model runs summarized in Chapters V and XI.

Description of Parameter	Parameter Value	Reference Section in Appendix B
Optimum spawning rate (number of eggs per hour per spawner)	24	Sect. B.4.b(2)(a)(ii)
Minimum, lower optimum, higher optimum, and maximum temperatures, respectively, for the nonoptimum temperature correction factor for the growth rate coefficient (°F)	50, 75, 85, 95 (egg) 10, 20, 900, 999 (all other life stages)	Fig. B-29 Sect. B.4.b(2)(c)(ii)
Minimum, lower optimum, higher optimum, and maximum temperatures, respectively, for the nonoptimum temperature correction factor for the maximum swimming speed (°F)	30, 75, 85, 95 (same for Juvenile I, II, III)	Fig. B-30 Sect. B.4.b(2)(e)(ii)
Minimum, lower optimum, higher optimum, and maximum salinities, respectively, for the nonoptimum salinity correction factor for the maximum swimming speed (ppt)	0.1, 0.2, 0.4, 1.0 (same for Juvenile I, II, III)	Fig. B-31 Sect. B.4.b(2)(e)(ii)
Critical and maximum temperatures, respectively, for the nonoptimum temperature correction factor for the probability of survival upon entrainment (°F)	85, 95 (same for all life stages)	Fig. B-33

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Appendix A

THERMAL DISCHARGES TO THE HUDSON RIVER

1. STAFF'S MULTIPLANT FAR-FIELD ANALYSIS

The staff applied its own transient one-dimensional model to the analysis of multiple power plant operation on the Hudson River.[1] The analysis included the effects of the Danskammer, Roseton, Indian Point, Lovett, and Bowline power plants (Table V-3).

The staff's model considers the river water physical properties, the river geometry (cross-sectional area), and the coefficient of heat exchange to the atmosphere as constants along the length of the river. The differential equation on which the model is based is

$$\frac{\delta T}{\delta t} + U(t)\frac{\delta T}{\delta X} = \frac{\delta}{\delta X}\left[E_L(X)\ \frac{\delta T}{\delta X}\right] - \frac{\overline{K}T}{\rho C_p H} + \frac{Q}{\rho C_p A \Delta X},$$

where

T = excess temperature,

E_L = longitudinal dispersion coefficient,

$\overline{K}$ = surface heat exchange coefficient,

Q = power plant heat discharge,

H = river depth,

X = distance along the river,

A = river cross-sectional area,

t = time,

ρ = water density,

C_p = specific heat of water,

and $U(t)$ is the instantaneous water velocity expressed as

$$U(t) = U_F + U_{max} \sin\left(2\pi \frac{t}{T_d}\right),$$

where

U_F = freshwater velocity,

U_{max} = maximum tidal velocity, and

T_d = tidal period.

The average river cross-sectional area of 168,100 ft^2 was based on a profile of the river taken from about five miles above the Danskammer Plant to about eight miles below the Bowline Plant. The river water velocity is a function of the freshwater flow and the phase of the tidal period. The analysis is concerned with calculation of temperature rises above the ambient; therefore, the exact ambient river temperature selected is not important (temperature rises calculated by the model are only weakly dependent on the ambient temperature used). A river temperature at the mouth 6F° lower then the ambient, due to the intrusion of ocean water, is believed by the staff to be more representative than assuming the same ambient temperature at all locations. Other input data for the staff's analysis are given in the footnotes to Table A-1.

As indicated above, a major problem associated with the use of any convection-diffusion model is correct evaluation of the longitudinal dispersion coefficient. Additional studies and field data are needed to establish the correct value of this coefficient, particularly in the vicinity of Indian Point. In the absence of definitive information and in spite of its reservations,[1] the staff elected to use the coefficients advanced by the applicant's consultant.[2]

Another input to the mathematical models to which the results are very sensitive is the assumed rate of heat transfer from the water to the atmosphere, since this is the primary mechanism for far-field heat dissipation. Actual coefficients constantly fluctuate due to a complicated interaction of a number of local variables. Lower values are usually found in the colder months when evaporation is less. The applicant used a range of 90 to 140 Btu/(day$\cdot$ft$^2\cdot$F°) [3.8 to 5.8 Btu/(hr$\cdot$ft$^2\cdot$F°)]; the physical model studies experimentally determined a value of about 118 Btu/(day$\cdot$ft$^2\cdot$F°) (ER, IP-3, Appendix DD, p. 1). In its own transient one-dimensional-model study, the staff used a value of 130 Btu/(day$\cdot$ft$^2\cdot$F°) which is typical for the summer and a value of 90 Btu/(day$\cdot$ft$^2\cdot$F°), which, coupled with a low freshwater flow rate of 4,000 cfs, represents severe drought conditions in the fall, such as occurred

Table A-1. Calculated temperatures at Indian Point using one-dimensional analysis for combined operation of Indian Point (Units Nos. 1, 2 and 3), Danskammer, Roseton, Lovett and Bowline power plants[a]

Case	Plants in operation	Indian Point Plant cooling system	Heat discharge from Indian Point (10^6 Btu/hr)[b]	River fresh-water flow (cfs)	Heat transfer to atmosphere [Btu/day·ft²·F°)]	Tidal temperatures at Indian Point (°F) Maximum	Average	Minimum
1-a	All five	Base design	15,755	4,000	90	86.7	86.3	85.7
1-b	All five	Base design	15,755	4,000	180[c]	84.6	84.2	83.7
2-a	All five	Base design	15,755	11,000	90	85.9	85.2	84.4
2-b	All five	Base design	15,755	11,000	180[c]	84.3	83.7	83.0
3	All five	Alternative A	9,592	4,000	90	84.9	84.6	84.2
4	All five	Alternative A	9,592	11,000	90	84.4	83.9	83.2
5	All five	Alternative B	2,345	4,000	90	82.8	82.6	82.3
6	All five	Alternative B	2,345	11,000	90	82.6	82.3	81.9
7	All except Indian Point		0	4,000	90	82.1	81.9	81.7
8	Indian Point only	Base design	15,755	4,000	90	84.4	84.1	83.8
9	All five	Base design	15,755	4,000	130	85.5	85.1	84.5
10	All five	Base design	15,755	4,000	260[c]	83.7	83.3	82.9
11	All five	Base design	15,755	11,000	260[c]	83.5	83.0	82.4
12	All except Indian Point		0	4,000	130	81.6	81.5	81.3
13	Indian Point only	Base design	15,755	4,000	130	83.7	83.5	83.2

[a]Based on parameters shown in table and on following input data for all cases:

Duration of tidal period, hr	12.4	Ambient river temperature, °F	80
Average river depth, ft	26.8	River temperature at mouth, °F	74
River cross-sectional area, ft²	168,100	Heat discharges from other four plants as listed in Table V-3	
Maximum river velocity (tidal), fps	1.856		

[b]See Table V-2 for explanation of these heat discharges.

[c]This heat transfer coefficient represents a thermal stratification factor of 2.

in 1964. A value of these rates, 180 and 260 Btu/(day•ft^2•F°), respectively, were also used to show possible effects of thermal stratification.*

The calculated results of the staff's study are summarized in Figs. A-1 through A-5. The temperatures shown are for quasi steady-state conditions and correspond to the tidal cycle conditions that would give a maximum river temperature at Indian Point. The highest river temperatures occur at Indian Point; maximum, minimum, and average temperatures during the tidal cycle at this location are shown in Table A-1.

The temperature rises in the river due to the thermal discharges can be obtained by subtracting from the indicated temperature the 80°F ambient river temperature assumed for the study.

The residual temperature effect at Indian Point from the heat discharges at Danskammer and Roseton indicated in Fig. A-1, suggests that the applicant's studies should have included these plants. The study also shows that there is an apparent elevation of the average river temperature in the vicinity of Indian Point due to operation of other power plants on the river and that the river intake temperature at the Indian Point Plant might become sufficiently high to cause concern whether the maximum of 90°F surface temperature specified by the State will be exceeded.

When using the results of these calculations, one must recognize that the estimates are strong functions of input variables; these variables are largely based on judgment and need verification by more substantive field data than are now available.

2. HIRST ROUND-JET NEAR-FIELD MODEL

The Hirst model has been previously described (FES, IP-2, p. III-37). Most of the cases studied assumed that a 4-ft x 15-ft port could be simulated by an equivalent circular port 8.7 ft in diameter. A closer approximation would be to assume that with the two end ports completely closed, the remaining ten ports would have to be

*Thermal stratification would increase the surface temperature above the cross-sectional average and, therefore, increase the heat loss from the surface. The one-dimensional model does not accommodate input of the thermal stratification factor except by adjustment of the heat transfer coefficient, as discussed above. Cross-sectional temperatures are related to the surface temperature by

$$\text{thermal stratification factor} = \frac{\text{average surface temperature rise}}{\text{average cross-sectional temperature rise}}.$$

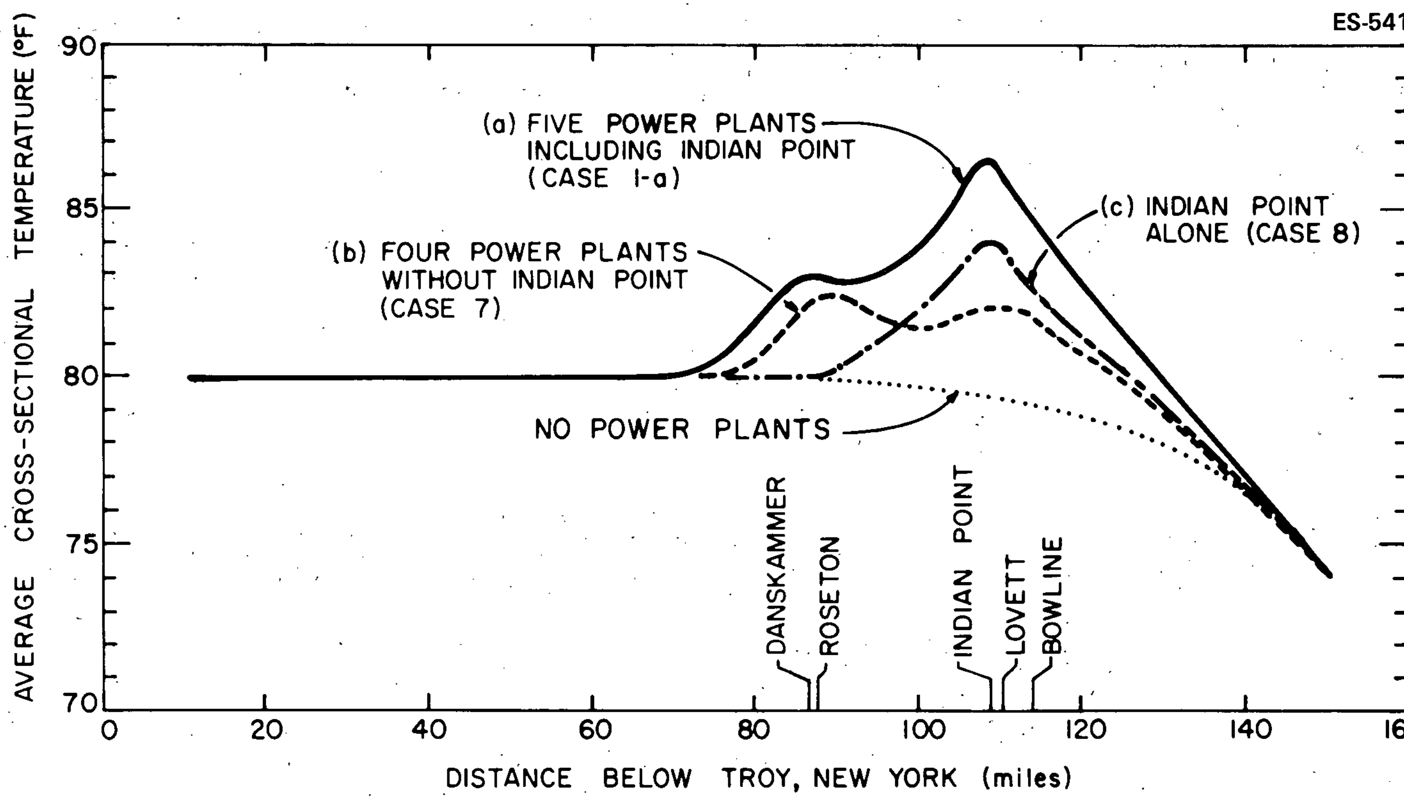

Fig. A-1. Calculated temperature distributions in the Hudson River with operation of (a) five power plants, (b) four plants without Indian Point, and (c) Indian Point alone. The Indian Point Plant is at base design conditions, and freshwater flow in the river is 4,000 cfs with heat transfer to the atmosphere of 90 Btu/(day·ft^2·F°). Case numbers refer to Table A-1.

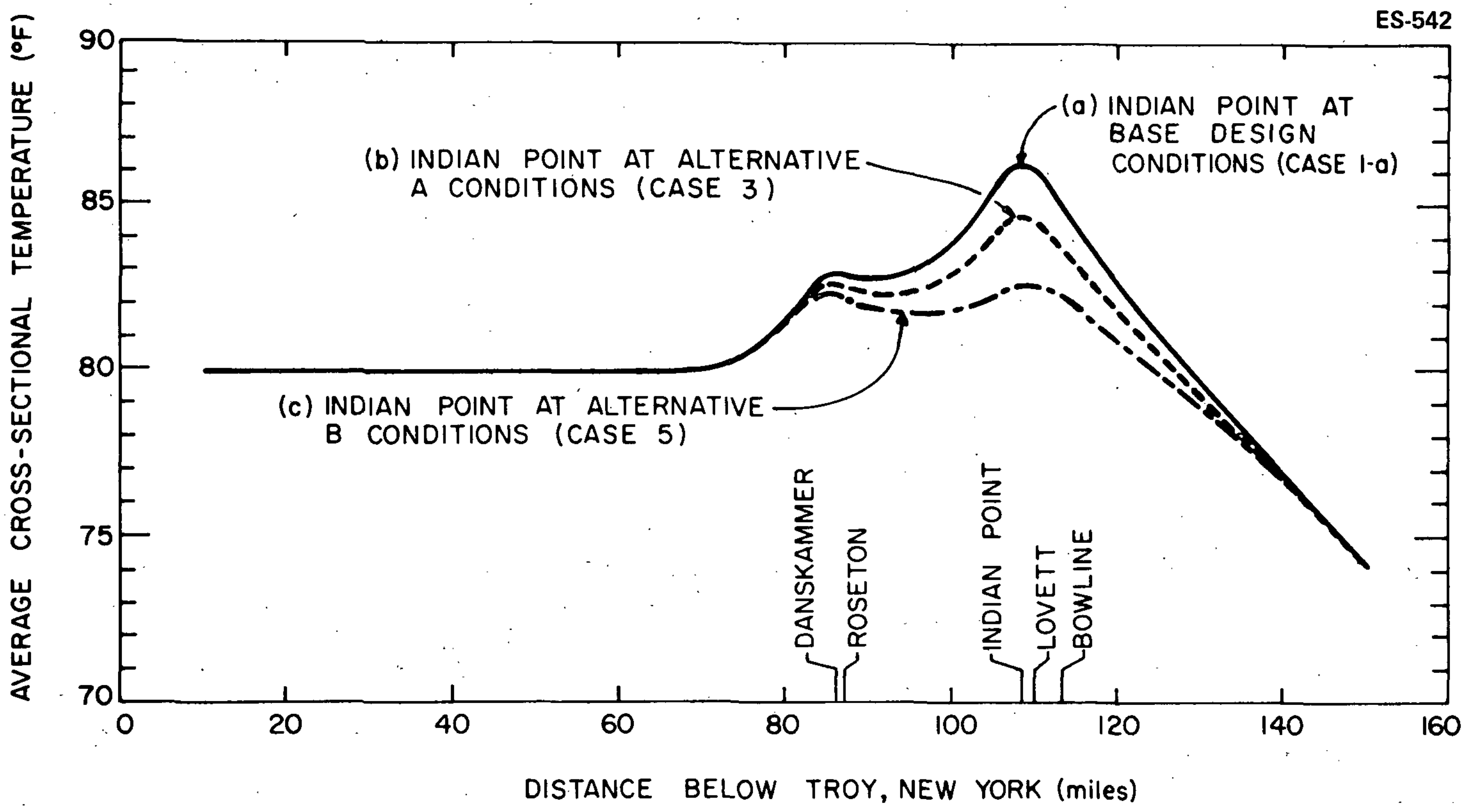

Fig. A-2. Calculated temperature distribution in the Hudson River with five power plants in operation and Indian Point at (a) base design conditions, (b) Alternative A conditions, and (c) Alternative B conditions. Freshwater flow in the river is 4,000 cfs, and the heat transfer to the atmosphere is 90 Btu/(day·ft^2·F°). Case numbers refer to Table A-1.

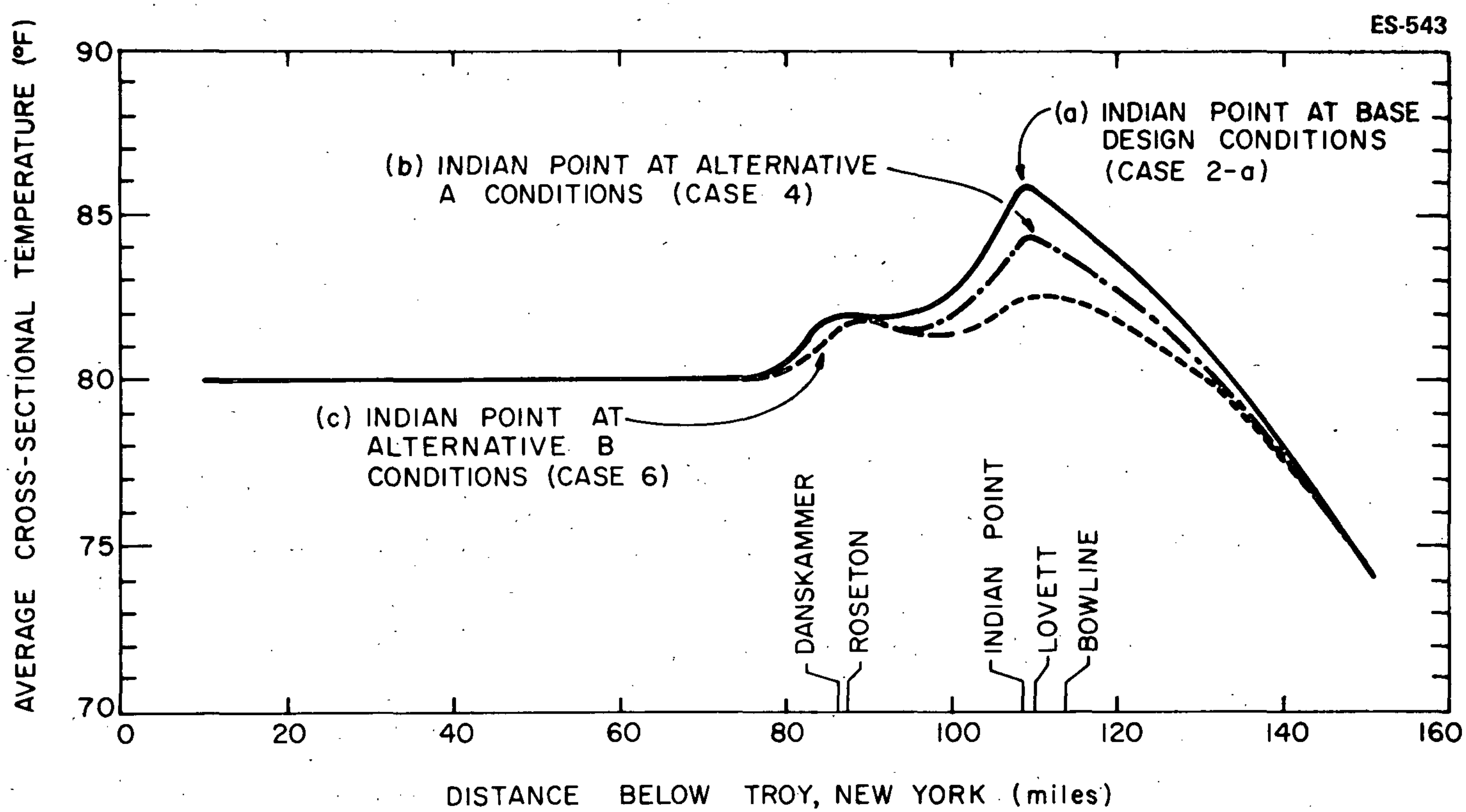

Fig. A-3. Calculated temperature distribution in the Hudson River with five power plants in operation and Indian Point at (a) base design conditions, (b) Alternative A conditions, and (c) Alternative B conditions. Freshwater flow is 11,000 cfs, and the heat transfer to the atmosphere is 90 Btu/(day$\cdot$ft$^2\cdot$F°). Case numbers refer to Table A-1.

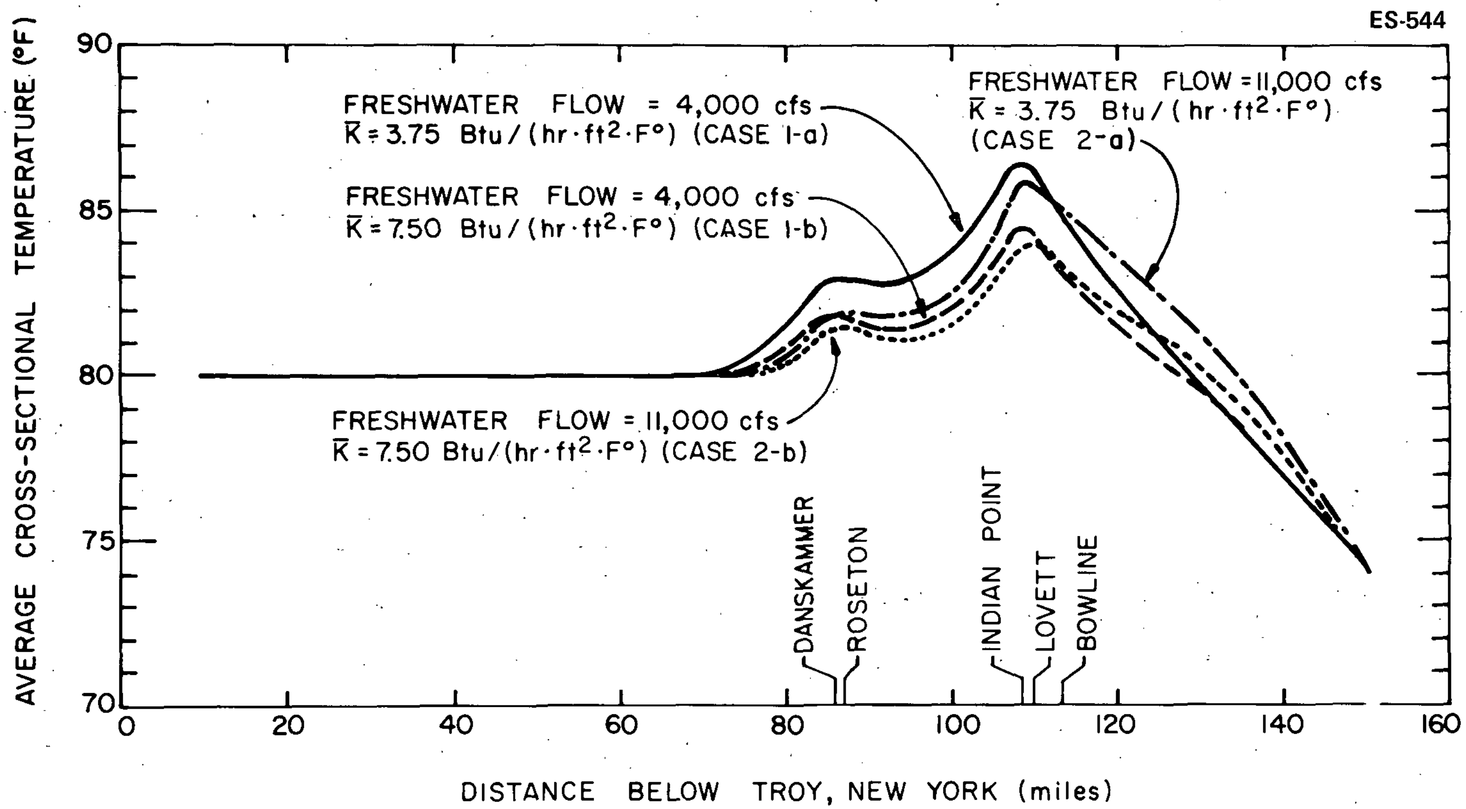

Fig. A-4. Calculated temperature distribution in the Hudson River with five power plants in operation at freshwater flow rates of 4,000 cfs and 11,000 cfs, and with heat transfer rates ($\bar{K}$) to the atmosphere of 90 Btu/(day·ft^2·F°) and 180 Btu/(day·ft^2·F°). Case numbers refer to Table A-1.

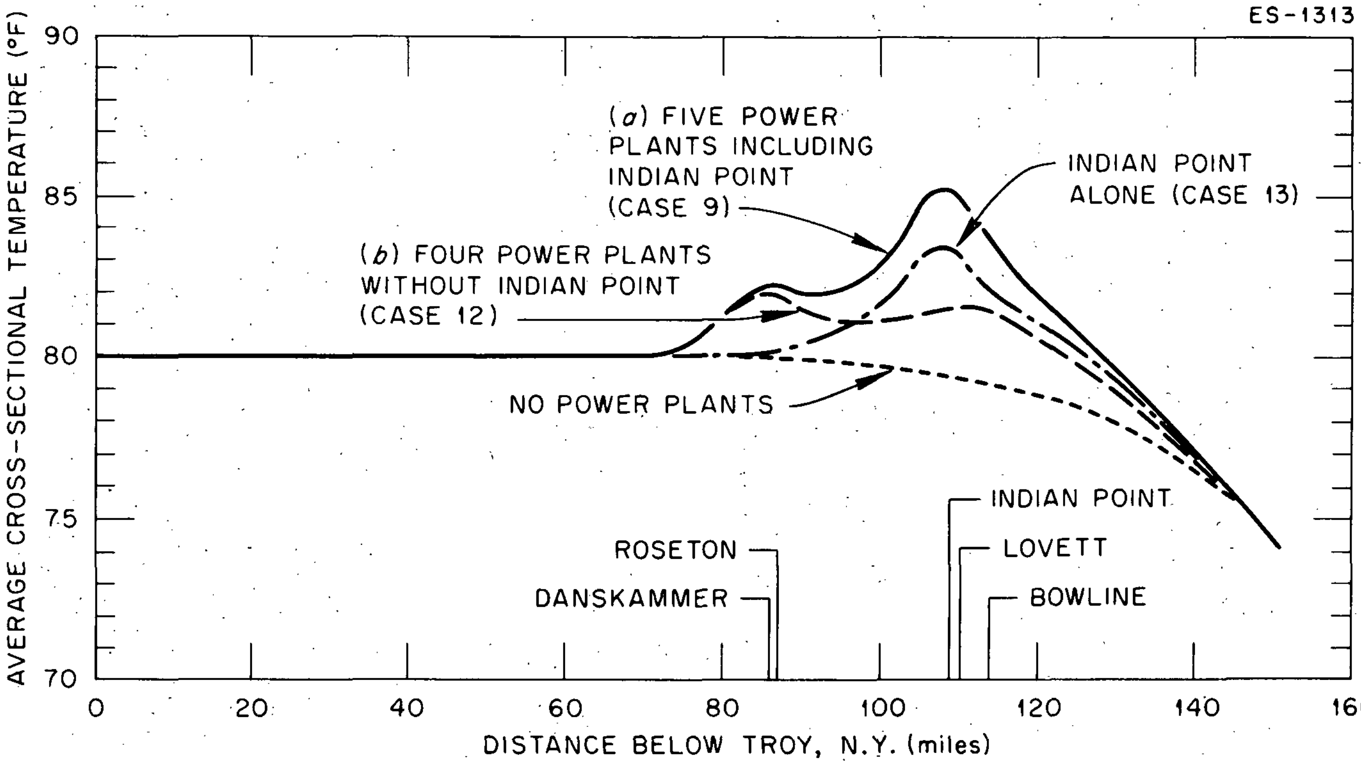

Fig. A-5. Calculated temperature distributions in the Hudson River with operation of (a) five power plants, (b) four plants without Indian Point, and (c) Indian Point alone. The Indian Point Station is at base design conditions, and freshwater flow in the river is 4,000 cfs with heat transfer to the atmosphere of 5.42 Btu/(hr·ft^2·F°), or 130 Btu/(day·ft^2·F°). Case numbers refer to Table A-6.

about 3/4 open to provide a 10-fps nominal exit throat velocity. This is equivalent to a port diameter of about 7.5 ft, but the effect of making this adjustment is small, as indicated in Case 6 of Table V-4.

The various parameters assumed in carrying out the Hirst round-jet analysis and the results obtained are indicated in Table V-4. If the port exit velocity is about 10 fps and the receiving water temperature is 79°F, the near-surface temperature at the center of the plume is below 90°F for all cases studied; if the exit velocity is as low as about 4 fps with 79°F receiving water temperature, the surface temperature may reach 90°F. Fig. A-6 summarizes the velocities that will produce calculated near-surface temperatures of about 90°F at other receiving water temperatures. The vertical profile of the plume for the base case and the time-temperature relationships are indicated in Fig. V-5.

During periods when the Hudson River temperature is below about 39°F, a combination of circumstances could possibly cause the discharged water plume to rise and then begin to sink.[3] The judgment of the staff is that suitable conditions for this phenomenon would occur very infrequently and would be transitory in nature.

3. KOH AND FAN SLOT-JET NEAR-FIELD MODEL

The Koh and Fan model[4] is for a multiport diffuser discharging into an infinite, stagnant body of receiving water (FES, IP-2, p. III-37). It more closely represents the actual conditions at the discharge ports of the Indian Point Plants than does the Hirst model discussed above.

A parametric study was made of the effect of the various input variables, with the results shown in Table V-5. To simulate more closely the effect of a series of rectangular ports in the discharge structure, each 4-ft x 15-ft opening was assumed to be equivalent to four ports 3.82 ft in diameter with a centerline spacing of 5.25 ft, or a total of 40 equivalent-sized ports for the base case with 100% circulating water flow. At 60% flow conditions, five ports were assumed to be open (with an equivalent diameter of 4.25 ft), and the remaining ports were closed (Cases 2 and 3, Table V-5). For the base case conditions, the plume will travel a horizontal distance of about 106 ft before surfacing and will have been diluted by a factor of about 2.3; for a 79°F river intake temperature, the maximum calculated centerline surface temperature is about 84°F. As with the Hirst round-jet model at a port exit velocity of about 10 fps, the calculated surface

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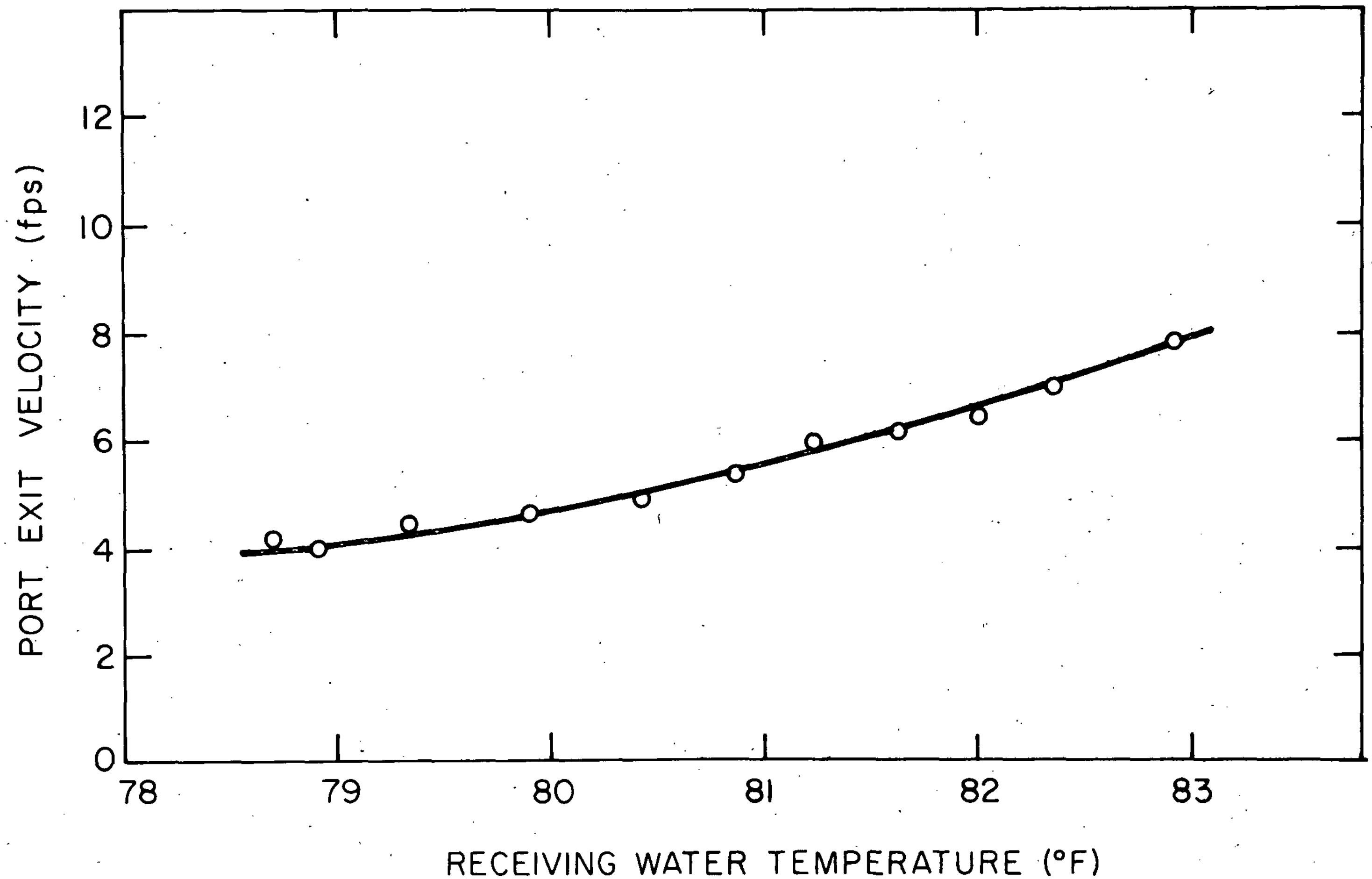

Fig. A-6. Discharge port exit velocity associated with 90°F calculated near-surface temperature using Hirst round-jet model. (Other parameters are as in base case, Table V-4.)

temperature does not exceed 90°F. In this analysis it was assumed that the intake temperature is not elevated by recirculation or effects of other thermal discharges into the river — an assumption that may not be correct as indicated by the far-field studies (Section V.C.1 and Section 1 of this appendix).

4. INTERMEDIATE-FIELD (PLANE OF DISCHARGE) STUDIES

The applicant used a number of mathematical and physical models to predict and assess the thermal effects in the plane of discharge of Indian Point Units Nos. 1, 2, and 3 (ER, IP-3, Section 9). A summary description of each, together with staff comments, has been previously given (FES, IP-2, pp. III-26 to III-36). As a result of these studies, the applicant concluded that with a 79°F river temperature, the extent of the 4F° isotherm in both cross-sectional and surface-area aspects would meet the New York State criteria. This assessment was made on the basis of the waste heat discharged from only the Indian Point units without the imposed effects of other plants on the Hudson River, and also on the basis that the most severe condition arises when the freshwater flow in the river is about 20,800 cfs (a flow rate at which the saltwater front is downstream of Indian Point and no density-induced upstream flow is said to exist).

The applicant's mathematical study is based on a simplified one-dimensional steady-state model. The staff has presented its reservations about the model (FES, IP-2, pp. III-34 and III-35) and pointed out that a time dependent three-dimensional model is desirable for accurate representation of the effects of the heat discharged into the Hudson River estuary. Since no such model has wide acceptance at the present time, the staff has used the applicant's model (with some modification) for a parametric study, as discussed below.

The applicant's one-dimensional model intuitively applied adjusting factors to make the calculated results correlate with one set of Unit No. 1 thermal discharge data. The staff believes that the supporting data are insufficient to provide confidence in the adjusting factors (FES, IP-2, p. III-34) and has assumed them to equal unity in its own analysis. Recirculation is not included in the applicant's model, but the staff has considered it as a parameter, because the plane of discharge could be subject to recirculation effects. Further, the applicant's studies involve selection of input values that are somewhat speculative because of a lack of substantive field data (FES, IP-2, pp. III-31 to III-36). The staff has, therefore, elected to substitute a range of possible parameters into the applicant's model, as follows:

Parameter	Range
River freshwater flow	4,000 and 7,000 cfs
Longitudinal dispersion coefficient	4 to 12 sq miles/day
Thermal stratification factor	1.0 to 3.5
Intake recirculation factor (fraction recirculated)	0 to 0.15
Submerged jet dilution factor	1.75 to 3.5
Surface heat exchange coefficient	90 to 130 Btu/(day·ft^2·F°) 3.75 to 5.42 Btu/(hr·ft^2·F°)

The staff study included a large number of cases. Results selected from the computer output as being representative or of interest are shown in Table V-6. The fractions of the total cross sections and river widths within the 4F° isotherm on a tidal average basis (Table V-6) do not represent the most severe or critical condition during a tidal cycle. To simulate tidal maximum conditions, the staff has used the empirical multiplying factor of 1.35 proposed by the applicant (ER, IP-3, Appendix EE, pp. 18-19). The staff does not endorse this method but has used this factor as an expedient to estimate the tidal maximum fractions shown in the last two columns and to depart as little as possible from the applicant's method of analysis.

During the ASLB hearings for the Indian Point Unit No. 2 case, the applicant stated that the staff improperly inserted the near field phenomenon of recirculation into a far-field model. The staff has responded to this objection in its written testimony dated February 22, 1973.* The main point in this response is the recognition that the extent of the 4 F° at the plane of discharge can not be predicted by a far-field model but needs to include both the near and far-field effects; and by any realistic point of view, the extent of the 4 F° isotherm is expected to increase the greater the percentage of heat recirculation into the intake structure. This factual statement does not depend on the mathematical model used but on the realistic observation that recirculation redistributes the heat in the river so that heat and mass are withdrawn from one point (intake) and discharged at another (discharge). Recirculation is not an important factor in the staff overall analysis and, as shown in Table V-6, even with zero recirculation the 4 F° surface excess temperature isotherm exceeds two-thirds of the river for almost all the cases studied.

*"Additional Discussion of Surface and Cross Sectional Temperature Distribution at Indian Point Site," M. Siman-Tov, February 22, 1973 (following Tr. 9892 in ASLB hearing proceedings).

From a mathematical point of view, the applicant's model cannot consider recirculation effects since it solves the basic differential equation by a point source solution in which the intake and discharge are assumed to be at the same point. Because there is a real distance between the intake and discharge structures, the point source solution probably predicts an average temperature that exists at some undefined point somewhere between the intake and discharge. The temperature at the actual discharge point is expected to be higher than that given by the point source solution, and the temperature at the intake point is expected to be lower. These effects can be seen with no difficulty in a mathematical model based on numerical increments. In this case, one can set the discharge at one space increment and the intake at a few space increments upstream. One can see that the average cross-sectional temperature at the discharge point is affected by the number of space increments chosen between the intake and the discharge, and it decreases to some point source value when both are located at the same space increment.

Because the staff has chosen to use the applicant's model for its parametric study, the staff elected to modify the model so that it will account for the effects of recirculation. The method used and a partial justification for it may be found in the reference cited at the bottom of this page.*

With some combinations of parameters the 4F° isotherm would encompass less than one-half the cross-sectional area of the river and thus meet the New York State criteria; with other combinations it would not meet the criteria. More significantly, the surface width included within the 4F° isotherm on a tidal maximum basis exceeded the two-thirds allowed in the criteria for all combinations of reasonable parameters, except in the instance when all the variables were selected as the most optimistic but unrealistic values within the ranges studied.** In substantially all the cases included within the parameters studied, the 4F° surface isotherm extends the total width of the river.

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*"Additional Discussion of Surface and Cross Sectional Temperature Distribution at Indian Point Site," M. Siman-Tov, February 22, 1973 (following Tr. 9892 in ASLB hearing proceedings).

**As shown in Case 22 of Table V-6, the thermal stratification factor equals 1.0, the recirculation factor is zero, the jet-dilution factor is 1.75, the freshwater flow is 7,000 cfs, the dispersion coefficient is 12 sq miles/day, and the heat exchange coefficient is 130 Btu/(day$\cdot$ft$^2\cdot$F°). The estimated fraction of the width within the 4F° isotherm is 0.65 — only marginally within the allowable two-thirds of the width.

REFERENCES FOR APPENDIX A

1. Siman-Tov, M., "Preliminary Study of the Expected Temperature Distribution in the Hudson River as a Result of Operation of Danskammer, Roseton, Indian Point Units 1 and 2, Lovett and Bowline Power Stations," written testimony presented at ASLB hearing for Unit No. 2, February 8, 1973 (Docket No. 50-247).

2. Quirk, Lawler, and Matusky Engineers, "Hudson River Water Quality and Waste Assimilative Capacity Study," report to the State of New York Department of Environmental Conservation, December 1970, Fig. 41.

3. Redirect-rebuttal testimony of John P. Lawler, of Quirk, Lawler and Matusky Engineers, for Indian Point Unit No. 2, "Behavior of the Indian Point Thermal Effluent During Winter Conditions and Its Effect on Hudson River Striped Bass," Docket No. 50-247, February 5, 1973.

4. Koh, R. C. Y., and Lah-Nien Fan, Tetra-Tech., Inc., "Mathematical Models for the Prediction of Temperature Distributions Resulting from the Discharge of Heated Water into Large Bodies of Water," Report 16130 DWO 10/70, Water Pollution Control Research Series, Environmental Protection Agency, Water Quality Office, October 1970.

Appendix B

SUPPLEMENTAL INFORMATION RELATING TO BIOLOGICAL MODELS

1. INTRODUCTION

One of the most important biological consequences of power plant operation with once-through cooling is associated with mortality of organisms entrained with the cooling water. In this way a power plant is similar to a large predator. The importance of such predation is related to the rate at which the organisms are "consumed," and for passive and nearly passive organisms, consumption rates are proportional to the rate at which the water is used.

Populations of organisms susceptible to entrainment and maintained by local reproduction may be reduced by operation of all three Units, and a considerable proportion of the biota will be withdrawn with the addition of Unit No. 3. These organisms will include bacteria, planktonic algae, many invertebrate species, fish eggs and larvae. Table B-1 lists the fish species in the area whose eggs or larvae are known to be vulnerable to entrainment. During their passage through the once-through cooling system, these organisms will be exposed to mechanical, thermal, and chemical damage. High mortality may result, especially for fragile species, during periods of chlorination. Plankton that migrate via transport flows to maintain their position in the river will be the most susceptible to entrainment, since they may remain in the area for several weeks.

Entrainment at the Indian Point Plant is influenced by seasonal variations of the estuarine hydraulics near the site. Under average conditions, the freshwater flow of the Hudson River ranges from a maximum of over 50,000 cfs in the spring to a minimum of 6,500 cfs during the late summer. The maximum water requirements of Indian Point Units Nos. 1, 2, and 3 of 4,585 cfs correspond to a range of less than 15% to about 71% of the available freshwater flow. During drought conditions, such as those in August 1964 when the freshwater flow rate dropped to about 3,050 cfs, the water requirements will exceed the freshwater flow by about 50%.

This proportionally high usage of Hudson River water appears to have a potential for exposing a large part of the planktonic community to thermal, physical, and chemical damage by entrainment with the circulating cooling water.

Table B-1. List of estuarine fishes with various life stages that are susceptible to entrainment and impingement and that have been collected during the sampling program at Indian Point

Species	Entrainment			Impingement
	Eggs	Larvae	Post-larval	
Striped bass	*a*	*a*	*a*	*a*
White perch		*a*	*a*	*a*
Tomcod	*b*	*a*	*a*	*a*
Bay anchovy	*b*	*a*	*a*	*a*
American eel			*a*	*b*
Smelt		*a*	*a*	*a*
Blueback herring		*a*	*a*	?
Alewife		*a*	*a*	*b*
Atlantic silverside		*a*	*a*	*b*
American shad		*b*	*b*	*b*

[a]Important fraction of local population may be subject to entrainment or impingement.

[b]Life stage present and susceptible to entrainment or impingement.

This Appendix gives, first, a discussion of the distribution of striped bass eggs, larvae, and juveniles in the Hudson River followed by a discussion of the local spatial distribution of striped bass ichthyoplankton ("f" factors). The fourth section describes the staff's striped bass young-of-the-year and life-cycle population models and concludes with a discussion of the applicant's striped bass life-cycle model.

2. DISTRIBUTION OF STRIPED BASS EGGS, LARVAE, AND JUVENILES IN THE HUDSON RIVER

In this section the staff considers (a) spawning and distribution of eggs, (b) distribution of larvae and juveniles, and (c) factors contributing to larval distribution. The discussion is based primarily on an analysis of data from the 1966-1968 Hudson River Fisheries Investigations, although earlier studies are cited where appropriate. The staff has not revised this section to include a comparable analysis of the 1973 data collected by TI, NYU, and QLM. However, the staff has made extensive use of these new data in revising the Indian Point Unit No. 3 DES, for example, in Sections V.D.2.b(2), V.D.2.d(3)(c), V.D.2.e, and XI.C.3c(4)(b), and in Appendix B, Sections B.3 and B.4.b. The staff hastens to add that the important task of evaluating the 1973 data has been made more difficult and is still in progress, because the staff has not received some of the data (e.g., the NYU 1973 transect and intake data at Indian Point required to estimate the intake f-factor).

Although the various 1972 and 1973 reports contain data from a more complete and intensive sampling problem than represented by the Rathjen and Miller study[6] or the Hudson River Policy Committee study,[7] the TI, NYU, and QLM studies, as they relate to longitudinal distribution of eggs, larvae, and juveniles, provide estimates of these distributions for 1973 only. They do not replace or negate the information relating to longitudinal distributions for 1955, 1966, and 1967.

The staff disagrees adamantly with the applicant (see Con Edison comment-156) that the data generated by Rathjen and Miller[6] in 1955 and by HRFI[7] in 1966-1968 are of very poor scientific quality compared to data now available from the applicant's ecological study. (See staff's response to Con Edison's comment 95.) Specifically, the staff's preliminary analysis of the 1973 data indicates that previously held notions about striped bass abundance, spawning areas, movement of young, distribution of larvae and juveniles, and factors contributing to larval distribution are essentially correct.

a. Spawning and Distribution of Eggs

Adult striped bass move upstream in late winter to early spring, and most spawn upstream from Indian Point. The eggs and larvae drift with the currents in a net downstream direction; large numbers pass the Indian Point site. Several studies have indicated that the principal nursery area for juveniles is below Indian Point in Haverstraw and Tappan Zee Bays, although there are some less extensive nursery areas upstream (Fig. B-2). Entrainment mortality of larvae and eggs, as they drift past Indian Point Units Nos. 1, 2, and 3, would result in loss of some of the larvae and eggs that pass the Plant en route to Haverstraw and Tappan Zee Bays.

The importance of entrainment is believed to be associated with the withdrawal of significant proportions of the water in the river. For the case of Units Nos. 1 and 2, the staff calculated the relative water usage by these Plants in comparison with the volume of various reaches of the Hudson River. The ratio of the amount of water circulated through the condensers over various periods of time to the volume of various reaches of the river provides a meaningful evaluation of the need for in-depth analysis. Comparison of these values with the distribution of larvae in the estuary in three different years (Figs. B-3 to B-5) indicates the potential magnitude of the entrainment situation. During a period equal to the length of time the juvenile fish will be susceptible

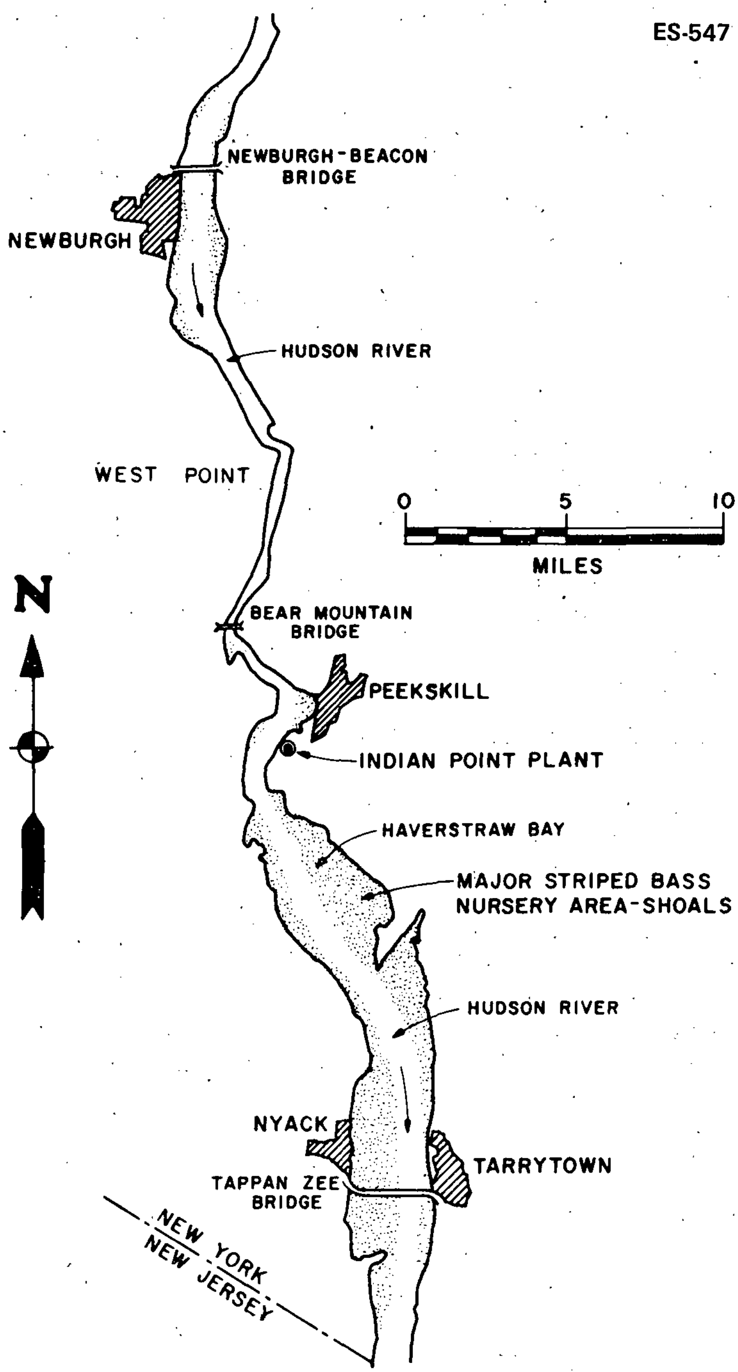

Fig. B-2. Major nursery and spawning areas of striped bass in the Hudson River.

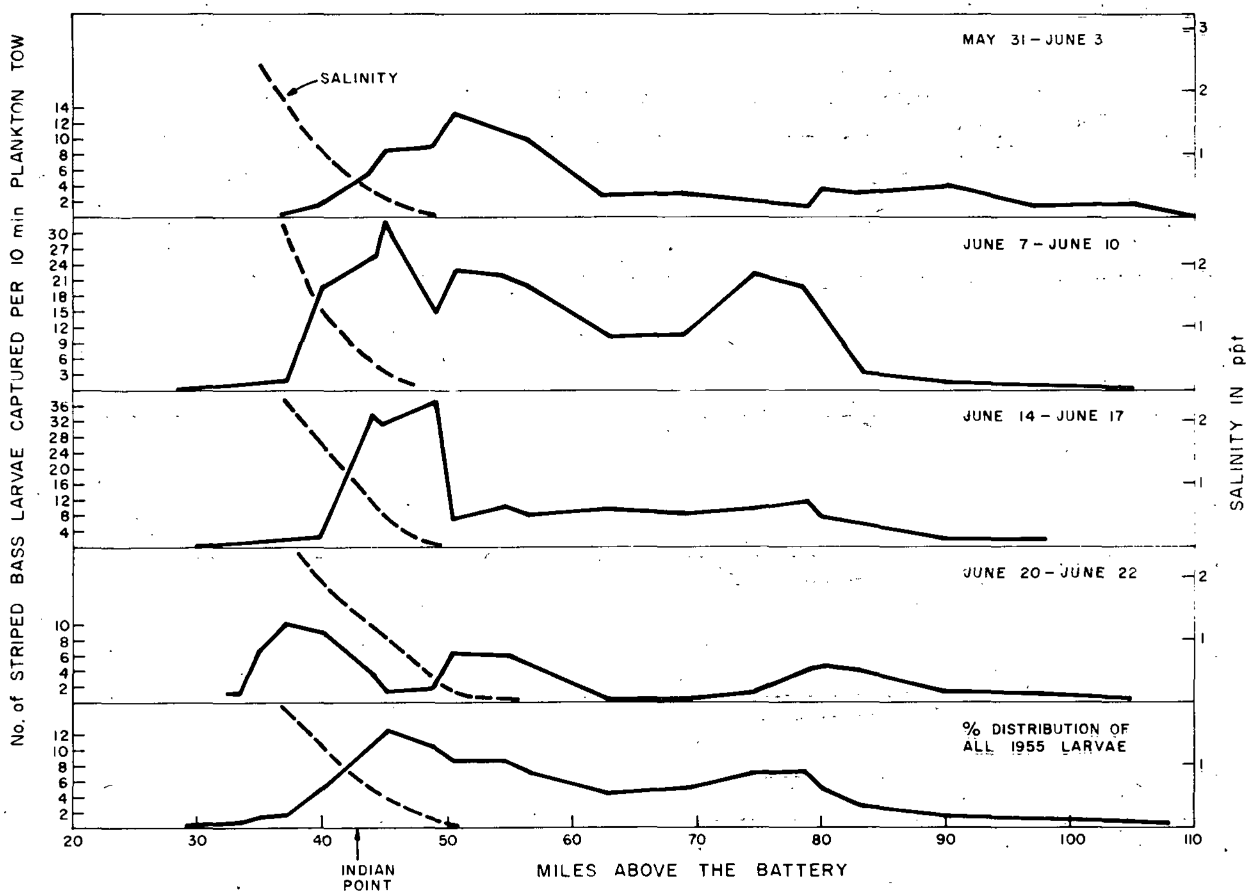

Fig. B-3. Longitudinal distribution of larval striped bass in the Hudson during 1955. 1955 data — Rathjen and Miller.

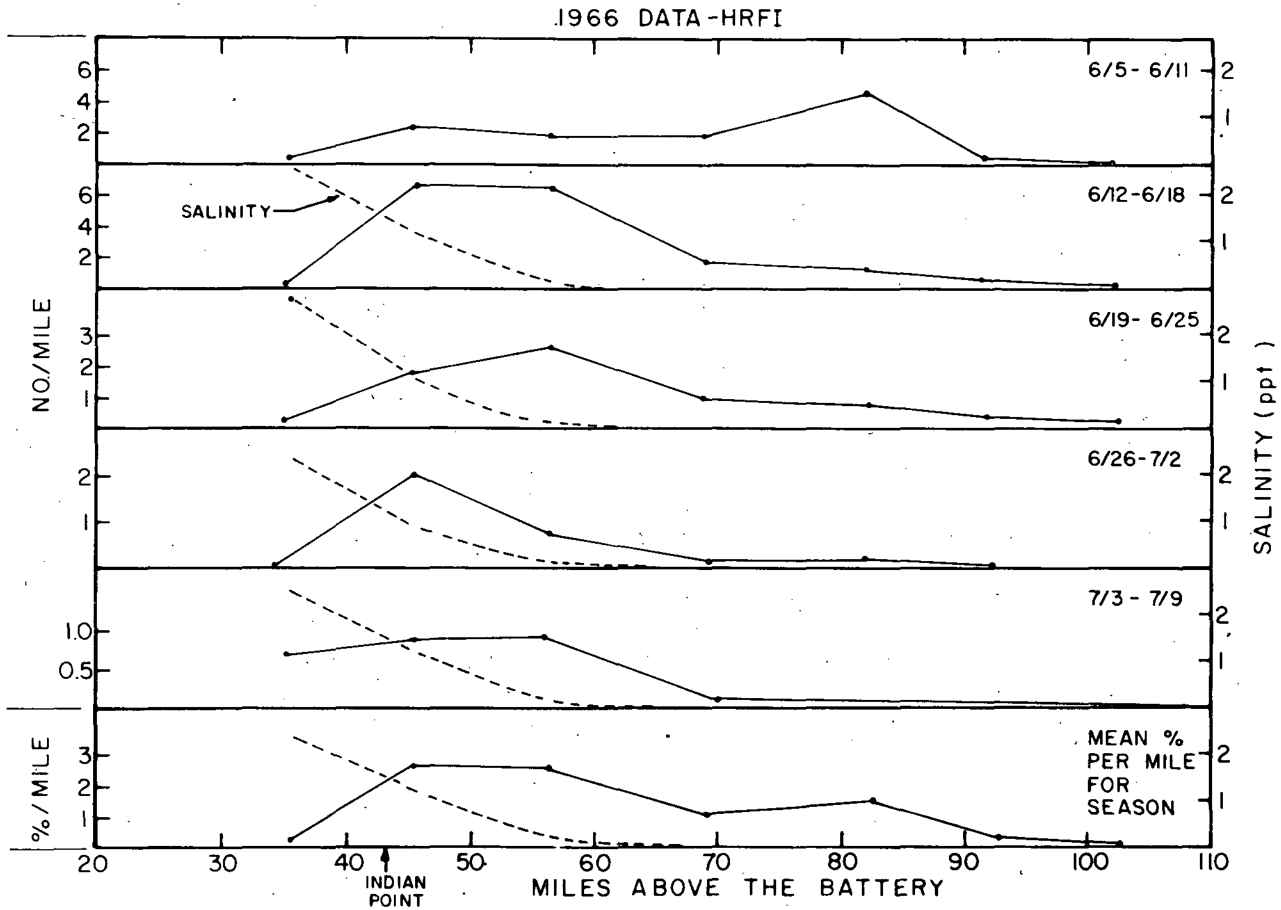

Fig. B-4. Longitudinal distribution of larval striped bass in the Hudson during 1966.

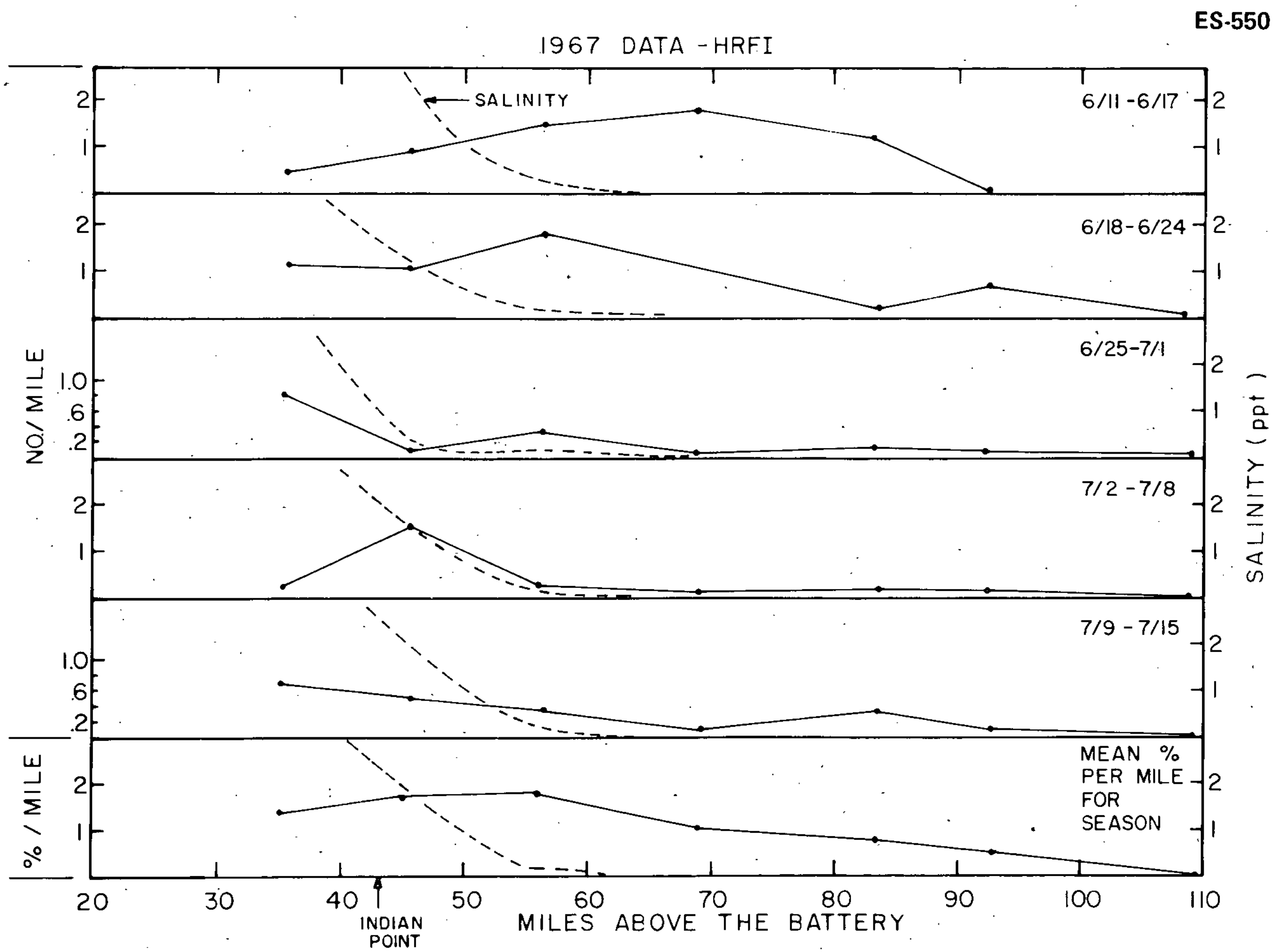

Fig. B-5. Longitudinal distribution of larval striped bass in the Hudson during 1967.

to entrainment (6 to 8 weeks), Units Nos. 1, 2, and 3 will use more water than is contained within the reach from Mile Point 40 to Mile Point 51, where larvae are in greatest abundance.

The most comprehensive data for the spawning activity in the Hudson were collected during the years 1966 through 1968.[8] These data were summarized by week and converted to total production by correcting for the incubation time (Table B-2). These estimates indicate that total egg production ranged from 3.6 x 10^8 eggs (1967) to 20.3 x 10^8 eggs (1968), although, as the authors pointed out, sampling difficulties probably caused the low values in 1967. Apparently the peak production of eggs occurs at about 60 to 63°F, with little or no spawning at temperatures of 70°F or more.

The zones within the river where spawning activity is most apparent have been described in several reports and are indicated in Fig. B-6. Rathjen and Miller[6] found eggs in the region from Iona Island (MP 45) upstream to Cruger Island (MP 90), with heaviest concentrations between Lady Cliff (MP 49) and Denning Point (MP 57) in essentially fresh water.

Data from the Cornwall report[7] generally agree with the Rathjen and Miller data, except that more upstream spawning activity was observed. These authors concluded,

> "In 1966, striped bass eggs were collected between Coxsackie and Croton (m.p. 125.0 to 35.5), but they were more abundant between Hyde Park and Peekskill (m.p. 82.0 to 45.5). Water temperature during the period of egg collections ranged from 50°F in late April to 75°F in late June, although most eggs were collected at temperatures of 59° to 63°F in late May and early June.
>
> In 1967, eggs were collected from Saugerties to Peekskill (m.p. 102.5 to 45.5) with the greater concentrations at Saugerties (m.p. 102.5) and Hyde Park (m.p. 82.0). Overall they were less abundant than in 1966. The period of their greatest abundance occurred again in late May to early June at water temperatures of 59° to 60°F although they were collected from early May to mid-June at temperatures from 50° to 68°F.
>
> North of Peekskill, striped bass eggs generally were more abundant near the bottom in the deeper part of a cross section sampled. At that location they were concentrated in the strata 15 to 30 ft off the bottom. Few eggs were taken at the surface at any location.

Table B-2. Effect of temperature on spawning of striped bass in the Hudson River during the Hudson River Fisheries Investigation (1966–1968)

Week	Temp (°F)	Incubation time, I (hr)	Weekly average	Total weekly egg production	Weekly % of total spawn
1966			× 10^6	× 10^6	
4/24–4/30	50.1	100	0.36	0.6	0.3
5/1–5/7	50.0	100	12.48	21.0	1.1
5/8–5/14	50.3	99	11.71	19.9	1.0
5/15–5/21	53.4	88	15.68	29.9	1.5
5/22–5/28	58.9	70	274.04	657.7	33.3
5/29–6/4	62.6	58	250.37	725.2	36.7
6/5–6/11	66.2	45	102.80	383.8	19.5
6/12–6/18	69.1	36	16.74	78.1	3.6
6/19–6/25	73.7	21	7.15	57.2	2.3
				1973.4	
1967					
5/7–5/13	50.7	98	9.00	15.43	4.3
5/14–5/20	52.5	92	4.15	7.58	2.1
5/21–5/27	55.4	82	26.46	54.21	15.0
5/28–6/3	57.6	77	66.51	145.11	40.2
6/4–6/10	64.4	52	42.03	135.8	37.7
6/11–6/17	68.5	38	0.17	0.75	0.2
6/18–6/24	69.5	35	0.29	1.39	0.4
				360.27	
1968					
4/21–4/27	53.1	90	0.29	4.0	0.2
4/28–5/4	56.0	81	10.25	96.0	4.7
5/5–5/11	58.3	73	24.18	413.0	20.4
5/12–5/18	60.4	66	42.41	796.0	39.3
5/19–5/25	61.5	63	14.87	295.0	14.6
5/26–6/1	62.7	58	11.32	243.0	12.0
6/2–6/8	65.2	50	3.07	74.0	3.7
6/9–6/15	66.6	44	3.55	96.0	4.7
6/16–6/22	68.4	39	0.096	4.0	0.2
6/23–6/29	70.7	31	0.096	4.0	0.2
6/30–7/6	73.2	23	0.096	0.6	0
				2025.6	

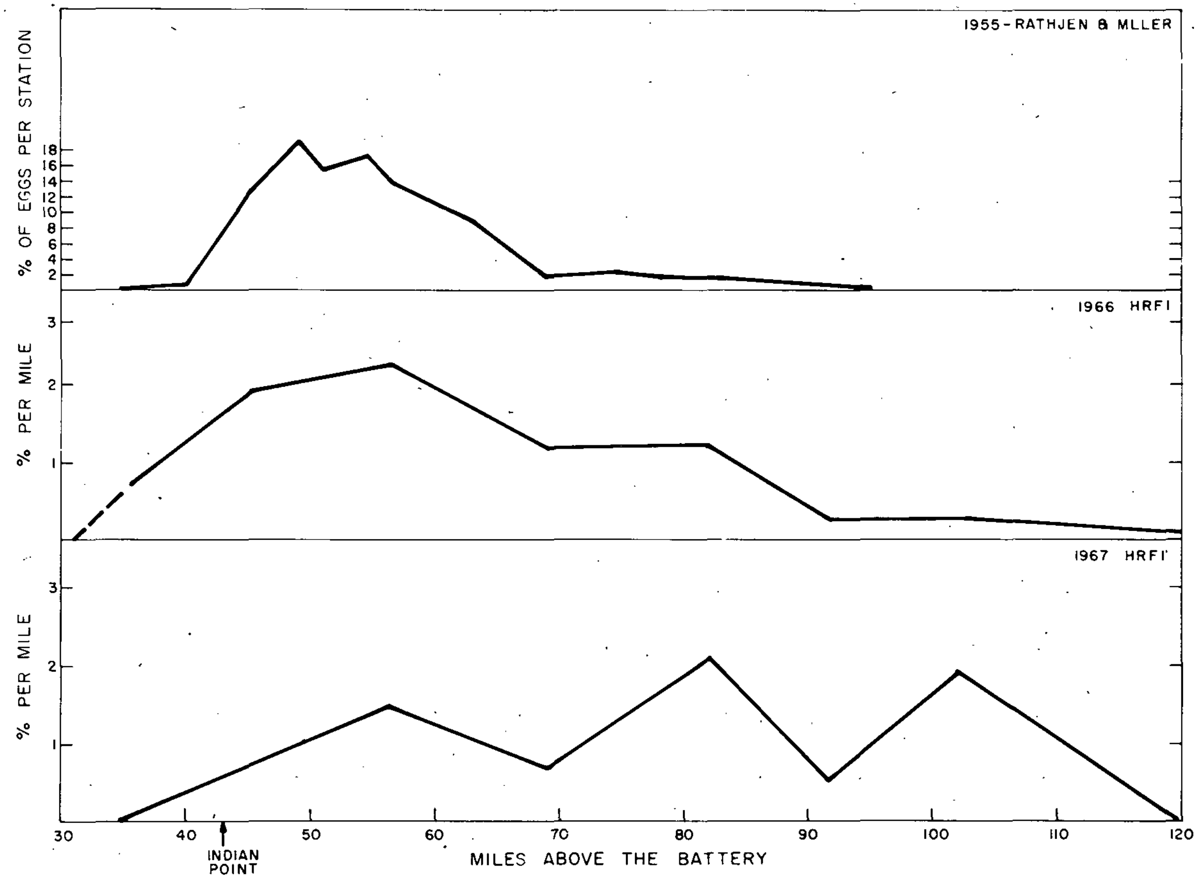

Fig. B-6. Longitudinal distribution of striped bass spawning in the Hudson as estimated by collection of eggs in plankton nets.

Our data on the spatial distribution of striped bass eggs supported the findings of Rathjen and Miller (1957) that the spawning of striped bass in the Hudson River was restricted to fresh or slightly brackish water. With two exceptions, striped bass eggs were not collected in salinities greater than 0.3% and most were collected where salinity measured less than 0.1%.

The upstream limit of striped bass spawning appeared to be in the vicinity of Coxsackie. Most probably the mature fish spawned throughout the reach north of the salinity threshold when the water temperature was suitable and the estuary south of Coxsackie was large enough to accommodate them. Water temperature did not rise at a uniform rate throughout the estuary in spring.

Our finding that striped bass eggs increased in abundance with increasing depth also was noted in earlier studies. Most of the eggs collected by Woodhull (1947) in the San Joaquin River in California were taken within 5 ft of the bottom. Rathjen and Miller (1957) collected more striped bass eggs in the Hudson River in nets towed at a depth of 12 to 18 ft than at the surface. McCoy (1959) determined that concentrations of eggs in the Roanoke River increased with depth. The concentrations of eggs off the bottom at Peekskill suggested that the increased density of the water there, combined with turbulence, prevented the eggs from sinking closer to the bottom as at upstream locations."

These data are consistent with actual observation of spawning,[9,10] and these collections of recently spawned, developing eggs by other researches[10-14] have shown that striped bass spawn in fresh water in a moderate to swift current. Mansueti[15] inferred that suspension of the semibuoyant striped bass egg by water current is necessary for its survival because of the failure of striped bass to reproduce in freshwater impoundments. His arguments were further developed by Talbot[16] in reference to the importance of the estuarine environment for striped bass reproduction.

b. Distribution of Larvae and Juveniles

The passive transport of striped bass eggs and larvae is generally accepted. Since the adult bass spawn in fresh water, the eggs and early larvae drift downstream with the net movement of water in the river. This was the situation which was observed during the Hudson River Fisheries Investigations (HRFI),[7] a project designed to evaluate the potential effect of the proposed pumped-storage generating station at Cornwall. A summary of the 1966 and 1967 egg and larval distribution data from the study is given in Tables B-3 to B-5. It is apparent that downstream drift is a real phenomenon. For example, in 1966 the periods of peak larval abundance were not preceded by periods of peak egg abundance at downstream locations. In addition, collections during 1967 showed greater concentrations of eggs than larvae at upstream locations, while larvae became more abundant than eggs in the downstream direction. This same pattern was also apparent in the Raytheon Company data[17] from 1969 and 1970 sampling between Bear Mountain Bridge and Croton Point. Thus, all of the more recent data show findings that confirm the 1955 study by Rathjen and Miller[7] (Table B-6).

The longitudinal distribution of larval bass during 1955, 1966, and 1967 all show increased concentrations of larval fish in the low salinity areas near the salt front (Tables B-3 to B-6 and Figs. B-3 to B-5).

In interpreting longitudinal distributions of striped bass larvae, it must be realized that because of the protracted spawning period (and downstream drift) the larval concentrations upstream would be composed of younger fish on the average. This trend would tend to underestimate the importance of the downstream concentrations of larvae because of the higher mortality rates of smaller larvae. This effect would largely disappear after most of the fish were beyond the yolk-sac stage. Thus, the postspawning distribution would be a better indication of larval movement patterns than would the average distribution over the entire season. For this reason, the data presented in Table B-7 will be used in later comparisons. However, note at this point that these data should not be too rigorously applied from a quantitative standpoint because of the type of sampling on which they are based (see Sect. V.D.2.e). Nonetheless, they do provide strong indications of the relative distribution.

The relationship between low salinity areas and larval abundance is particularly obvious in the 1967 data (Fig. B-5). During sampling in the last week of June, the salinity at the Peekskill site was depressed and most larvae were downstream; on the following week the salt front had moved back upstream and was accompanied by an influx of larval bass.

During July of 1966 and 1967, the plankton gear catches of small bass began to decline at similar rates throughout the sampling area. A similar pattern that occurred in 1968 (Table B-8) coincided with the period when a sharp increase in growth was observed (Fig. B-7). This sharp increase in growth rate is generally believed to be associated with the change in food habits and is probably a

Table B-3. Weekly abundance (number per 1000 ft³) of striped bass eggs and larvae in the Hudson River estuary in 1966

Week	Coxsackie	Saugerties	Kingston	Hyde Park	Marlboro	Cornwall	Peekskill	Croton
				Eggs				
4/17–4/23								
4/24–4/30		0.05						
5/1–5/7						0.02		0.53
5/8–5/14						1.22		
5/15–5/21		0.18	0.17	0.11		1.31		
5/22–5/28	1.10	1.94	1.41	1.54	3.81	6.31	10.18	0.46
5/29–6/4	0.59	3.00	1.03	5.06	7.43	6.01	2.96	1.65
6/5–6/11	0.11	0.14	0.10	6.81	0.70	3.83	3.04	1.12
6/12–6/18				0.12	0.20	0.25		0.51
6/19–6/25						0.02		0.30
Total	1.80	5.31	2.71	13.64	12.14	18.97	16.18	4.57
corrected for volume (× 10⁶)	7.48	38.15	15.46	96.76	100.73	182.02	145.65	105.97
%	1.08	5.50	2.37	13.96	14.53	26.26	21.01	15.29
				Larvae				
5/15–5/21						0.02		
5/22–5/28					0.25	0.01		
5/29–6/4			0.17	1.31	0.18	0.05	0.11	
6/5–6/11			0.62	4.07	1.87	0.46	0.80	0.14
6/12–6/18		0.23	0.40	1.45	0.92	4.38	2.36	0.13
6/19–6/25		0.11	0.64	0.86	0.89	1.81	0.89	0.17
6/26–7/2			0.07	0.20	0.04	0.56	0.75	0.12
7/3–7/9			0.15	0.66	0.16	0.65	0.38	0.20
7/10–7/16			0.07	0.14	0.17	0.39		
Total	0	0.34	2.12	8.79	4.48	8.33	5.29	0.76
corrected for volume (× 10⁶)	0	2.44	12.88	61.65	37.17	79.93	47.62	17.62
%	0	0.94	4.97	23.77	14.33	30.82	18.36	6.79
%/mile	0	0.05	0.59	2.1	1.2	2.6	1.7	0.34

Table B-4. Weekly abundance of striped bass larvae
in the Hudson River in 1966 based on total tows, in number per tow

Week	Coxsackie	Saugerties	Kingston	Hyde Park	Marlboro	Cornwall	Peekskill	Croton
4/17–4/23								
4/24–4/30								
5/1–5/7								
5/8–5/14								
5/15–5/21						0.02		
5/22–5/28					0.13	0.02		
5/29–6/4			0.82	1.83	0.14	0.11	0.25	
6/5–6/11		0.20	0.78	7.11	2.76	2.15[a]	2.81	0.12
6/12–6/18		0.31	0.50	2.00	2.79	8.12	8.29	0.14
6/19–6/25		0.17	0.73	1.17	1.45	3.25	2.27	0.31
6/26–7/2			0.08	0.25	0.19[a]	0.92	2.24	0.12
7/3–7/9			0.08	0.17	0.14[a]	1.10	1.06	0.64
7/10–7/16			0.06	0.23	0.11	0.54		
7/17–7/23						0.63		
Total	0	0.68	3.05	12.76	7.71	16.86	17.12	1.33
corrected for volume ($\times 10^6$)	0	4.89	18.53	90.52	63.97	161.77	154.11	30.84
%	0	0.09	3.53	17.26	12.19	30.8	29.38	5.88
%/mile	0	0.005	0.35	1.53	1.00	2.61	2.67	0.29

[a]Value corrected from original table.

Table B-5. Weekly abundance (number per 1000 ft^3) of striped bass eggs and larvae in the Hudson River estuary in 1967

Week	Coxsackie	Saugerties	Kingston	Hyde Park	Marlboro	Cornwall (regular)	Peekskill	Croton
				Eggs				
5/7–5/13		1.02	0.03	0.15	0.04	0.01		
5/7–5/13		0.09		0.31		0.07	0.07	
5/21–5/27		2.03	0.28	0.11		0.36	0.66	
5/28–6/3		4.45	0.70	1.70	0.45	1.06	0.48	
6/4–6/10		0.08	0.35	2.69	0.97	1.14	0.14	
6/11–6/17					0.02			
6/18–6/24						0.03		
Total	0	7.67	1.36	4.96	1.48	2.67	1.35	0.00
corrected volume (× 10^6)	0	55.10	8.26	35.19	12.28	25.62	12.15	0.00
%	0	37.08	5.56	23.68	8.26	17.24	8.18	0.00
				Larvae				
5/21–5/27			0.41					
5/28–6/3			0.10	0.13	0.06			
6/4–6/10				0.09	0.97	0.28	0.01	
6/11–6/17				2.00	2.49	1.72	1.18	0.43
6/18–6/24		0.26	1.01	0.06	*a*	2.17	1.51	1.08
6/25–7/1		0.03	0.18	0.16		0.44	0.05	0.71
7/2–7/8		0.03	0.37	0.45	0.26	0.33	1.63	0.19
7/9–7/15		0.10	0.16	0.58	0.13	0.48	0.58	0.59
7/16–7/22			0.08	0.04	0.02	0.11	0.03	0.03
7/23–7/29				0.01				0.07
Total	0	0.42	2.31	3.52	3.94	5.53	4.99	3.10
corrected for volume (× 10^6)	0	3.02	14.03	24.97	32.69	53.06	44.92	71.89
%	0	1.23	5.76	10.21	13.37	21.69	18.37	29.3
%/mile		0	0.51	0.9	1.09	1.82	1.66	1.47

[a] Not sampled.

Table B-6. Distribution of larval striped bass in the Hudson estuary during the spring of 1955 (data from Rathjen and Miller) (number collected at each station)

Mile point	Cruise					
	III 5/31–6/3	IV 6/7–6/10	V 6/14–6/17	VI 6/20/6/22	V + VI	Mean
21	0	0	0	0	0	0
29	0	0	0	0	0	0
33	0	2	1	0	1	0.2
35	0	1[a]	0	5	5	1.2
37	0	0	2	16	18	3.1
40	0	61	5	9[a]	14	0.9
44	5.5[a]	13	0	2	2	10.8
45	11	25	93	0	93	20.0
49	9[a]	5	2	1.5[a]	3.5	5.5
50.5	7	40	14	3	17	5.0
54.5	24	20	5	15	20	14.4
56.5	1	2	15	0	15	6.5
63	5	16	4	0	4	1.9
69	1	21	8	0	8	5.0
74.5	3	30	13	0	13	7.7
78.5	2	7	7	3	10	8.2
80	0	1	15	9	24	5.5
83	9	3	1	1	2	2.2
90	0	0	1	2	3	1.0
97	3	0[a]	0	1	1	0.7
105	1.5[a]	0	0	0	0	0
108	0	0	0.5[a]	0[a]	0.5	0
111	0	0	1	0	1	0.2

[a]Missing value extrapolated from adjacent station values.

Table B-7. Post-spawning distribution (%) of larval striped bass in the Hudson estuary during the 1966 and 1967 Hudson River Fisheries Investigation

Segment	1966 (6/26–7/16) *a*	1966 *b*	1966 *c*	1966 Mean	1967 (7/2–7/22) *a*	1967 *c*	1967 Mean	Average 66–67
Coxsackie	0	0	0	0	0	0	0	0
Saugerties	0	0	0	0	1.5	1.5	1.5	0.8
Kingston	4.4	2.0	3.9	3.4	6.7	5.9	6.3	5.2
Hyde Park	9.3	5.2	8.1	7.5	12.5	11.8	12.2	9.8
Marlboro	5.9	4.1	6.8	5.6	5.3	5.5	5.4	5.5
Cornwall	29.8	23.0	30.0	27.6	14.3	13.9	14.1	20.9
Peekskill	32.2	44.7	34.4	37.1	33.5	31.8	32.7	34.9
Croton	18.3	20.9	16.8	18.7	25.7	29.7	27.7	23.2

[a]Estimated from ratio of number of larvae collected to the total volume strained for each segment over entire interval.

[b]Estimated from ratio of number of larvae collected to the number of tows for each segment over entire interval.

[c]Estimated from mean of weekly average concentrations for each segment over interval.

Table B-8. Weekly abundance of striped bass eggs and larvae in the Hudson River estuary in 1968.

Week	Mean water temperature (°F)	Mean salinity (ppt)	Number of tows	Volume strained (ft³)	Striped bass eggs: Number collected	Striped bass eggs: Number per 1000 ft³	Striped bass larvae: Number collected	Striped bass larvae: Number per 1000 ft³
4/21–4/27	53.1	<0.1	113	348,372	10	0.03	0	
4/28–5/4	56.0	<0.1	448	1,226,095	791	0.65	82	0.18
5/5–5/11	58.3	<0.1	369	873,853	2,206	2.52	54	0.15
5/12–5/18	60.4	<0.1	481	1,183,148	5,224	4.42	1,219	2.53
5/26–6/1	62.7	<0.1	329	814,043	964	1.18	3,201	9.73
6/2–6/8	65.2	<0.1	490	1,136,685	369	0.32	861	1.76
6/9–6/15	66.6	<0.1	609	1,255,141	459	0.37	6,207	12.19
6/16–6/22	68.4	<0.1	524	1,250,388	16	0.01	2,279	4.35
6/23–6/29	70.7	<0.1	415	1,278,049	13	0.01	729	1.76
6/30–7/6	73.2	<0.1	331	884,125	1	0.01	122	0.37
7/7–7/13	73.7	<0.1	400	1,449,948	0		695	1.74
7/14–7/20	76.8	<0.1	179	489,743	0		193	1.08
Total			5,106	13,368,901	11,926		18.939	

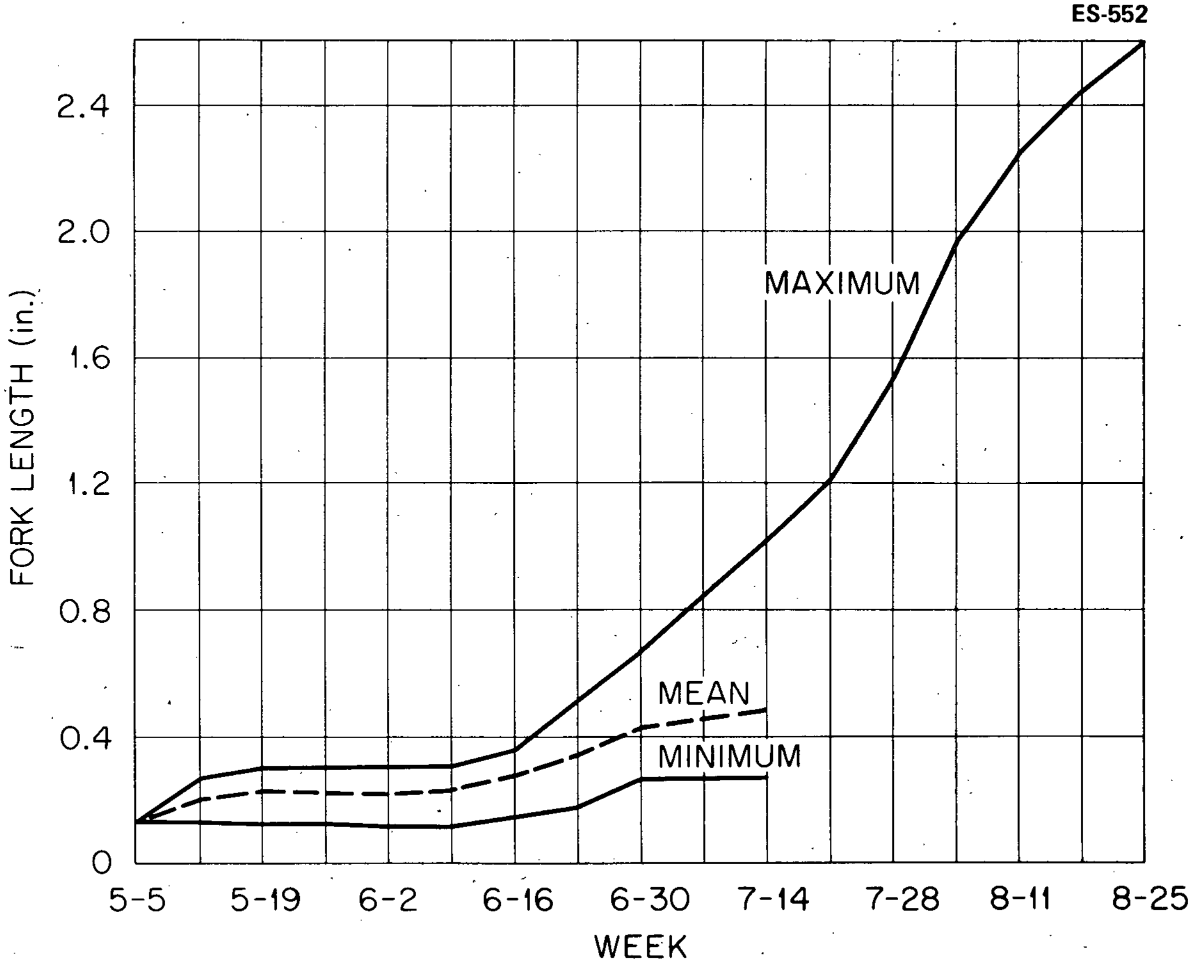

Fig. B-7. Growth of striped bass in Hudson River.

sign that the fish are beginning to become more bottom-oriented. The length of fish as a function of age will determine the ability of the fish to swim away and escape the intake velocities to avoid being entrained (Fig. B-8 and Table 10).

An additional support for this conclusion — the Raytheon Company data for 1970 — shows that the decreased catches by plankton gear and surface trawls occurred at the same time that bottom trawling showed the bass were moving onto the shoals of Haverstraw and Peekskill Bays (Table B-9).

The affinity of small bass for comparatively shallow water is obvious from their distribution in both the Raytheon Company data reproduced in Table B-9 and the 1966 HRFI trawl data (Tables B-10 and B-11). In 1968, shoal surveys were conducted by HRFI investigators by making periodic 10-min trawl samples on shoals between Mile Points 11 and 125. The catch data were then corrected for the size of the shoals, and the relative longitudinal distribution was examined (Table B-12). The overall average of three periods corresponds to an estimate of 85% of the young-of-the-year bass below Indian Point. Similar corrections must be applied for proper interpretation of annual seine haul abundance estimates; however, that the lower estuary is the primary nursery area is reflected even without such corrections (Figs. B-9 to B-11).

c. Factors Contributing to Larval Distribution

The increased abundance in the low salinity zone in the estuary shows that the striped bass do not drift with the flow of fresh water once they enter the salt-intruded region. The principal reason for this relationship is believed to be a result of the vertical distribution of the larvae and their corresponding diurnal migration patterns. The interactions of these patterns with the vertical variations in velocity would tend to retard the downstream movement of the larvae and concentrate them in the region below the salt front.

Vertical and lateral variations in distributions were observed both in the HRFI and Raytheon Company studies.[17] However, the 1968 HRFI data were far more extensive and were, therefore, selected for analysis. The degree of lateral variation in mean concentration was determined by averaging the day/night concentrations with respect to the 15-ft depth intervals that were sampled. Considerable variation was apparent, but no pattern of decreased lateral abundance was evident (Table B-13). The less extensive 1967 data showed similar results (Table B-14).

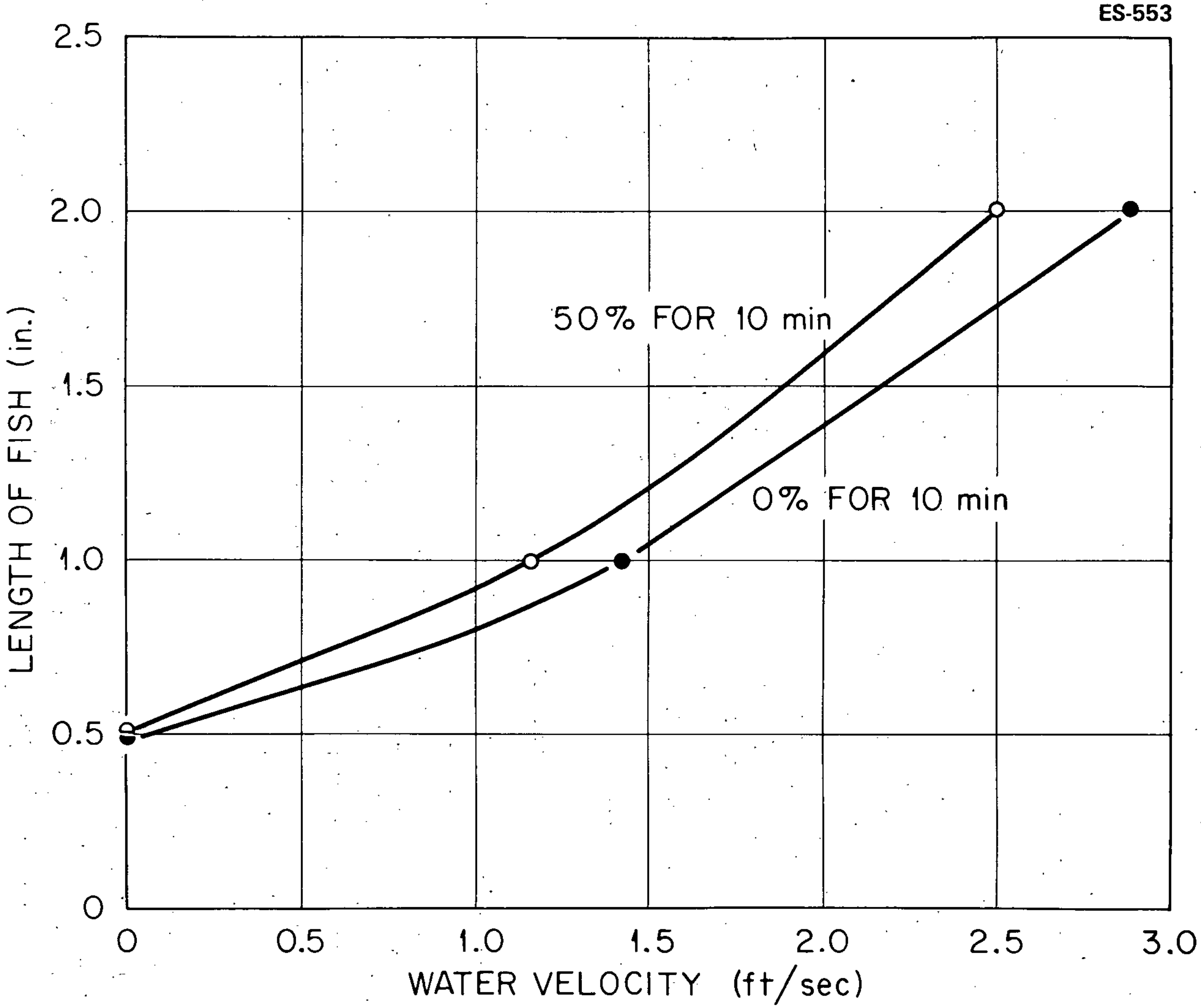

Fig. B-8. Ability of fish to escape intake velocities.

Table B-9. Catch of striped bass in bottom trawls in the Lower Hudson estuary in 1969 and 1970, showing importance of shallow shoals as nursery grounds (number per 7-min trawl haul)

Depth level	Station[a]	Mile point	Depth (ft)	1969						1970									
				July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Shallow	1	29	10	77	58	98	231												
	5	36	12	291	126	108	354	88	21						12	196	555	308	0
	3	35	10	355	61	28	14	4	5						41	14	112	252	39
	7	38	11	115	217	168	168	31	1				1	18	9	84	100	56	196
	8	39	12	485	64	39	69	61	20			6			19	22	84	145	145
	9	40	12	149	119	335	146	29	3			0	1	0	2	78	112	112	140
	12	44	12	100	144	87	19	83	21	39		0	0	10	3				
Intermediate	2	29	26	4	51	0	21												
	4	35	34	10	19	1	120	3	3						0	0	0	0	0
	6	38	30	62	312	4	122	0	1				1	<1	9	0	0	0	0
Deep	15	40	45			0	7	1	3			1	0		0	0	0	0	0
	16	41	45			1		0	4			16			0	0	0	0	0
	11	42	50	1	1	1	1	<1	4	22	1	3	0	2	2	0	0	0	0
	10	42	45	0	4	8	16	1	0	61	4	2	0	<1	<1	0	0	0	0
	13	45	50	1	3	3	1		0				0	1	1	0	0	0	0
	14	47	47	0	1	3	1	2	1						0	0	0	0	0

[a]Raytheon Company stations.

Table B-10. Estimated velocities of water entering plankton nets during 1966 sampling period of Cornwall study that indicate susceptibility of larvae to entrainment at these velocities

Station	Total tows	Volume strained (ft^3)	Average velocity[a] (fps)
Coxsackie	85	126,000	0.93
Saugerties	86	153,000	1.11
Kingston	94	151,000	1.01
Hyde Park	76	121,000	1.00
Malboro	141	211,000	0.94
Cornwall	509	884,000	1.09
Peekskill	95	150,000	0.99
Croton	81	129,000	1.00

[a] $\text{Velocity} = \dfrac{\text{Volume strained}}{\text{No. of tows} \times 900 \text{ sec/tow} \times \pi(0.75 \text{ ft})^2}$

Table B-11. Relationship between water depth and abundance of young-of-the-year striped bass at Cornwall in 1966 as determined by catch per 7-in. trawl haul

Depth (ft)	No. of tows	No. of fish	Fish/tow
15	34	1941	57.1
20	29	115	3.97
40	34	85	2.5
65	12	18	1.5

Table B-12. Data on distribution of young-of-the-year striped bass taken by shoal trawls in July – August 1968

Reach	Index of shoal area	Period[a]						Mean of means	
		July 28–Aug. 3		Aug. 11–Aug. 17		Aug. 25–Aug. 31			
		No.	Index	No.	Index	No.	Index	No.	Index
Coxsackie	17.3	0	0	0	0	0	0	0	0
Saugerties	16.5	0.2	3.3	0	0	0	0	0.1	1.1
Kingston	10.0	1.7	16.7	0	0	0.3	3	0.7	6.6
Hyde Park	2.1								
Marlboro	4.8	0.3	1.4		2.4	1	4.8	0.60	2.9
Cornwall	7.6	22.9	173.4	0	0	104	787.3	42.3	320
			194.8		2.4		795.1		330.8
Peekskill	4.8								
Haverstraw Bay	24.1	102	2458.2	12	289	29.7	715.8	48	1156.8
Tappan Zee	38.5	9.6	369.6	36	1386	29.7	1074	25.1	962.5
			2827.8		1675.2		1789.8		2119.3
Total			3022.6		1677.6		2584.9		2449.9
% above Indian Point			6.4		0.1		30.8		12.4
% below Indian Point			93.6		99.9		69.2		87.6[b]

[a]The period index is the product of the shoal area index and the number of fish caught per trawl haul.
[b]From the published mean of samples, this value is 85.4%.

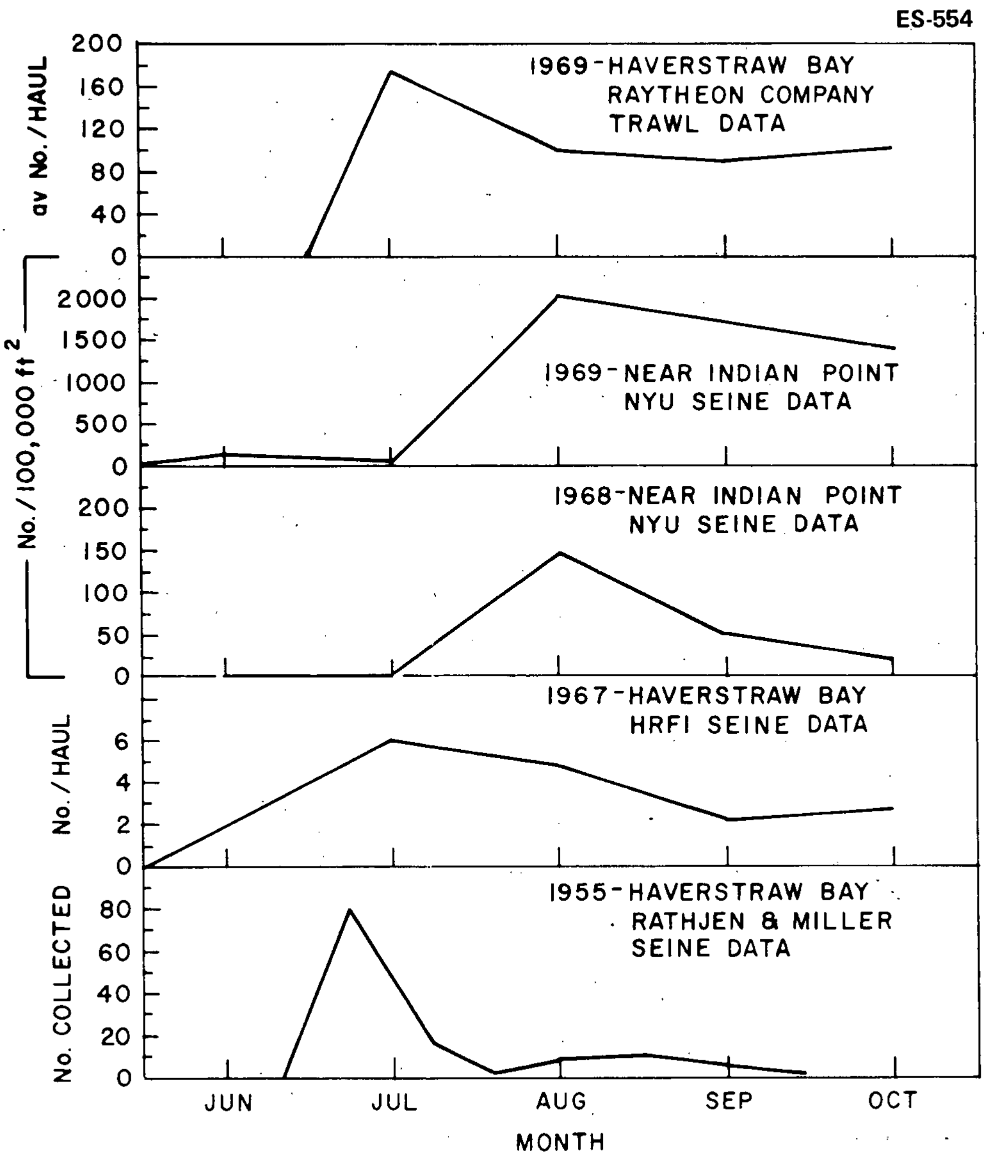

Fig. B-9. Season of peak abundance of young striped bass in the Hudson estuary below Peekskill.

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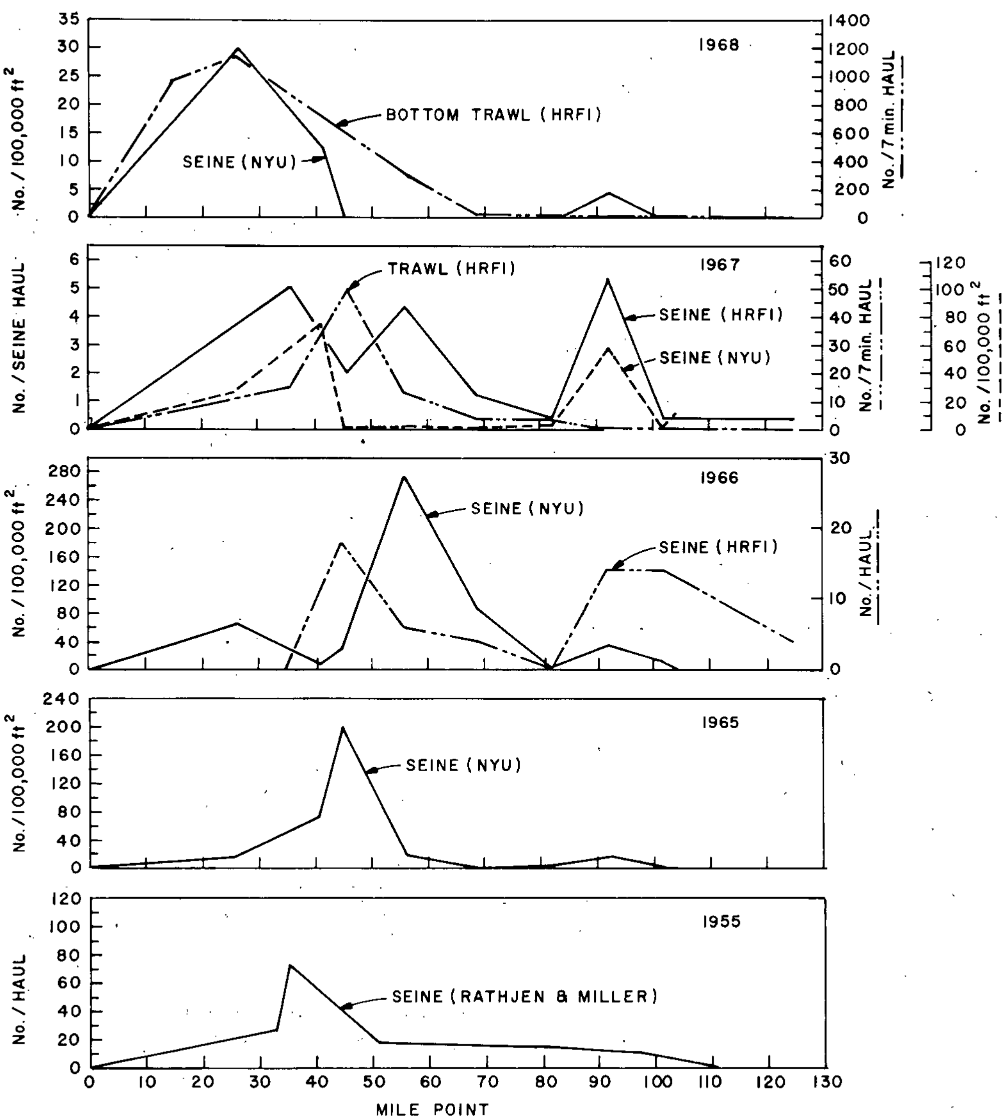

Fig. B-10. Annual estimates of longitudinal distribution of young-of-the-year striped bass in the Hudson.

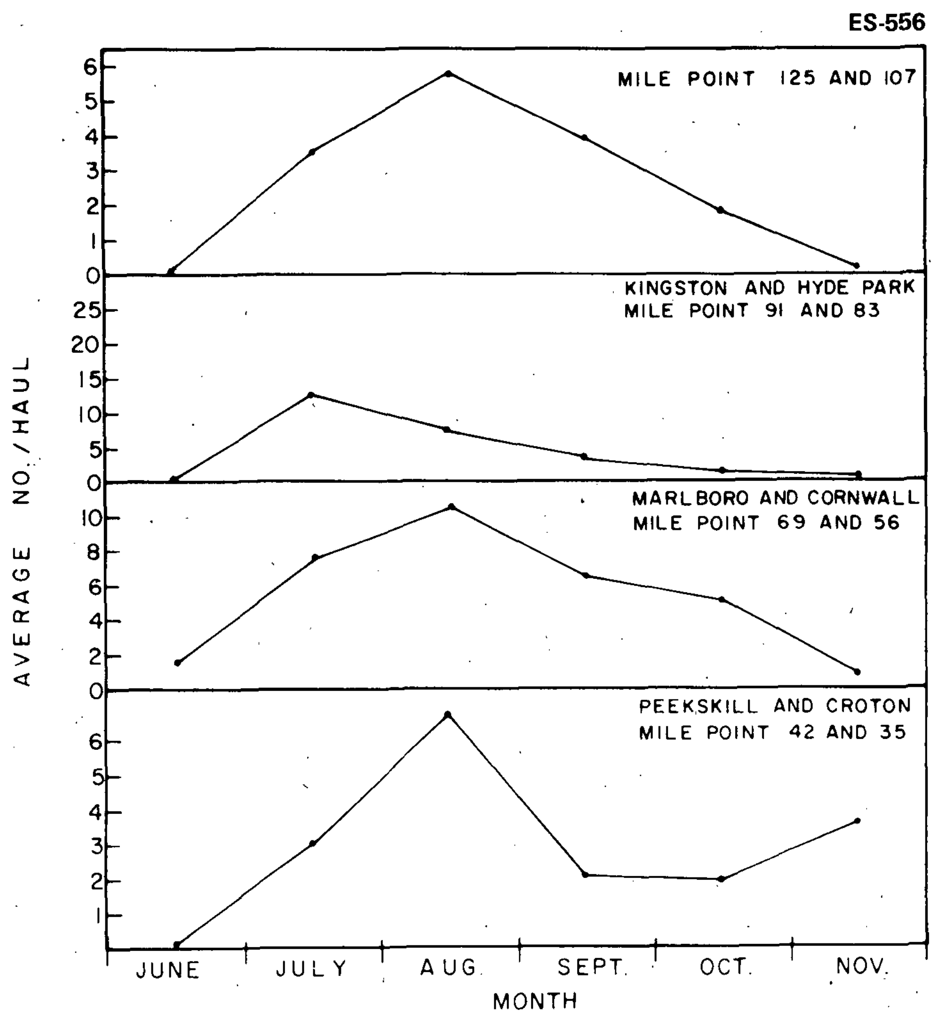

Fig. B-11. Seasonal abundance of young-of-the-year striped bass as determined from the 1967 seine haul data of the Hudson River Fisheries Investigation.

Table B-13. Lateral distribution of larval striped bass for a 12-week period at Cornwall in 1968

(average concentration of larvae per 15-ft interval)

Period[a]	W 15	W 30	W 45	W 60	C 75	E 60	E 45	E 30	E 15	E 5	Mean concentration of larvae (number per 1000 ft³)	Standard error
4/28–5/4												
D	0.06	0.067	0.13	0.034	0.01	0.05	0.035	0.097	0.04	0.0	0.052	0.012
N	0.315	0.02	0.098	0.264	0.042	0.188	0.085	0.137	0.03	0.0	0.118	0.034
5/5–5/11												
D	0.03	0.027	0.102	0.04	0.03	0.052	0.09	0.0	0.15	0.0	0.079	0.015
N	0.0	0.0	0.0	0.11	0.608	0.0	0.0	0.08	0.0	0.0	0.080	0.060
5/12–5/18												
D	0.26	0.54	0.79	0.878	1.57	1.48	1.837	1.95	3.535	2.96	1.58	0.331
N		2.13	1.30	1.008	0.64	1.26	1.235	1.237		1.06	1.234	0.149
5/19–5/25												
D	1.13	2.653	4.05	3.752	4.11	3.296	2.478	3.33	2.325	1.77	2.889	0.313
N	2.11		4.133	5.07	3.242	2.054	4.062	1.693	3.01	3.00	3.153	0.372
5/26–6/1												
D	0.945	4.523	4.468	3.172	1.825	3.542	2.43	4.913	1.705	0.81	2.833	0.478
N	3.445	23.483	7.22	7.818	7.242	2.494	4.213	4.70	3.375	2.81	6.68	1.967
6/2–6/8												
D	0.29	0.75	0.783	0.488	1.112	0.65	1.037	0.71	1.2	1.23	0.825	0.090
N	0.18	0.577	0.997	0.756	0.812	1.032	0.66	0.923	0.995	1.05	0.795	0.086
6/9–6/15												
D	6.975	6.477	6.175	5.945	5.737	3.674	4.382	4.46	2.65	1.23	4.771	0.308
N	7.835	24.197	6.61	4.57	2.185	2.336	1.018	4.13	5.725	2.80	6.141	2.116
6/16–6/22												
D	2.975	3.56	1.882	1.592	1.363	0.752	1.417	1.793	1.765	0.95	1.805	0.638
N	2.28	2.993	0.702	0.526	0.99	1.444	1.83	4.817	3.385	3.58	2.255	0.447
6/23–6/29												
D	0.49	0.763	0.478	0.644	0.322	0.864	0.59	0.653	1.09	0.70	0.659	0.139
N		0.62	1.118	0.262	0.622	1.12	0.938	1.943	1.13	1.13	0.987	0.157
6/30–7/6												
D	0.04	0.07	0.0	0.028	0.0	0.04	0.072	0.227	0.155	0.54	0.117	0.055
N	0.0	0.07	0.115	0.394	0.095	0.0	0.478	0.037	0.0	0.0	0.119	0.063
7/7–7/13												
D									1.48	0.44	0.96	0.520
N									1.055	0.22	0.638	0.417
7/14–7/20												
D	0.18	0.11	0.435	0.0	0.0	0.518	0.048	1.107	0.34	0.0	0.274	0.109
N			0.0		0.177	1.056	0.35	0.533	0.485	2.83	0.776	0.365
$\overline{D}$	1.216	1.785	1.754	1.507	1.462	1.356	1.311	1.749	1.37	0.886	1.440	0.088
$\overline{N}$	2.021	6.010	2.027	2.078	1.514	1.180	1.352	1.839	1.745	1.540	2.131	0.441

[a]D = day; N = night.

Table B-14. Abundance of striped bass larvae in the Hudson River estuary by station sampled per location, 1967

Station	Mile point	Depth (ft)	Number of larvae per 1000 ft³								
Saugerties[a]	102.5			West			Center			East	
				45			60			45	
		0		0.00			0.00			0.00	
		15		0.08			0.00			0.00	
		30		0.14			0.18			0.04	
		45		0.04			0.05			0.27	
		60					0.00				
		Mean		0.07			0.05			0.08	
Kingston[b]	91.5			West			Center			East	
				30			45				
		0		0.00			0.15			30	
		15		0.17			0.09			0.00	
		30		0.28			0.69			0.03	
		45					0.45			0.41	
		Mean		0.15			0.35			0.15	
Hyde Park[a]	82.0			West			Center			East	
				60			45			45	
		0		0.04			0.24			0.20	
		15		0.11			0.32			0.77	
		30		0.24			0.44		0.42	0.42	
		45		0.18			0.48			0.36	
		60		0.24							
		Mean		0.16			0.37			0.44	
Marlboro[b]	69.0			West			Center			East	
				30			45			30	
		0		0.00			0.00			0.13	
		15		1.29			0.00			0.16	
		30		1.18			0.65			0.27	
		Mean		0.82			0.90			0.19	
Cornwall[a]	56.5		West	West	West	West	Center	East	East	East	East
			5[c]	15	30	45	75	45	30	15	5
		0	0.48	0.90	1.25	0.56	0.32	0.72	0.36	0.47	0.64
		5	0.49	*d*	*d*	*d*	*d*	*d*	*d*	*d*	0.57
		15		0.86	1.58	0.84	1.51	0.57	0.69	0.56	
		30			0.81	0.71	0.49	0.48	1.01		
		45				0.62	1.05	0.65			
		60					0.33				
		75					0.92				
		Mean	0.49	0.88	1.21	0.68	0.77	0.61	0.69	0.52	0.61
Peekskill[a]	45.5			West			Center			East	
				60			110			90	
		0		0.30			0.15			0.36	
		15		2.30			*d*			*d*	
		30		1.39			*d*			0.22	
		45		0.90			0.47			0.24	
		60		1.35			0.45			0.42	
		75					0.04			1.07	
		90					1.48			1.00	
		110					0.74				
		Mean		1.25			0.56			0.55	
Croton[b]	35.5			West			Center			East	
				30			45			30	
		0		0.03			0.00			0.13	
		15		0.03			0.32			0.69	
		30		0.29			0.11			1.63	
		45					0.83				
		Mean	0.12	0.12			0.32			0.82	

[a] Day and night samples combined.
[b] Day samples only.
[c] Off Moodna Creek.
[d] Not sampled.

Vertical variation was similarly treated except that the data were averaged according to depth for this situation. A significant diurnal variation was observed (Table B-15). Thus, the data used in this analysis showed a vertical variation for each transect (but one), which was confined to the transect and did not contribute any large degree of lateral movement to deeper water during the day. As a consequence, the susceptibility of larvae to an intake in this region of the river would not be altered by a day-night vertical movement pattern. On the other hand, the longitudinal transport of the population may well be affected by this pattern of movement. This additional complication results from their vertical diurnal movement pattern that tends to keep them in the lower layer for sufficient time so that net downriver convective transport in the saline region is reduced. The interaction of the vertical migration with water currents would tend to concentrate the fish in the low salinity portions of the estuary. Thus, a physical rationale exists for the observed distribution, which can be used to predict the movement patterns and the distribution of larval fish.

3. LOCAL SPATIAL DISTRIBUTION OF STRIPED BASS ICHTHYOPLANKTON

As discussed in Section V.D.2.b(2)(e), sampling programs were designed and executed in 1973 by Quirk, Lawler, and Matusky at the Bowline, Lovett, Danskammer, and Roseton Plants to estimate, for striped bass yolk-sac larvae, post yolk-sac larvae, and non-screenable juveniles, the ratio of concentration of organisms in the intake to the average concentration of organisms in a cross section of the river in front of the plant (= transect). In response to the staff's request, the raw data and final estimates of a composite "f" factor (= $f_c \cdot f_I$) for each life stage at each plant were provided (Table B-16).

The staff has done its own analysis of the Quirk, Lawler, and Matusky data. Part of this analysis is given in Section V.D.2.b (2)(e), where the staff has summarized, by sampling date and life stage for each of the three transects (the same transect was used for Danskammer and Roseton), the number of transect samples, the number of these samples containing one or more striped bass, and the number of these samples containing 10 or more striped bass; this part of the analysis is not repeated here. On the basis of this analysis, however, the staff selected for each transect and each life stage the two sampling dates having the greatest number of samples containing striped bass; this section of Appendix B deals with the analysis of these data.

Table B-15. Mean concentration of larvae at Cornwall in 1968 averaged over depth across all sample locations, expressed as number per 1000 ft^3

Week	Depth (ft)	Day Total	Day Av	Day %	Night Total	Night Av	Night %
4/28–5/4	0	0.07	0.007	2.258	0.83	0.083	13.584
	15	0.31	0.034	10.968	1.00	0.111	18.167
	30	0.81	0.116	37.419	0.42	0.06	9.820
	45	0.45	0.09	29.032	0.52	0.104	17.021
	60	0.19	0.063	20.323	0.76	0.253	41.408
	75	0.0	0.0	0.0	0.0	0.0	0.0
			0.310			0.611	
5/5–5/11	0	0.0	0.0	0.0	0.14	0.014	0.393
	15	0.41	0.045	13.120	0.12	0.013	0.365
	30	0.45	0.064	18.659	0.40	0.057	1.601
	45	0.58	0.097	28.280	0.12	0.024	0.674
	60	0.41	0.137	39.942	0.31	0.103	2.892
	75	0.0	0.0	0.0	3.35	3.35	94.075
			0.343			3.561	
5/12–5/18	0	4.47	0.447	3.752	13.09	0.131	2.569
	15	9.19	1.021	8.570	5.47	0.781	15.475
	30	11.40	1.629	13.673	7.51	1.073	21.260
	45	14.02	2.804	23.535	5.91	1.182	23.420
	60	6.97	2.323	19.498	4.49	1.50	29.721
	75	3.69	3.69	30.972	0.38	0.38	7.529
			11.914			5.047	
5/19–5/25	0	3.81	0.381	1.092	39.24	3.924	16.947
	15	10.66	1.184	3.395	19.72	2.191	9.463
	30	27.73	3.961	11.356	8.09	1.348	5.822
	45	33.28	6.56	18.808	20.57	4.114	17.768
	60	21.55	7.183	20.594	16.10	5.367	23.180
	75	15.61	15.61	44.755	6.21	6.21	26.820
			34.879			23.154	
5/26–6/1	0	3.97	0.397	1.685	50.04	5.004	10.671
	15	13.32	1.48	6.283	54.53	6.059	12.920
	30	37.60	5.371	22.800	68.04	9.72	20.727
	45	24.68	4.936	20.953	37.81	7.562	16.125
	60	23.38	7.793	33.081	19.14	6.38	13.605
	75	3.58	3.58	15.197	12.17	12.17	25.952
			23.557			46.895	
6/2–6/9	0	1.79	0.179	2.541	7.10	0.710	13.485
	15	4.90	0.544	7.722	7.27	0.808	15.347
	30	5.96	0.851	12.079	4.73	0.676	12.839
	45	9.19	1.838	26.089	7.04	1.408	26.743
	60	4.18	1.393	19.773	2.35	0.783	14.872
	75	2.24	2.24	31.796	0.88	0.88	16.714
			7.045			5.265	
6/9–6/15	0	17.10	0.171	0.496	32.24	3.224	9.208
	15	40.81	4.534	13.148	47.28	5.253	15.003
	30	57.89	8.27	23.982	69.49	9.927	28.352
	45	33.33	6.666	19.331	27.6	5.52	15.765
	60	21.16	7.053	20.453	14.91	4.97	14.194
	75	7.79	7.79	22.590	6.12	6.12	17.479
			34.484			35.014	

Table B-15 (continued)

Week	Depth (ft)	Day			Night		
		Total	Av	%	Total	Av	%
6/16–6/22	0	6.10	0.610	5.763	26.87	2.687	29.737
	15	16.88	1.875	17.725	16.30	1.811	20.042
	30	20.95	2.993	28.279	10.23	1.461	16.169
	45	9.79	1.958	18.500	7.37	1.474	16.313
	60	4.19	1.397	13.199	2.83	0.943	10.436
	75	1.75	1.75	16.534	0.66	0.66	7.304
			10.584			9.036	
6/23–6/29	0	3.21	0.321	9.838	16.86	1.686	43.387
	15	9.54	1.06	32.485	5.14	0.643	16.547
	30	3.76	0.537	16.457	4.19	0.599	15.414
	45	3.71	0.742	22.740	2.89	0.578	15.106
	60	1.54	0.513	15.722	1.14	0.38	9.779
	75	0.09	0.09	2.758	0.0	0.0	0.0
			3.263			3.886	
6/30–7/6	0	0.62	0.062	20.130	1.92	0.192	18.234
	15	0.82	0.091	29.545	0.33	0.037	3.514
	30	0.83	0.119	38.636	0.49	0.07	6.648
	45	0.18	0.036	11.688	0.52	0.104	9.877
	60	0.0	0.0	0.0	1.97	0.65	61.728
	75	0.0	0.0	0.0	0.0	0.0	0.0
			0.308			1.053	
7/14–7/20	0	0.40	0.04	2.591	4.14	0.591	24.093
	15	1.95	0.217	14.054	7.40	0.925	37.709
	30	3.51	0.501	32.448	1.32	0.264	10.762
	45	1.02	0.204	13.212	1.21	0.303	12.352
	60	2.33	0.582	37.694	0.0	0.0	0.0
	75	0.0	0.0	0.0	0.37	0.37	15.084
			1.544			2.453	

Table B-16. Summary of Quirk, Lawler, and Matusky's estimates of composition f factors (1973) with f_c = 1.0

Plant	Egg stage[a]	Yolk-sac larval stage	Post yolk-sac larval stage	Juvenile stage
Bowline	0.2	0.1	0.1	0.6
Lovett	0.2	0.2	0.1	0.2
Roseton	0.2	0.1	0.5	0.3
Danskammer	0.2	0.2	0.5	0.3

[a]Based on river average observation of striped bass egg behavior surveyed by Texas Instruments in 1973. Since the duration time of the egg stage is approximately 1 to 3 days, the exposure of eggs to entrainment is much smaller than the exposure during the larval stage. Consequently, the f factors for the egg stage are not critical.

Source: Letter from E. R. Fidell (Le Boeuf, Lamb, Leiby, and MacRae) to J. F. Scinto (USAEC), dated August 27, 1974.

The analysis is divided into the following sections: (1) correlations between number of organisms in a sample and volume of water sampled; (2) estimates of the intake f-factor (f_I), using four techniques based on two methods of estimating 24-hr average intake and transect concentrations; (3) estimates of a standard deviation for f_I; (4) a comparison of intake and discharge concentrations; and (5) a separate analysis comparing Bowline Pond and Bowline transect data.

a. Correlation Coefficients

The (product-moment) correlation coefficient was calculated between number of yolk-sac larvae in a sample and volume of the sample and between number of post yolk-sac larvae and volume of the sample for each of the sampling dates at each of the plants; the results of this analysis are summarized in Table B-17. Juveniles have not been included in this part of the staff's analysis because of the relatively few samples containing juveniles. The analysis indicates the absence of a statistically significant (at the 5% level) correlation in 9 out of 10 cases. This result is most easily explained by the existence of patchiness (clumping) in the spatial distribution of organisms and/or by vertical migration. One apparent example of such patchiness is the 12 intake samples at Bowline on June 13-14. There were eleven 2-hr samples containing no yolk-sac larvae and a total of four post yolk-sac larvae and one 2-min sample containing two yolk-sac larvae and three post yolk-sac larvae.

Table B-17. Summary of the (product moment) correlation coefficients between the number of yolk-sac larvae and volume of the sample and between the number of post yolk-sac larvae and volume of the sample for each sampling date at each of the plants

Plant[a]	Date	Yolk-sac larvae		Post yolk-sac larvae	
		N[b]	r	N[b]	r
Bowline	6/13–14	84	−0.15	84	−0.14
	6/27–28	75	0.08	75	0.12
Lovett	6/5–6	94	0.10		
	6/19–20	74	0.10	74	0.14
	7/3–4			84	0.11
Danskammer–Roseton[c]	6/7–8	41	0.18		
	6/19–20			54	0.31[d]
	7/2–3			67	−0.10

[a]For this analysis, the intake and transect samples at each plant were combined. Discharge samples were deleted; pond and plume samples at Bowline were deleted; and mid-depth samples were not given double weight.

[b]Total number of samples.

[c]On June 7–8 and June 19–20 the Danskammer–Roseton transect data were combined with the Danskammer intake data. On July 2–3 the transect data were combined with the Roseton intake data. There was no second sampling date at the Roseton intake for which enough striped bass were identified to merit analysis; samples were not collected on June 19–20 and only one of five samples on June 7–8 was analyzed by species.

[d]Statistically significant at the 0.05 probability level.

b. Estimates of the Intake f-Factor (f_I)

The staff has estimated f_I using four techniques based on two methods of estimating the 24-hr average intake and transect concentrations. The f_I values, as well as the information necessary to calculate these f_I values, are given in Table B-19. Definitions of the acronyms used in this table and in Table B-21 are given in Table B-18. The values in Table B-19 were calculated from the raw data supplied to the staff by the applicant.[18] The staff repeats that this analysis includes data for only the two "best" sampling dates for each life stage and each plant. In some cases (e.g., for juveniles), there were not two sampling dates having enough samples with striped bass to merit analysis by the staff. Discharge samples have not been included in this part of the staff's analysis.

The two methods of estimating the 24-hr average concentrations at either the intake or in the transect are:

Table B-18. Glossary of acronyms used in Tables B-19 and B-21

Variable	Definition			
	Code number	Plant		
		Bowline	Lovett	Danskammer–Roseton
		Part A. Classification variables		
Date	1	6/13–14	6/5–6	6/7–8 (Danskammer)
	2	6/27–28	6/19–20	6/19–20 (Danskammer)
	3		7/3–4	7/2–3 (Roseton)
Plant	*Code number*	*Plant*		
	1	Bowline		
	2	Lovett		
	3	Danskammer–Roseton		
Stage	*Code number*	*Stage*		
	1	Yolk-sac larvae		
	2	Post yolk-sac larvae		
	3	Juveniles		
OBS	Row number in Tables B-19 and B-21. Each row gives the variables at one plant on one date for one life stage.			

Part B. Calculated variables. The acronyms indicate whether the variable relates to an intake (I) or transect (T) sample and to a night (N) or day (D) sample.

Variable	Definition
	Technique 1
FI1	Ratio of the 24-hr average intake concentration to the 24-hr average transect concentration using Method 1 to calculate both concentrations.
	Technique 2
FI2	Ratio of the 24-hr average intake concentration to the 24-hr average transect concentration using Method 2 to calculate both concentrations.
	Technique 3
FI3	Ratio of the 24-hr average intake concentration to the 24-hr average transect concentration using Method 2 to calculate the intake concentration and Method 1 to calculate the transect concentration.
	Technique 4
FI4	Ratio of the 24-hr average intake concentration to the 24-hr average transect concentration using Method 1 to calculate the intake concentration and Method 2 to calculate the transect concentration.
NID	Number of intake samples during the day (= 0600 to 2100).
NIN	Number of intake samples during the night (= 2101 to 0600).
NTD	Number of transect samples during the day.
NTN	Number of transect samples during the night.
SDXID	Standard deviation of the intake day concentrations (number of organisms/1000 m^3).
SDXIN	Standard deviation of the intake night concentrations (number of organisms/1000 m^3).

Table B-18 (continued)

SDXTD	Standard deviation of the transect day concentrations (number of organisms/1000 m^3).
SDXTN	Standard deviation of the transect night concentrations (number of organisms/1000 m^3).
SDYID	Standard deviation of the intake day number-of-organism values.
SDYIN	Standard deviation of the intake night number-of-organism values.
SDYTD	Standard deviation of the transect day number-of-organism values.
SDYTN	Standard deviation of the transect night number-of-organism values.
SDZID	Standard deviation of the intake day volumes (1000 m^3).
SDZIN	Standard deviation of the intake night volumes (1000 m^3).
SDZTD	Standard deviation of the transect night volumes (1000 m^3).
SDZTN	Standard deviation of the transect night volumes (1000 m^3).
TSDFI1	Two times the standard deviation of $f_{I,1}$.
TSDFI2	Two times the standard deviation of $f_{I,2}$.
XID	Average of the intake day concentrations (number of organisms/1000 m^3).
XIN	Average of the intake night concentrations (number of organisms/1000 m^3).
XTD	Average of the transect day concentrations (number of organisms/1000 m^3).
XTN	Average of the transect night concentrations (number of organisms/1000 m^3).
YID	Average of the intake day number-of-organism values.
YIN	Average of the intake night number-of-organism values.
YTD	Average of the transect day number-of-organism values.
YTN	Average of the transect night number-of-organism values.
ZID	Average of the intake day volumes (1000 m^3).
ZIN	Average of the intake night volumes (1000 m^3).
ZTD	Average of the transect day volumes (1000 m^3).
ZTN	Average of the transect night volumes (1000 m^3).

Table B-19. Sample size, mean and standard deviation for night and day, intake and transect values for number of organisms, volume of sample, and concentration. Also tabulated (on the next page) are intake f factor values (f_I), calculated using four techniques, and approximate 95% confidence intervals for $f_{I,1}$ and $f_{I,2}$. Values are given for yolk-sac larvae, post yolk-sac larvae, and juveniles at Bowline, Lovett, and Danskammer–Roseton. Acronyms are defined in Table B-18.

The lower half of this page is a continuation of the upper half. The next page is a further continuation of the table and contains the footnotes; see numbers in "OBS" column.

OBS	PLANT[a]	DATE	STAGE	NIN	YIN	SDYIN	ZIN	SDZIN	XIN	SDXIN	NID	YID	SDYID	ZID	SDZID	XID
1	1	1	1	11	0.000	0.000	.1270	.0000	0.00	0.00	9	0.444	0.881	.0992	.0551	222.20
2	1	1	2	11	0.545	1.210	.1270	.0000	4.29	9.56	9	0.889	1.269	.0992	.0551	335.10
3	1	2	1	8	0.000	0.000	.0146	.0039	0.00	0.00	20	0.000	0.000	.0160	.0000	0.00
4	1	2	2	8	0.500	0.756	.0146	.0039	48.40	76.30	20	0.400	0.995	.0160	.0000	25.00
5	1	2	3	8	0.375	0.744	.0146	.0039	23.40	46.50	20	0.000	0.000	.0160	.0000	0.00
6	2	1	1	12	0.500	0.798	.0640	.0635	6.75	13.90	8	0.125	0.354	.0210	.0000	5.95
7	2	2	1	7	1.570	3.050	.0321	.0160	34.90	67.70	8	3.000	3.510	.0450	.0000	66.70
8	2	2	2	7	1.290	1.600	.0321	.0160	41.30	39.40	8	1.500	1.600	.0450	.0000	33.30
9	2	3	2	7	0.000	0.000	.0150	.0000	0.00	0.00	12	0.167	0.389	.0250	.0148	7.41
10	2	3	3	7	0.000	0.000	.0150	.0000	0.00	0.00	12	0.000	0.000	.0250	.0148	0.00
11	3	1	1	12	24.750	22.030	.1030	.0726	233.60	147.30	8	6.125	7.920	.0566	.0457	168.90
12	3	2	2	6	0.833	1.330	.1010	.0779	4.14	6.61	12	4.750	6.540	.1010	.0742	48.50
13	3	3	2	12	0.750	1.360	.0222	.0137	44.40	78.50	10	1.600	2.880	.0119	.0052	127.00

OBS	SDXID	NTN	YTN	SDYTN	ZTN	SDZTN	XTN	SDXTN	NTD	YTD	SDYTD	ZTD	SDZTD	XTD	SDXTD
1	441.0	20	36.850	28.400	.162	.0271	223.70	156.10	56	20.140	33.700	.166	.0188	129.800	214.90
2	660.5	20	52.000	39.640	.162	.0271	313.50	215.70	56	22.710	50.500	.166	.0188	156.700	369.10
3	0.0	15	7.070	12.940	.180	.0280	37.10	59.50	41	23.660	46.840	.178	.0295	152.800	317.30
4	62.2	15	66.870	66.190	.180	.0280	396.50	417.10	41	79.540	133.940	.178	.0295	503.600	904.10
5	0.0	15	3.670	6.260	.180	.0280	21.70	39.70	41	1.320	5.400	.178	.0295	8.190	34.40
6	16.8	37	14.050	18.890	.163	.0371	95.50	134.20	64	18.500	26.540	.170	.0294	111.000	148.60
7	77.9	31	28.870	30.960	.157	.0223	203.50	235.50	49	17.240	27.610	.160	.0246	111.000	179.20
8	35.6	31	73.290	74.460	.157	.0223	498.30	518.90	49	57.140	102.010	.160	.0246	368.100	634.60
9	19.7	35	2.200	1.680	.165	.0343	13.40	9.45	56	6.040	12.920	.166	.0373	39.100	82.20
10	0.0	35	0.429	0.608	.165	.0343	2.84	4.06	56	0.661	1.080	.166	.0373	4.280	6.81
11	222.0	32	107.840	121.130	.184	.0181	598.90	671.80	0	0.000	0.000	.000	.0000	0.000	0.00
12	62.3	20	8.050	11.040	.181	.0234	41.00	54.90	34	6.260	7.890	.195	.0307	32.500	40.40
13	171.1	24	2.830	4.750	.211	.0912	20.90	40.60	53	0.170	0.509	.212	.1760	0.999	2.88

Table B-19 (continued)

OBS	PLANT	DATE	STAGE	FI1	TSDFI1	FI2	TSDFI2	FI3	FI4
1	1	1	1	0.8988	1.2191	0.0188	0.0376	0.9336	0.0181
2	1	1	2	1.0661	1.4508	0.0391	0.0814	1.1444	0.0364
3	1	2	1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	1	2	2	0.0711	0.0647	0.0667	0.1478	0.0792	0.0599
5	1	2	3	0.7431	1.2061	0.8821	3.0011	0.8036	0.8157
6	2	1	1	0.0593	0.0777	0.0660	0.1456	0.0620	0.0631
7	2	2	1	0.3730	0.2921	0.4383	0.9614	0.4001	0.4087
8	2	2	2	0.0867	0.0537	0.0900	0.1946	0.0909	0.0858
9	2	3	2	0.1585	0.2542	0.1515	0.3031	0.1681	0.1429
10	2	3	3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	3	1	1	0.3225	0.2146	0.2691	0.5728	0.3296	0.2634
12	3	2	2	0.8939	0.7076	0.8907	1.7974	0.8737	0.9113
13	3	3	2	13.3333	13.6475	20.4894	41.4747	20.3459	13.4273

[a]Bowline Plume and Pond samples deleted; discharge samples at all plants deleted; and mid-depth samples both at the intakes and in the transects given double weight (i.e., QLM's Method B). None of the June 7–8 transect day samples at Danskammer–Roseton were analyzed for striped bass. June 7–8 and June 19–20 Danskammer–Roseton transect data were combined with Danskammer intake data. July 2–3 transect data were combined with Roseton intake data. There was no second sampling date at Roseton for which enough striped bass were identified to merit analysis by the staff. The TI 1973 ichthyoplankton data indicated that the "larvae" collected at Danskammer–Roseton on June 7–8 were probably all yolk-sac larvae, that those collected on June 19–20 were probably all post yolk-sac larvae, and that those collected on July 2–3 were probably mostly post yolk-sac larvae.

(1) Method 1: for each sample calculate a concentration as the ratio of the number of organisms in the sample to the volume of water filtered, and then calculate the average of the individual concentrations over the 24-hr period,

(2) Method 2: calculate the 24-hr average number of organisms in a sample and the 24-hr average volume of water filtered, and then take the ratio of these two 24-hr averages.

The four techniques of combining these two methods to estimate f_I are defined in Table B-18.

The values in Table B-19 indicate that the manner in which these two methods are combined can have a pronounced effect on the estimate of f_I. For instance, in the second row of Table B-19, at Bowline on June 13-14, 1973, for post yolk-sac larvae, $f_{I,1} = 1.07$ and $f_{I,3} = 1.14$, while $f_{I,2} = 0.04$ and $f_{I,4} = 0.04$; the Quirk, Lawler, and Matusky technique of estimating f_I corresponds to $f_{I,4}$.* Although other differences are less pronounced, the staff's analysis does make clear that, disregarding problems with sampling design and sampling techniques, the technique of calculation alone has an influence on the estimate of f_I.

The staff's best judgment is that either technique 1 or 2 is preferable to technique 3 or 4. The staff sees no justification in mixing apples and prunes by calculating 24-hr average intake concentrations with one method and 24-hr average transect concentrations with a second method, and the staff considers that such an approach is not statistically acceptable. The choice between technique 1 and 2 ($f_{I,1}$ and $f_{I,2}$) is not clear cut, although technique 2 is the more commonly used and accepted approach.[19]

c. Estimates of Standard Deviations for the Intake f-Factor (f_I)

The staff has estimated the standard deviation of $f_{I,1}$ and $f_{I,2}$ as follows (acronyms are defined in Table B-18):

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*This difference and the one for yolk-sac larvae at Bowline on the same date are due to the "unusual" (patchy) intake samples mentioned previously (viz., eleven 2-hr samples containing no yolk-sac larvae and four post yolk-sac larvae and one 2-min sample containing two yolk-sac larvae and three post yolk-sac larvae).

(1) FI1 (= $f_{I,1}$)

$$FI1 = (0.375\ XIN + 0.625\ XID)/XT24 \quad (1)$$

where

$$XT24 = (NTN \cdot XTN + NTD \cdot XTD)/(NTN + NTD)\ . \quad (2)$$

Variance of the ratio of two random variables, Y and Z, may be approximated by the following expression:

$$Var(Y/Z) \approx \left(\frac{Y}{Z}\right)^2 \left[\frac{Var(Y)}{Y^2} + \frac{Var(Z)}{Z^2} - \frac{2\ Cov(Y,Z)}{YZ}\right]. \quad (3)$$

In the present application Y = 0.375 XIN + 0.625 XID, Z = XT24, and Cov(Y,Z) = 0 since the intake and transect samples used to calculate the concentrations are assumed to be statistically independent. It is also assumed that night and day intake or transect samples are statistically independent, i.e., Cov(XIN, XID) = 0 and Cov(XTN, XTD) = 0.

Thus,

$$Var(FI1) = (FI1)^2 \left[\frac{0.375^2\ Var(XIN) + 0.625^2\ Var(XID)}{(0.375\ XIN + 0.625\ XID)^2} + \frac{Var(XT24)}{XT24^2}\right] \quad (4)$$

$$Var(XIN) = SDXIN^2/NIN\ , \quad (5)$$

and

$$Var(XID) = SDXID^2/NID\ . \quad (6)$$

Division by the sample size is appropriate because XIN and XID are averages.

$$\mathrm{Var(XT24)} = \frac{1}{(\mathrm{NTN} + \mathrm{NTD})^2} [\mathrm{NTN}^2\ \mathrm{Var(XTN)} + \mathrm{NTD}^2\ \mathrm{Var(XTD)}] \ , \quad (7)$$

where

$$\mathrm{Var(XTN)} = \mathrm{SDXTN}^2/\mathrm{NTN} \text{ and } \mathrm{Var(XTD)} = \mathrm{SDXTD}^2/\mathrm{NTD} \ .$$

Finally, two standard deviations of $f_{I,1}$ is calculated as:

$$\mathrm{TSDFI1} = 2\sqrt{\mathrm{Var(FI1)}} \ . \quad (8)$$

TSDFI1 values are given in Table B-19. To a first approximation, FI1 ± TSDFI1 provides an estimate of a 95% confidence interval for the true FI1 value.

(2) FI2 (= $f_{I,2}$)

$$\mathrm{FI2} = \frac{0.375(\mathrm{YIN/ZIN}) + 0.625(\mathrm{YID/ZID})}{\mathrm{YT24/ZT24}} \quad (9)$$

where YT24 and ZT24 are defined in a manner analogous to XT24 in Eq. (2).

Application of Eq. (3) is appropriate again. In this case Y = 0.375(YIN/ZIN) + 0.625(YID/ZID), Z = YT24/ZT24, and again Cov(Y,Z) = 0. Also, since night and day intake or transect samples are assumed to be statistically independent, Cov(YIN/ZIN, YID/ZID) = 0.

Thus,

$$\mathrm{Var(FI2)} = (\mathrm{FI2})^2 \left\{ \frac{0.375^2\ \mathrm{Var(YIN/ZIN)} + 0.625^2\ \mathrm{Var(YID/ZID)}}{[0.375(\mathrm{YIN/ZIN}) + 0.625(\mathrm{YID/ZID})]^2} + \frac{\mathrm{Var(YT24/ZT24)}}{(\mathrm{YT24/ZT24})^2} \right\} \quad (10)$$

Again applying Eq. (3),

$$\mathrm{Var(YIN/ZIN)} = \left(\frac{\mathrm{YIN}}{\mathrm{ZIN}}\right)^2 \left[\frac{\mathrm{Var(YIN)}}{\mathrm{YIN}^2} + \frac{\mathrm{Var(ZIN)}}{\mathrm{ZIN}^2} - \frac{2\ \mathrm{Cov(YIN,ZIN)}}{\mathrm{YIN} \cdot \mathrm{ZIN}}\right] \quad (11)$$

where Var(YIN) = $SDYIN^2/NIN$ and Var(ZIN) = $SDZIN^2/NIN$, in a manner analogous to Eqs. (5) and (6), and

$$Cov(YIN, ZIN) = r_{YIN,ZIN} \sqrt{Var(YIN) \cdot Var(ZIN)} \ . \qquad (12)$$

The staff's analysis in Section B.3.a of the correlation between number of yolk-sac larvae or post yolk-sac larvae in a sample and the volume of the sample indicates the absence of a statistically significant correlation in 9 out of the 10 cases. Thus, the staff has assumed that the r value in Eq. (12) is equal to zero, which means that the covariance term on the right side of Eq. (11) drops out.

A similar development of the type in Eqs. (11) and (12) applies to Var(YID/ZID) and Var(YT24/ZT24) in Eq. (10). In the latter case Var(YT24) and Var(ZT24) are calculated using equations analogous to Eq. (7).

Once Var(FI2) is calculated, two standard deviations of $f_{I,2}$ is calculated as

$$TSDFI2 = 2 \sqrt{Var(FI2)} \ . \qquad (13)$$

TSDFI2 values are given in Table B-19. Again, to a first approximation, FI2 ± TSDFI2 provides an estimate of a 95% confidence interval for the true FI2 value.

An examination of the $f_{I,1}$, $f_{I,2}$, and "two standard-deviation" values in Table B-19 indicates that 9 of the 26 approximate confidence intervals include (or exceed) 1.0. In the other 17 cases, the data themselves, apart from problems with the sampling design and sampling techniques, do suggest f_I values of less than 1.0.

d. Comparison of Intake and Discharge Concentrations

The intake and discharge concentrations for yolk-sac larvae, post yolk-sac larvae, and nonscreenable juveniles at Bowline are summarized in Table B-20. The staff's analysis indicates that:

(1) the concentration of yolk-sac larvae tends to be lower in the discharge samples than in the intake samples;

(2) the concentration of post yolk-sac larvae tends to be lower in the discharge samples than in the intake samples;

(3) the concentration of nonscreenable juveniles tends to be higher in the discharge samples than in the intake samples;

(4) in all cases the variability is too large to say whether these indications of differences are real.

Table B-20. Intake and discharge 24-hr average concentrations[a] for yolk-sac larvae, post yolk-sac larvae, and juveniles at Bowline[b]

Life stage	Date	Intake			Discharge		
		Sample size	24-hr Average (number/1000 m^3)	Standard deviation (number/1000 m^3)	Sample size	24-hr Average (number/1000 m^3)	Standard deviation (number/1000 m^3)
Yolk-sac larvae	6/13–14	20	100.0	307.8	17	26.2	66.6
	6/27–28	28	0	0	9	0.6	1.7
Post yolk-sac larvae	6/13–14	20	153.2	460.7	17	40.3	139.1
	6/27–28	28	31.7	65.9	9	25.5	58.1
Juveniles	6/27–28	28	6.7	26.0	9	12.1	30.8

[a]Twenty-four hour average concentrations calculated as the average of the individual concentrations.
[b]Discharge data at the other plants were not adequate for this analysis.

The intake velocity is 0.2 to 0.3 fps at Bowline, while the velocity at the point of sampling in the discharge is 8 to 10 fps.

The staff's a priori reasoning was that, because of this large difference in water velocity at the two sampling points at Bowline (similar differences exist at the other plants), there would be apparent concentration differences even if in fact there were not. The staff reasons [Sections V.D.2.b(2)(e) and V.D.2.e(3)] that the concentration of yolk-sac larvae might be lower in the discharge samples at higher velocities due to net damage and bursting of the relatively fragile yolk-sac stage. On the other hand, the staff reasons that the concentration of juveniles (or in general, life stages with high avoidance ability) might be lower in the intake samples due to net avoidance; avoidance is less likely to occur in the discharge at the higher velocities, particularly if passage through the plant kills the organisms.

After analyzing the Bowline data, the staff's conclusion is that the data are consistent with the staff's a priori reasoning but too variable to verify it. There is not sufficient information to offer a sound interpretation of the results for post yolk-sac larvae.

e. Comparison of Bowline Pond and Bowline Transect Data

An analysis similar to the one given in Section B.3.b and B.3.c, comparing the intake and transect data at Bowline, Lovett, Danskammer, and Roseton, is given here for the Bowline Pond and Bowline transect data. Results are given in Table B-21, which is similar in format to Table B-19; each of the acronyms has the same definition as given in Table B-18 except that Bowline Pond must be substituted for intake wherever the word "intake" appears.

This analysis indicates f_I may be less than 1.0 for yolk-sac larvae and post yolk-sac larvae, but it may be greater than 1.0 for juveniles. The staff's understanding is that the same sampling techniques (e.g., nets, towing speeds, and towing times) were used in Bowline Pond and in the Bowline transect. For this reason the staff places greater confidence in the f_I values calculated from these data than in the f_I values calculated from intake and transect data collected using significantly different sampling techniques [see Sections V.D.2.b(2)(e) and V.D.2.e]. The staff's best judgment is that an f_I value of 0.5 is reasonable for yolk-sac larvae and post yolk-sac larvae at Bowline. On the other hand, the data available to the staff suggest that the juveniles may be using Bowline Pond as a shoaling area and that an f_I value of 2.0 is reasonable.

f. Tests for Normality and Homogeneity of Variance

Parametric tests of statistical significance, whether they involve hypothesis testing or confidence intervals, are based on the assumptions that for each subset of the total data set the random variable is normally distributed and that among the various subsets the true variance is the same. For this reason the staff has examined the concentration values and the logarithms of the concentrations values for normality and homogeneity of variance. (The logarithmic transformation is the most commonly used transformation in analyzing plankton data.)[1-3]

The normality assumption was examined by (1) plotting histograms of concentration and $\log_{10}$ (concentration) for yolk-sac larvae and post yolk-sac larvae for each plant (totaled over dates) and for each date at each plant, (2) plotting $\log_{10}$ (concentration) versus cumulative percent frequency for selected life stages, plants, and

Table B-21. Sample size, mean and standard deviation for night and day, Bowline Pond and transect values for number of organisms, volume of sample, and concentration. Also tabulated are intake f factor values (f_I), calculated using four techniques and approximate 95% confidence intervals for $f_{I,1}$ and $f_{I,2}$. Values are given for yolk-sac larvae, post yolk-sac larvae, and juveniles. Acronyms are defined in Table B-18.

Material under the second two sets of headings is a continuation of that under the first; note the values in the "OBS" column.

OBS	PLANT	DATE	STAGE	NIN	YIN	SDYIN	ZIN	SDZIN	XIN	SDXIN	NID	YID	SDYID	ZID	SDZID	XID
1	1	1	1	9	6.110	9.14	.196	.0410	36.3	52.5	18	9.440	22.61	.165	.0165	58.50
2	1	1	2	9	29.670	27.26	.196	.0410	141.8	115.8	18	14.170	35.78	.165	.0165	87.20
3	1	2	1	15	0.733	2.34	.100	.0625	5.7	15.3	26	0.846	1.85	.151	.0500	5.79
4	1	2	2	15	24.000	25.04	.100	.0625	331.2	445.1	26	3.270	7.24	.151	.0500	16.10
5	1	2	3	15	6.130	8.56	.100	.0625	73.6	104.7	26	0.000	0.00	.151	.0500	0.00

OBS	SDXID	NTN	YTN	SDYTN	ZTN	SDZTN	XTN	SDXTN	NTD	YTD	SDYTD	ZTD	SDZTD	XTD	SDXTD
1	142.9	20	36.85	28.40	.162	.0271	223.7	156.1	56	20.14	33.70	.166	.0188	129.80	214.9
2	221.0	20	52.00	39.64	.162	.0271	313.5	215.7	56	22.71	50.50	.166	.0188	156.70	369.1
3	14.7	15	7.07	12.94	.180	.0280	37.1	59.5	41	23.66	46.84	.178	.0295	152.80	317.3
4	32.5	15	66.87	66.19	.180	.0280	396.5	417.1	41	79.54	133.94	.178	.0295	503.60	904.1
5	0.0	15	3.67	6.26	.180	.0280	21.7	39.7	41	1.32	5.40	.178	.0295	8.19	34.4

OBS	PLANT	DATE	STAGE	FI1	TSDFI1	FI2	TSDFI2	FI3	FI4
1	1	1	1	0.32474	0.30144	0.31896	0.65619	0.33729	0.30708
2	1	1	2	0.54391	0.41752	0.59889	1.25536	0.58389	0.55789
3	1	2	1	0.04726	0.04764	0.05807	0.14298	0.05348	0.05131
4	1	2	2	0.28271	0.22260	0.24275	0.54961	0.31480	0.21801
5	1	2	3	2.33725	2.55999	2.10524	5.31045	2.52766	1.94665

sampling dates, and (3) using the Kolmogorov-Smirnov test for goodness of fit to normality[4,5] for yolk-sac larvae and post yolk-sac larvae for Lovett.

The histograms clearly indicated that the untransformed concentration values were strongly skewed toward zero. The logarithmic transformation reduced the skewness, but there was still an excess of low values. The excess of low values is illustrated in Fig. B-11a, which is plot of the logarithm of the concentration of yolk-sac larvae versus cumulative percent frequency for the transect samples at Bowline on June 13-14, 1973. If the observations were distributed normally, they would fall on a straight line. The results of the Kolmogorov-Smirnov test for goodness of fit are summarized for the Lovett data in Table B-21a. In 17 out of the 18 tests the assumption of normality is rejected.

The staff concludes that neither the concentration values nor the logarithms of the concentration values are normally distributed, although the latter do not violate the assumption of normality as severely.

The homogeneity of variance assumption was examined by (1) plotting the means versus the variances for concentration and $\log_{10}$ (concentration) values and (2) using an F-test (2-sided) for homogeneous variance for the $\log_{10}$ (concentration) values. The plots with untransformed data indicated larger variances with larger means, but this dependence of the variance on the mean was largely eliminated by the logarithmic transformation. In 13 out of the 17 F-tests performed on the transformed data the null hypothesis of homogeneous variances was not rejected at the 5% level of significance. The staff concludes that the log-transformed data do not in general violate the assumption of homogeneity of variance. The results of this subsection are made use of in the next subsection.

g. Tests for Significant Differences Between Intake and Transect Means and Medians

In both the staff's and the applicant's striped bass y-o-y models, the appropriate manner in which to allow for the possibility that the average intake concentration of striped bass ichthyoplankton may differ from the average transect or segment concentration is by means of a multiplicative ratio such as f_I (in the staff's model) or $f_1 \cdot f_2$ (in the applicant's model). As indicated in Sect. B.3.c, it is possible to place an approximate 95% confidence interval around a calculated f_I value and on the basis of such an analysis to tentatively conclude whether or not the calculated f_I value differs significantly from 1.0. If f_I is statistically significantly less than 1.0, this suggests that the intake concentration is statistically significantly less than the transect concentration.

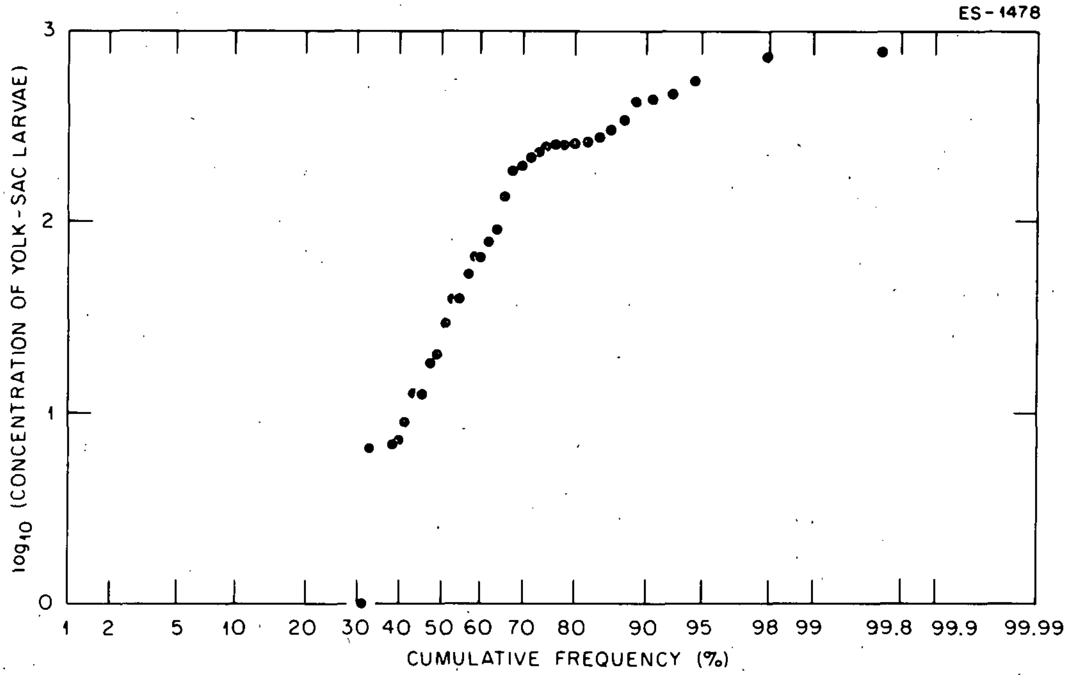


Fig. B-11a. Plot of the logarithm of the concentration of yolk-sac larvae versus cumulative percent frequency for the transect samples at Bowline on June 13-14, 1973. The excess of low values, and thus the deviation from a normal distribution, is indicated by the deviation of the points from a straight line.

Table B-21a. Results of the Kolmogorov-Smirnov test for goodness of fit of the 1973 Lovett data to a normal distribution

Life stage	Date[a]	Site[b]	Sample size	Probability of obtaining the observed D	Reject null hypothesis
Yolk-sac larvae	All	All	160	<0.01	Yes
	6/5–6	All	90	<0.01	Yes
	6/19–20	All	70	<0.01	Yes
	All	Intake	26	<0.01	Yes
	All	Transect	134	<0.01	Yes
	6/5–6	Intake	15	<0.01	Yes
	6/5–6	Transect	75	>0.20	No
	6/19–20	Intake	11	<0.05	Yes
	6/19–20	Transect	59	0.01	Yes
Post yolk-sac larvae	All	All	149	<0.01	Yes
	6/19–20	All	70	<0.01	Yes
	7/3–4	All	79	<0.01	Yes
	All	Intake	25	<0.01	Yes
	All	Transect	124	<0.01	Yes
	6/19–20	Intake	11	<0.01	Yes
	6/19–20	Transect	59	<0.01	Yes
	7/3–4	Intake	14	<0.01	Yes
	7/3–4	Transect	65	<0.01	Yes

[a]"All" means June 5–6 and June 19–20 data combined for yolk-sac larvae and June 19–20 and July 3–4 data combined for post yolk-sac larvae.
[b]"All" means intake and transect data combined.

However, there is a much more direct approach available to test the hypothesis that the intake concentration is significantly less than the transect concentration.

The staff has tested the null hypothesis that the mean intake concentration is greater than or equal to the mean transect concentration using a t-test on the $\log_{10}$ (concentration) values. Since a t-test is a parametric technique, it is assumed that the observations within each subset of the total data set are normally distributed and that among the subsets the true variance is the same (see Sect. B.3.f). The staff also has tested the null hypothesis that the median intake concentration is greater than or equal to the median transect concentration using the median test[4,5] on the untransformed concentration values.

The results of these two methods of analysis are summarized in Table B-21b. There are significant differences (at the 5% level) between intake and transect mean $\log_{10}$ (concentration) values in 11 of the 17 t-tests. There are significant differences (at the 5% level) between intake and transect median concentration values in 10 of the 17 median tests. Because the log transformed data are not normally distributed (Sect. B.3.f), the staff has greater confidence in the nonparametric median test.

On the basis of the analysis in this subsection, apart from problems with the sampling design and sampling techniques, the staff concludes that for striped bass, yolk-sac larvae and post yolk-sac larvae in particular, the mean and the median concentrations entering the intakes at Bowline, Lovett, Danskammer, and Roseton are less than the mean and median concentrations in the transects the majority of the time. This conclusion is in agreement with the conclusion of Sect. B.3.c.

h. The Appeal Board's Conclusion with Respect to the f_1 Factor

The Atomic Safety and Licensing Appeal Board concluded in its decision on Indian Point Unit No. 2[20] (p. 132) that "both the applicant and staff data support an f_1 factor of considerably less than 1.0." The staff is in agreement with this conclusion, but the staff feels that certain aspects of this issue need further clarification. Figure B-11b should be referred to as an aid in understanding the following line of reasoning.

1) The applicant defines f_1 as the ratio of the daily average river concentration of stage i in the upper east (or west) quadrant to the daily average river concentration of stage i in the entire transect.[57]

Table B-21b. Summary of results from t-tests and median tests by plant, date, and life stage for the null hypothesis that the mean intake $\log_{10}$ (conc) or median intake conc ⩾ mean transect $\log_{10}$ (conc) or median transect conc

Plant	Date	Life stage[a]	t-Test: Mean concentration[b] Intake	t-Test: Mean concentration[b] Transect	t-Test: Reject H_0[d] (α = 0.05)	Median test: Combined sample size	Median test: Combined median (M)[c]	Median test: Intake Number > M	Median test: Intake Number ⩽ M	Median test: Transect Number > M	Median test: Transect Number ⩽ M	Median test: Reject H_0[d] (α = 0.05)
Bowline	[6/13–14+ 6/27–28]	YSL	30.3	122.3	Y	133	5.92	1	32	64	36	Y
		PYSL	67.6	310.7	Y	133	23.7	6	27	60	40	Y
	6/13–14	YSL	138.9	154.7	Y	67	8.13	1	11	32	23	Y
		PYSL	211.0	198.0	N	67	6.02	3	9	30	25	N
	6/27–28	YSL	0	121.8	Y	66	2.41	0	21	33	12	Y
		PYSL	33.8	474.9	Y	66	62.3	5	16	28	17	Y
		JUV	8.78	11.8	N	66	0	2	19	14	31	N
Lovett	[6/5–6+ 6/19–20]	YSL	0.76	1.56	Y	160	35.1	7	19	73	61	Y
	[6/19–20+ 7/3–4]	PYSL	0.56	1.36	Y	149	13.3	8	17	66	58	N
	6/5–6	YSL	6.25	105.3	Y	90	28.5	2	13	43	32	Y
	6/19–20	YSL	54.8	146.8	N	70	44.8	4	7	31	28	N
		PYSL	36.3	418.6	Y	70	77.9	2	9	33	26	Y
	7/3–4	PYSL	4.63	29.2	Y	79	6.80	2	12	38	27	Y
		JUV	0	3.73	Y	79	0	0	14	21	44	Y
Danskammer	6/7–8	YSL	193.2	598.9	N	36	177.9	7	9	11	9	N
	6/19–20	PYSL	31.9	35.6	N	51	14.7	9	7	16	19	N
Roseton	7/2–3	PYSL	96.0	7.20	N	60	0	5	9	12	34	N

[a]YSL = yolk-sac larvae; PYSL = post yolk-sac larvae; JUV = juveniles.
[b]Concentrations have units of number of organisms per 1000 cubic meters. The analysis of variance F test was for the intake and transect mean $\log_{10}$ (concentration) values and not the mean concentration values given in these two columns.
[c]M has units of number of organisms per 1000 cubic meters.
[d]Y = yes and N = No. H_0: mean intake $\log_{10}$ (conc) [or median intake conc] ⩾ mean transect $\log_{10}$ (conc) [or median transect conc].

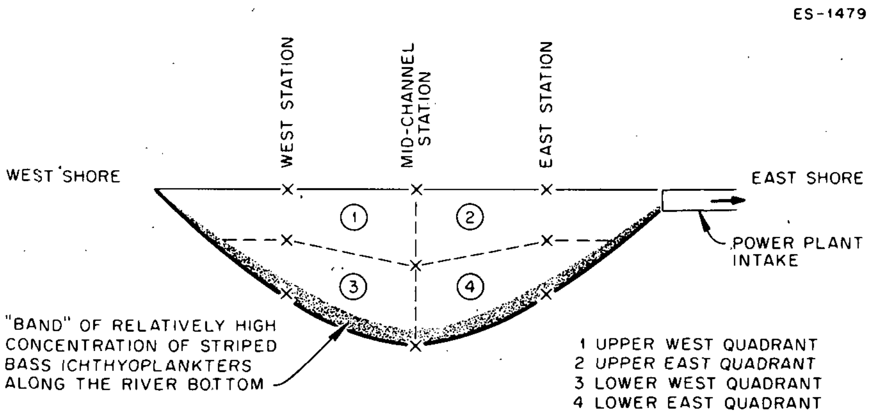


Fig. B-11b. Hypothetical cross section of the Hudson River illustrating the applicant's four quadrants, the location of the three typical sampling stations and sampling depths, and a band of relatively high concentration of striped bass ichthyoplankters along the river bottom.

2) The applicant defines[57] the upper east (west) quadrant as "extending from mid-channel to the east (west) shore and from surface to mid-depth."

3) The concentrations used in the calculation of f_1 values are based on surface and bottom samples and a variable number of intermediate-depth samples; generally these samples are collected at three stations (east, mid-channel, and west).[18] A mid-depth concentration is calculated as the average of the concentrations in the intermediate-depth sample. Each of the stations typically has a depth of two or more times the depth of the intake structure. For example at Lovett, the river depth of the west sampling station was 60 feet, while the intake structure goes from the surface to the bottom of the river, which at that point is approximately 20 feet.

4) The measured vertical distributions of entrainable life stages of striped bass all indicate a tendency for higher concentrations toward the bottom than toward the surface, regardless of depth.[59,60] In other words, striped bass ichthyoplankters tend to be concentrated toward the bottom of the river whether the bottom is near an intake in 20 or 30 feet of water or in the middle of the channel in 100 feet of water.

5) There do not appear to be systematic lateral (i.e., across the river from the east to the west shore) differences in the average concentration in the water column of striped bass eggs, yolk-sac larvae, and post yolk-sac larvae.[61,62]

6) Given items (1) through (5) above, the staff would expect a priori, without analyzing a given set of transect data, that calculated values of f_1 would be less than 1.0.

7) The applicant defines f_2[57] as the ratio of the daily average concentration of stage i in the water actually entering the plant to the daily average river concentration of stage i in the upper east (or west) quadrant.

8) The concentrations used to estimate the numerator of f_2 are based on samples collected at the surface, mid-depth, and bottom of the intake structure, which in all cases rests on the bottom of the river.

9) Given items (2) to (8), the staff would expect a priori that calculated values of f_2 would be ≥ 1.0. [The values of f_2 at a particular power plant would depend on the bottom profile in the immediate vicinity of the intake and the distribution of the streamlines into the intake.] Stated another way, no bottom samples

(again, which tend to have higher concentrations) are used to estimate the average daily river concentration of stage i in the upper east (or west) quadrant, whereas bottom samples are used to estimate the average daily concentration of stage i in the water actually entering the plant.

10) What is relevant in determining the actual impact and the impact forecast by QLM's and the staff's models is the average daily value of the product of f_1 and f_2, i.e., f_I.

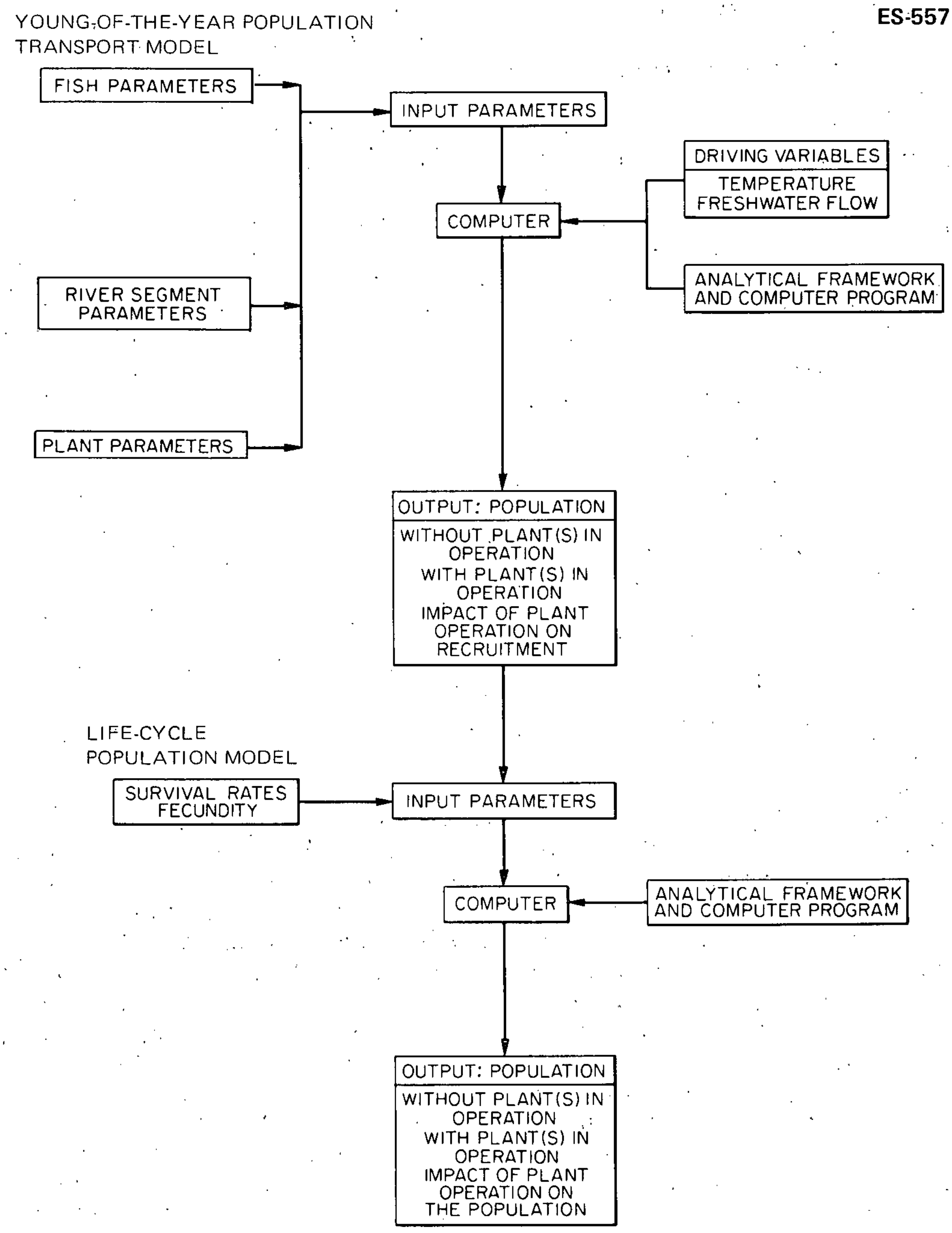
In summary, the points the staff has attempted to clarify in this subsection are that the staff would expect calculated values of f_1 to be less than 1.0 and calculated values of f_2 to be $\geq$1.0, and that what is relevant in determining the actual impact and the impact forecast by the models is the product of f_1 and f_2.

4. DESCRIPTION OF STAFF'S STRIPED BASS YOUNG-OF-THE-YEAR AND LIFE-CYCLE POPULATION MODELS

a. Introduction

These simulation models seek to forecast the long-range impact on a striped bass population of entrainment and impingement of striped bass eggs, larvae, and juveniles due to the withdrawal of water by power plants. The models are designed to help the staff make sound decisions concerning alternative cooling methods and alternative sites. This is being done in two ways. First, the models provide quantitative estimates of impact on a striped bass population. Second, the models are useful in placing previously qualitative statements into a quantitative framework and in defining issues where field and laboratory research are essential for more accurate forecasts.

An overview of the modeling framework is given in Fig. B-12. There are two major efforts: (1) a model to evaluate the impact of entrainment and impingement on recruitment to the yearling age class, and (2) a model to evaluate the impact of reduced recruitment on the total population.[21] The first model focuses on the short-term (i.e., one year) impact on the young-of-the-year of entrainment and impingement at power plants; the second model focuses on the long-term (e.g., 10 years or more) impact on the striped bass fishery and on the size and age structure of the striped bass population. Entrainment and impingement probably act in most situations as density-independent sources of mortality (i.e., the probability of entrainment or impingement is a constant, independent of the size of the population). The general question the staff is addressing is what happens to a fishery when density-independent sources of mortality that act on the zero age class (young-of-the-year), such as entrainment and



Striped Bass Model.

Fig. B-12. Overview of the young-of-the-year and life-cycle population models.

impingement, are introduced. Jensen[22] used a Leslie population matrix model similar to the staff's model to address a similar question for a brook trout population.

For each model there is an analytical framework and a computer program based on that analytical framework (Fig. B-12). The analytical framework is essentially a mathematical translation of what the staff considers to be the pertinent features of the real system. There is an input to the computer of parameters for each age group of fish, river segment, and power plant in the young-of-the-year model and of parameters for fecundity and survival of each age class in the life-cycle model. The computer output is for two conditions: (1) without the plant(s) in operation and (2) with the plant(s) in operation. The impact of plant operation is estimated by subtraction.

b. Striped Bass Young-of-the-Year Model

A computer simulation model[23] has been employed in the assessment of the entrainment and impingement impact of the power plant operation on the striped bass young-of-the-year populations in the Hudson River. A schematic representation of the computational parts and the operational sequence of the daily transient (tidal-averaged), longitudinally one-dimensional (cross-section averaged), discrete element model is presented in Fig. B-13.

The simulation model has a temporal resolution of 24 hour daily variation (tidal averaged). This resolution was used for two reasons. First, a higher temporal resolution, particularly within the tidal cycle variation (e.g., three hours), for any important phenomenon would require the inclusion of the periodic tidal velocity field as the fundamental convective phenomenon in the model, since the tidal flow rates are significantly higher than the net freshwater flow rates in the Hudson River. This would result in the introduction of additional uncertainties rather than in the improvement of the accuracy of the model. Since the reversing, periodic tidal flow field is associated with the short time variations (hourly) of local velocity, temperature and salinity conditions, the inclusion of the phenomenon would require the necessary information about the vertical, and to a lesser extent, lateral variations in flow conditions resulting from turbulent velocity profiles and stratification conditions due to temperature and salinity distributions over the cross-sections. Although it is theoretically possible to develop three dimensional, short time transient (high temporal and spatial resolution) formulations, considering the accuracy of the available physical data for velocity, temperature and salinity conditions as input and the sampled data for striped bass young-of-the-year population distributions for the verifications, it is

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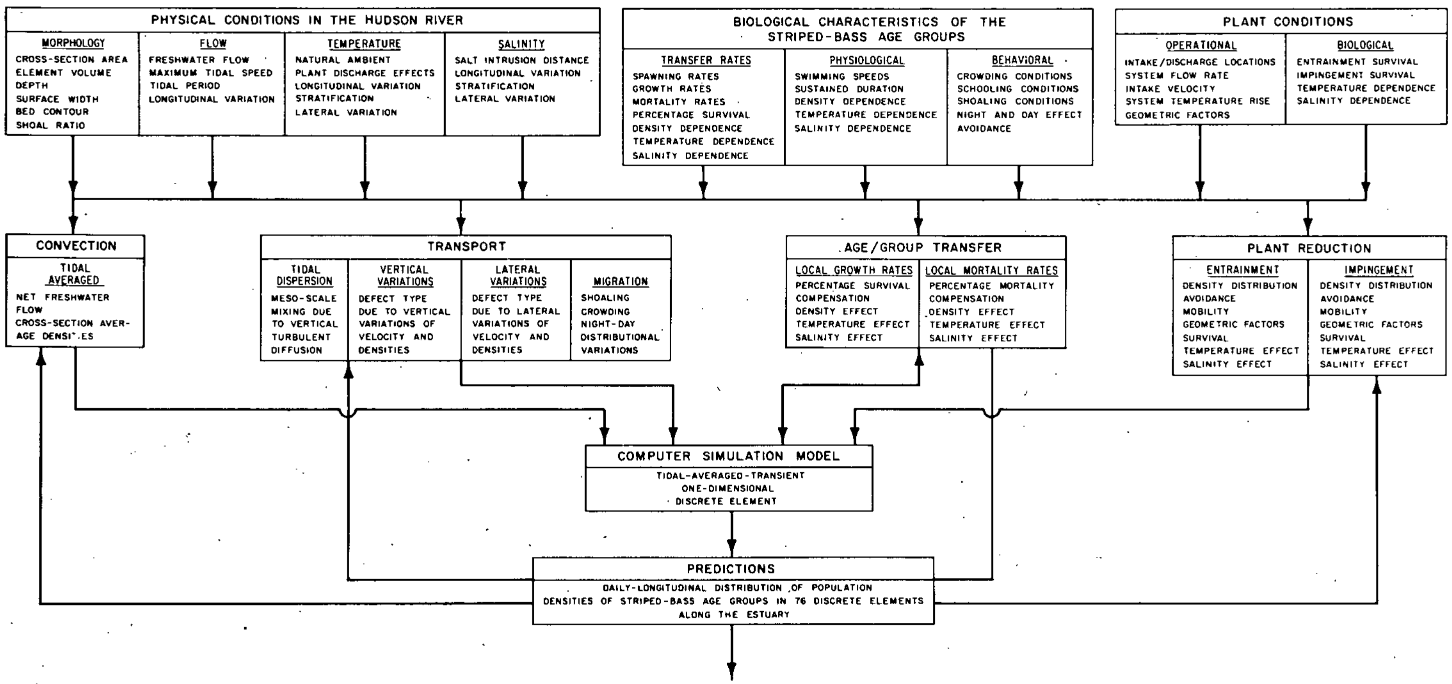

Fig. B-13. Schematic representation of the computational parts and the operational order of the staff's striped bass young-of-the-year model for the Hudson River.

unrealistic and indeed superfluous to undertake such sophisticated modeling efforts in an attempt to improve the accuracy of the simulations.

Second, a lower temporal resolution such as weekly variations, which are consistent with the available reduced data for the striped bass young-of-the-year-populations, could introduce errors in the modeling due to the durations of the certain life-stages of the striped bass. Considering the approximate durations for the egg life stage as 2 days and for the yolk-sac larva stage as 7 days, lower temporal resolutions with time variations longer than these durations would automatically result in inaccuracies in the simulations of the particular age group populations. Since the rates of entrainment and impingement at the intakes depend on the age group population densities of the specific life stages, the errors due to low temporal resolutions could cause errors in the assessment of the impact of power plant operations on the striped bass young-of-the-year in the Hudson River.

Hence, the staff has used a temporal resolution of 24 hour daily variations (tidal-averaged) to avoid the necessity of inclusion of tidal flow conditions, and to guarantee sufficient accuracy for the simulation of age group populations with short life-stage durations. Although the internal computational procedure of the model employs a time step size of 4 hours, based on the stability criterion of the numerical solutions, the results are only presented at six step size intervals (24 hours) to be consistent with the daily averaged assumption of the general formulation.

The analysis considers 152 miles of the estuary, from Troy Dam to the Battery, as consisting of 76 segments each of 2-mile length as shown in Fig. B-14. This high spatial resolution was selected in order to assure the necessary accuracy in specifying the locations of the intakes and discharges relative to the existing morphological characteristics and the flow conditions in the river, which can influence the distributions of the populations and hence the local conditions of entrainment and impingement at the power plants.

The mathematical formulation of the model is based on the straightforward concept of balancing the instantaneous rates of change of the age group population numbers in each discrete element (see Fig. B-15) resulting from longitudinal convection; transport and migration across the element enclosure surfaces; mortality of life stages within the element; transfer to older life stages; and rates of reduction by entrainment and impingement at the existing power plants in the element.

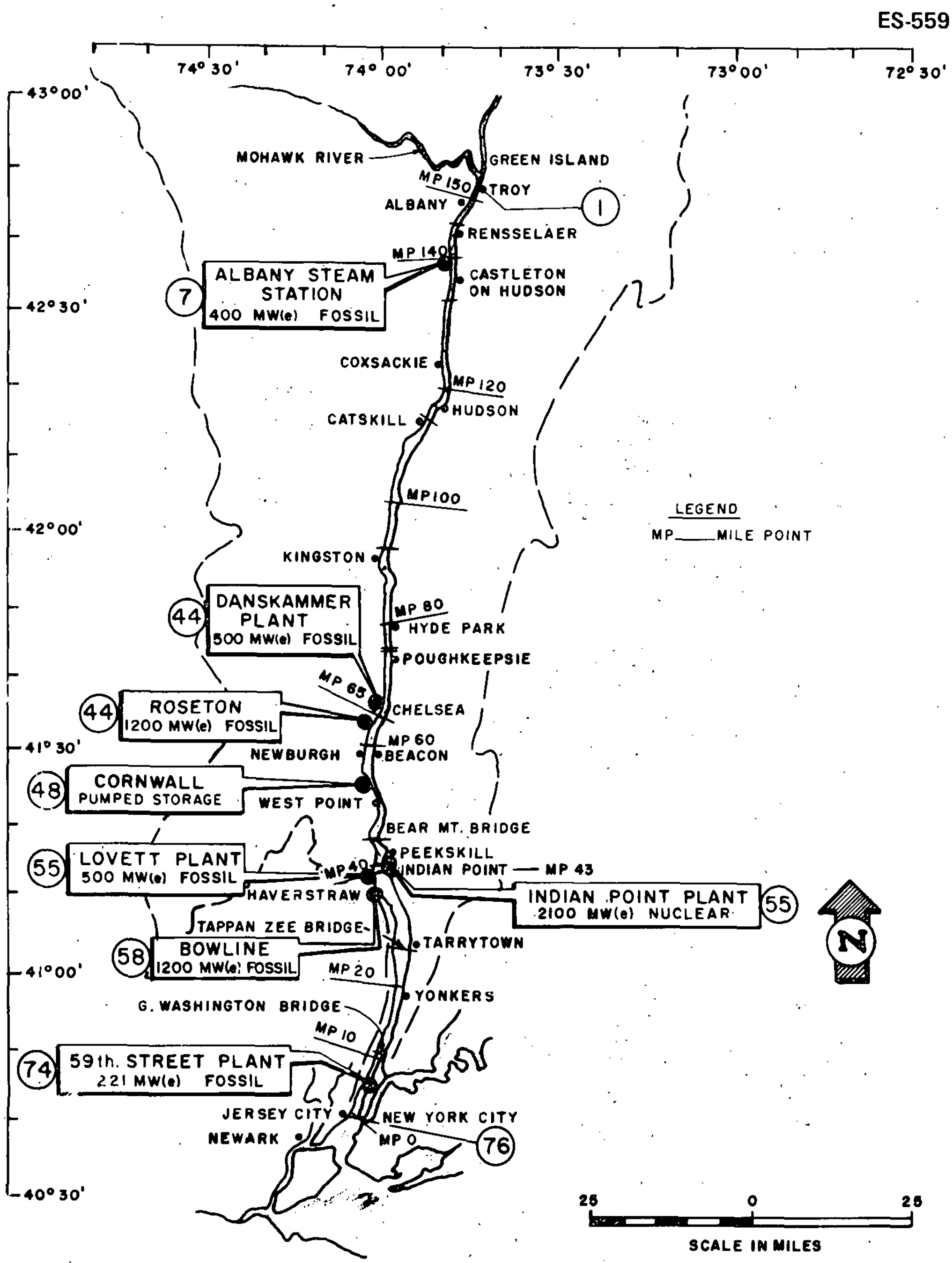

Fig. B-14. Geometrical segmentation of the estuary and the locations of the discrete elements containing power plants.

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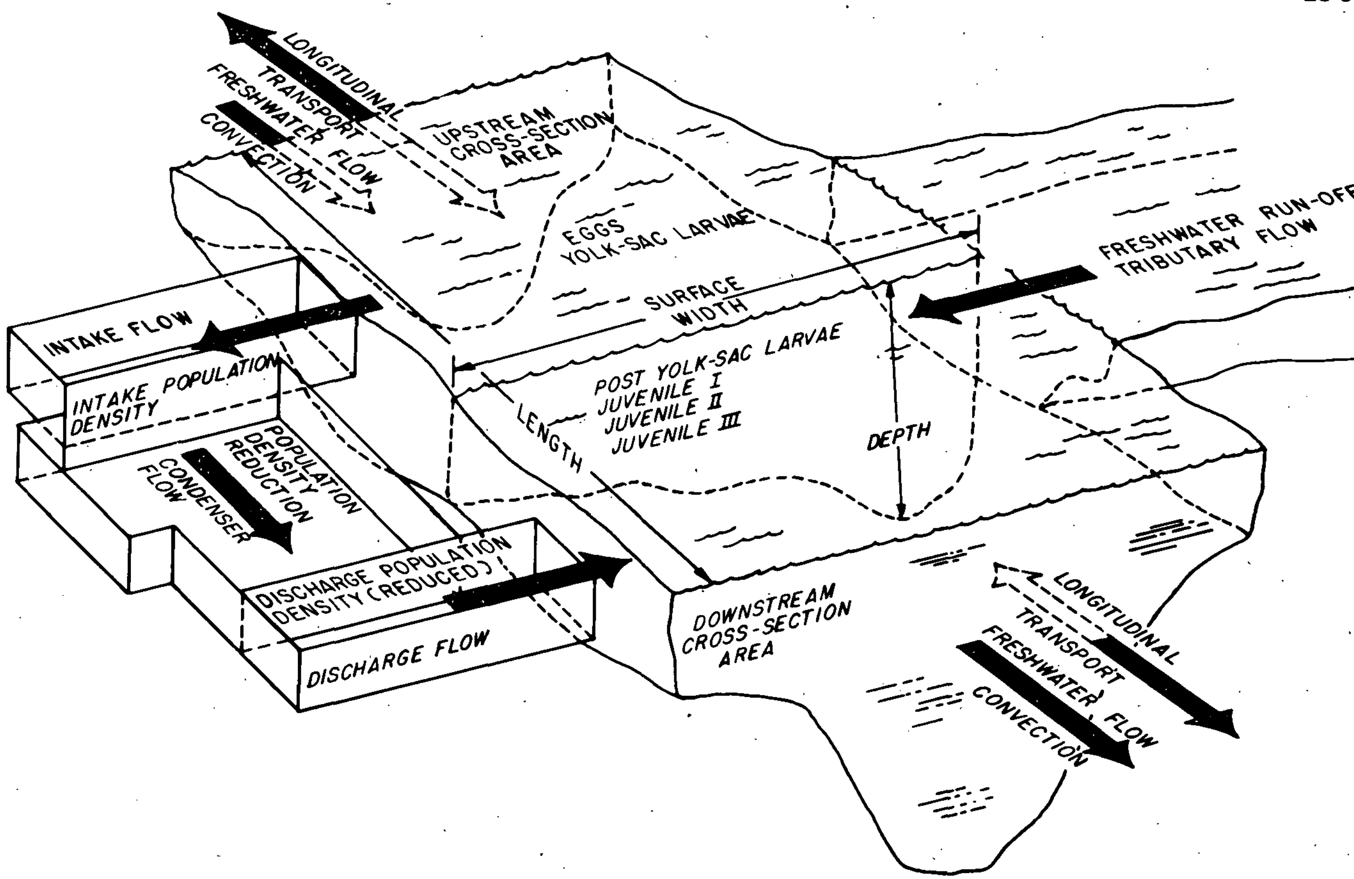

Fig. B-15. Schematic representation of a discrete element for the conceptual development of the computer simulation model.

(1) Physical Conditions in the Hudson River

Input to the model includes certain physical conditions that influence the biological phenomena in the estuary.

(a) Geometrical Properties of the Estuary

The cross-sectional profiles of the river are determined from the geometric data[24] by considering transects at the upstream and downstream ends of the specified segments. The pertinent geometric properties of the discrete elements of the model (area, volume, depth, and surface width) are calculated from the cross-sectional profiles.

Since the juvenile populations of the striped bass young-of-the-year tend to concentrate in shoal areas along the estuary, it is necessary to incorporate a quantitative parameter to represent the extent of shoaling areas in each discrete element.

The migration of the juveniles to shoal areas along the estuary could be attributed to various behavioral characteristics (e.g., search for food, schooling, etc.) which are not necessarily related to strictly geometrical properties of the cross-sections. Furthermore, the extent of shoal areas in a discrete element could depend on various standard geometrical properties (e.g., surface width, average width, average depth, hydraulic radius, etc.) of the river section. Hence, in the selection of a specific shoal parameter both the observed juvenile population distributions and the geometrical properties of the river must be considered.

The quantitative shoal parameter which represents the extent of shoal areas in a discrete element is defined as:

$$\text{shoal parameter} = \frac{\text{surface width of the element}}{\text{maximum depth of the element}} .$$

The particular definition was based on trials with various plausible combinations of standard geometric properties of the river cross-sections to represent both the location along the estuary (e.g., Newbury-Beacon, Tappanzee-Havershaw, etc.) and also the relative magnitude of the extent of shoal areas in these locations. The selection of the particular definition was also based on the success with its use of accurately representating the relative magnitudes of the population concentrations in shoal areas according to the 1973 juvenile distributions along the Hudson River.

The geometric properties of the 76 discrete elements are presented in Table B-22. The longitudinal distribution of the shoal parameter is shown in Fig. B-16, which also illustrates the correlation of the parameter with the actual locations of shoal areas along the river.

(b) Flow Conditions in the Estuary

The flow conditions are employed as input data to the model. Flow is a one-dimensional parameter, which varies longitudinally along the estuary.

(i) Daily Net Freshwater Flow Rate

Because the model considers tidal-average daily variations, net nontidal freshwater flow, estimated primarily from discharge at Troy Dam, constitutes the convective transfer phenomenon, which gradually moves the striped bass young-of-the-year populations from their upstream spawning locations toward the Battery.

Daily averaged flow rates at Green Island for year 1973[25] were used. The actual daily variations were reduced by a five-day averaging technique to eliminate the excessive noise in the raw data. Fig. B-17 shows these five-day averaged values.

To simulate tributary flow into the Hudson River below Troy Dam, the freshwater flow rate values in Fig. B-17 were multiplied within each segment by a factor that varied linearly from 1.0 at Troy Dam to 1.25 at the Battery.

(ii) Maximum Cross-Section-Averaged Tidal Velocity

The overall mixing phenomenon is strongly dominated by the local tidal flow conditions in the Hudson River. Hence, the model calculates the distribution of the maximum cross-section-averaged tidal velocity longitudinally along the estuary from input date. These data can be either measured tidal flow rates[26] or solutions of a hydrodynamic computer simulation model.[27] For 1973 simulations the maximum tidal velocity distributions, as shown in Fig. B-18, were assumed to remain approximately uniform by neglecting the relatively small effect of the variations of the net freshwater flow in the estuary.

(c) Temperature Conditions in the Estuary

The biological phenomena associated with spawning and growth of the striped bass eggs are assumed to depend in part on the local water temperature of the river. The necessary temperature data for the model comes from three sources.

Table B-22. Geometrical proportion of the discrete river elements employed in the young-of-the-year population model

ELEMENT IX	LOCATION(MP) X(IX)	LENGTH(FT) DX(IX)	DEPTH(FT) DHB(IX)	AREA(FT**2) ACR(IX)	VOLUME(FT**3) VCR(IX)	AVERAGE WIDTH(FT) BCR(IX)	SURFACE WIDTH(FT) BSR(IX)	SHOAL RATIO RSH(IX)
1	-0.151000E 03	0.105600E 05	0.162000E 02	0.722249E 04	0.762695E 08	0.445833E 03	0.525000E 03	0.324074E 02
2	-0.149000E 03	0.105600E 05	0.163875E 02	0.996374E 04	0.105217E 09	0.608009E 03	0.750000E 03	0.457666E 02
3	-0.147000E 03	0.105600E 05	0.165375E 02	0.120938E 05	0.127710E 09	0.731293E 03	0.937500E 03	0.566894E 02
4	-0.145000E 03	0.105600E 05	0.255500E 02	0.147863E 05	0.156143E 09	0.578718E 03	0.975000E 03	0.381605E 02
5	-0.143000E 03	0.105600E 05	0.344600E 02	0.160189E 05	0.169160E 09	0.464856E 03	0.922500E 03	0.267702E 02
6	-0.141000E 03	0.105600E 05	0.343850E 02	0.139049E 05	0.146836E 09	0.404388E 03	0.716250E 03	0.208303E 02
7	-0.139000E 03	0.105600E 05	0.343000E 02	0.151453E 05	0.159935E 09	0.441555E 03	0.843750E 03	0.245991E 02
8	-0.137000E 03	0.105600E 05	0.342250E 02	0.197924E 05	0.209008E 09	0.578304E 03	0.101400E 04	0.296275E 02
9	-0.135000E 03	0.105600E 05	0.342500E 02	0.250038E 05	0.264040E 09	0.730038E 03	0.114190E 04	0.333285E 02
10	-0.133000E 03	0.105600E 05	0.343400E 02	0.223418E 05	0.235929E 09	0.650604E 03	0.114000E 04	0.331974E 02
11	-0.131000E 03	0.105600E 05	0.343900E 02	0.191573E 05	0.202301E 09	0.557059E 03	0.900000E 03	0.261704E 02
12	-0.129000E 03	0.105600E 05	0.343500E 02	0.232200E 05	0.245203E 09	0.675983E 03	0.150000E 04	0.436681E 02
13	-0.127000E 03	0.105600E 05	0.342500E 02	0.300675E 05	0.317513E 09	0.877884E 03	0.187500E 04	0.547449E 02
14	-0.125000E 03	0.105600E 05	0.341500E 02	0.291248E 05	0.307557E 09	0.852848E 03	0.174750E 04	0.511713E 02
15	-0.123000E 03	0.105600E 05	0.340250E 02	0.276548E 05	0.292034E 09	0.812777E 03	0.227250E 04	0.667891E 02
16	-0.121000E 03	0.105600E 05	0.340150E 02	0.362744E 05	0.383058E 09	0.106643E 04	0.375000E 04	0.110246E 03
17	-0.119000E 03	0.105600E 05	0.339900E 02	0.335444E 05	0.354229E 09	0.986892E 03	0.382500E 04	0.112533E 03
18	-0.117000E 03	0.105600E 05	0.338600E 02	0.335430E 05	0.354214E 09	0.990638E 03	0.307500E 04	0.908152E 02
19	-0.115000E 03	0.105600E 05	0.337850E 02	0.400980E 05	0.423435E 09	0.118686E 04	0.262500E 04	0.776972E 02
20	-0.113000E 03	0.105600E 05	0.337250E 02	0.337875E 05	0.356796E 09	0.100185E 04	0.187500E 04	0.555967E 02
21	-0.111000E 03	0.105600E 05	0.337000E 02	0.369900E 05	0.390614E 09	0.109763E 04	0.270000E 04	0.801187E 02
22	-0.109000E 03	0.105600E 05	0.337000E 02	0.624956E 05	0.659953E 09	0.185447E 04	0.510000E 04	0.151335E 03
23	-0.107000E 03	0.105600E 05	0.447000E 02	0.707212E 05	0.746815E 09	0.158213E 04	0.555000E 04	0.124161E 03
24	-0.105000E 03	0.105600E 05	0.472000E 02	0.689080E 05	0.727668E 09	0.145992E 04	0.412500E 04	0.873941E 02
25	-0.103000E 03	0.105600E 05	0.417000E 02	0.758155E 05	0.800612E 09	0.181812E 04	0.427500E 04	0.102518E 03
26	-0.101000E 03	0.105600E 05	0.462000E 02	0.787893E 05	0.832014E 09	0.170540E 04	0.487500E 04	0.105519E 03
27	-0.990000E 02	0.105600E 05	0.412000E 02	0.710849E 05	0.750657E 09	0.172536E 04	0.502500E 04	0.121966E 03
28	-0.970000E 02	0.105600E 05	0.462000E 02	0.751462E 05	0.793544E 09	0.162654E 04	0.427500E 04	0.925325E 02
29	-0.950000E 02	0.105600E 05	0.502000E 02	0.976009E 05	0.103067E 10	0.194424E 04	0.382500E 04	0.761952E 02
30	-0.930000E 02	0.105600E 05	0.382000E 02	0.124522E 06	0.131495E 10	0.325974E 04	0.577500E 04	0.151178E 03
31	-0.910000E 02	0.105600E 05	0.437000E 02	0.132664E 06	0.140093E 10	0.303578E 04	0.562500E 04	0.128719E 03
32	-0.890000E 02	0.105600E 05	0.539500E 02	0.115547E 06	0.122018E 10	0.214174E 04	0.465000E 04	0.861909E 02
33	-0.870000E 02	0.105600E 05	0.684375E 02	0.999619E 05	0.105560E 10	0.146063E 04	0.405000E 04	0.591781E 02
34	-0.850000E 02	0.105600E 05	0.721675E 02	0.976764E 05	0.103146E 10	0.135347E 04	0.345000E 04	0.478055E 02
35	-0.830000E 02	0.105600E 05	0.576550E 02	0.105333E 06	0.111231E 10	0.182695E 04	0.375000E 04	0.650421E 02
36	-0.810000E 02	0.105600E 05	0.776400E 02	0.104644E 06	0.110504E 10	0.134781E 04	0.258750E 04	0.333269E 02
37	-0.790000E 02	0.105600E 05	0.103625E 03	0.111173E 06	0.117398E 10	0.107283E 04	0.217500E 04	0.209891E 02
38	-0.770000E 02	0.105600E 05	0.836100E 02	0.123167E 06	0.130064E 10	0.147311E 04	0.258750E 04	0.309473E 02
39	-0.750000E 02	0.105600E 05	0.775750E 02	0.118759E 06	0.125409E 10	0.153089E 04	0.262500E 04	0.338382E 02
40	-0.730000E 02	0.105600E 05	0.800375E 02	0.108279E 06	0.114343E 10	0.135285E 04	0.285000E 04	0.356083E 02
41	-0.710000E 02	0.105600E 05	0.677625E 02	0.108979E 06	0.115081E 10	0.160824E 04	0.288750E 04	0.426121E 02
42	-0.690000E 02	0.105600E 05	0.612625E 02	0.139014E 06	0.146799E 10	0.226915E 04	0.371250E 04	0.605999E 02
43	-0.670000E 02	0.105600E 05	0.620500E 02	0.157551E 06	0.166374E 10	0.253910E 04	0.420000E 04	0.676873E 02
44	-0.650000E 02	0.105600E 05	0.620875E 02	0.156753E 06	0.165531E 10	0.252470E 04	0.510000E 04	0.821421E 02
45	-0.630000E 02	0.105600E 05	0.456000E 02	0.154470E 06	0.163120E 10	0.338750E 04	0.622500E 04	0.136513E 03
46	-0.610000E 02	0.105600E 05	0.411000E 02	0.154988E 06	0.163667E 10	0.377099E 04	0.577500E 04	0.140511E 03

Table B-22 (continued)

47	-0.590000E 02	0.105600E 05	0.461000E 02	0.174323E 06	0.184085E 10	0.378140E 04	0.645000E 04	0.139913E 03
48	-0.570000E 02	0.105600E 05	0.646000E 02	0.160256E 06	0.169230E 10	0.248074E 04	0.502500E 04	0.777864E 02
49	-0.550000E 02	0.105600E 05	0.816000E 02	0.136811E 06	0.144472E 10	0.167661E 04	0.315000E 04	0.386029E 02
50	-0.530000E 02	0.105600E 05	0.921000E 02	0.118590E 06	0.125231E 10	0.128762E 04	0.262500E 04	0.285016E 02
51	-0.510000E 02	0.105600E 05	0.991125E 02	0.100133E 06	0.105741E 10	0.101030E 04	0.168750E 04	0.170261E 02
52	-0.490000E 02	0.105600E 05	0.103637E 03	0.979603E 05	0.103446E 10	0.945220E 03	0.165000E 04	0.159209E 02
53	-0.470000E 02	0.105600E 05	0.123662E 03	0.124341E 06	0.131304E 10	0.100549E 04	0.260250E 04	0.210452E 02
54	-0.450000E 02	0.105600E 05	0.110687E 03	0.153072E 06	0.161644E 10	0.138292E 04	0.324000E 04	0.292716E 02
55	-0.430000E 02	0.105600E 05	0.677375E 02	0.155546E 06	0.164257E 10	0.229631E 04	0.360000E 04	0.531463E 02
56	-0.410000E 02	0.105600E 05	0.688000E 02	0.166532E 06	0.175857E 10	0.242052E 04	0.517500E 04	0.752180E 02
57	-0.390000E 02	0.105600E 05	0.603375E 02	0.204317E 06	0.215758E 10	0.338623E 04	0.982500E 04	0.162834E 03
58	-0.370000E 02	0.105600E 05	0.328750E 02	0.241819E 06	0.255360E 10	0.735570E 04	0.157500E 05	0.479088E 03
59	-0.350000E 02	0.105600E 05	0.373500E 02	0.216608E 06	0.228738E 10	0.579940E 04	0.156000E 05	0.417671E 03
60	-0.330000E 02	0.105600E 05	0.392500E 02	0.198120E 06	0.209215E 10	0.504764E 04	0.121125E 05	0.308599E 03
61	-0.310000E 02	0.105600E 05	0.386500E 02	0.217253E 06	0.229419E 10	0.562102E 04	0.118125E 05	0.305627E 03
62	-0.290000E 02	0.105600E 05	0.400500E 02	0.206223E 06	0.217771E 10	0.514914E 04	0.123000E 05	0.307116E 03
63	-0.270000E 02	0.105600E 05	0.419750E 02	0.213483E 06	0.225438E 10	0.508596E 04	0.127500E 05	0.303752E 03
64	-0.250000E 02	0.105600E 05	0.474250E 02	0.196699E 06	0.207714E 10	0.414757E 04	0.102000E 05	0.215076E 03
65	-0.230000E 02	0.105600E 05	0.499375E 02	0.146992E 06	0.155224E 10	0.294352E 04	0.570000E 04	0.114143E 03
66	-0.210000E 02	0.105600E 05	0.455250E 02	0.137354E 06	0.145046E 10	0.301711E 04	0.483750E 04	0.106260E 03
67	-0.190000E 02	0.105600E 05	0.461000E 02	0.151038E 06	0.159496E 10	0.327631E 04	0.528750E 04	0.114696E 03
68	-0.170000E 02	0.105600E 05	0.486625E 02	0.145804E 06	0.153968E 10	0.299622E 04	0.495000E 04	0.101721E 03
69	-0.150000E 02	0.105600E 05	0.557500E 02	0.133454E 06	0.140927E 10	0.239379E 04	0.448500E 04	0.804484E 02
70	-0.130000E 02	0.105600E 05	0.663500E 02	0.136640E 06	0.144291E 10	0.205937E 04	0.409500E 04	0.617182E 02
71	-0.110000E 02	0.105600E 05	0.654375E 02	0.129486E 06	0.136737E 10	0.197877E 04	0.379500E 04	0.579943E 02
72	-0.900000E 01	0.105600E 05	0.565000E 02	0.121209E 06	0.127996E 10	0.214528E 04	0.406500E 04	0.719469E 02
73	-0.700000E 01	0.105600E 05	0.510625E 02	0.124819E 06	0.131808E 10	0.244443E 04	0.437250E 04	0.856304E 02
74	-0.500000E 01	0.105600E 05	0.526000E 02	0.132250E 06	0.139656E 10	0.251426E 04	0.408000E 04	0.775665E 02
75	-0.300000E 01	0.105600E 05	0.511250E 02	0.168600E 06	0.178041E 10	0.329779E 04	0.498750E 04	0.975550E 02
76	-0.100000E 01	0.105600E 05	0.506750E 02	0.204034E 06	0.215459E 10	0.402632E 04	0.585000E 04	0.115442E 03

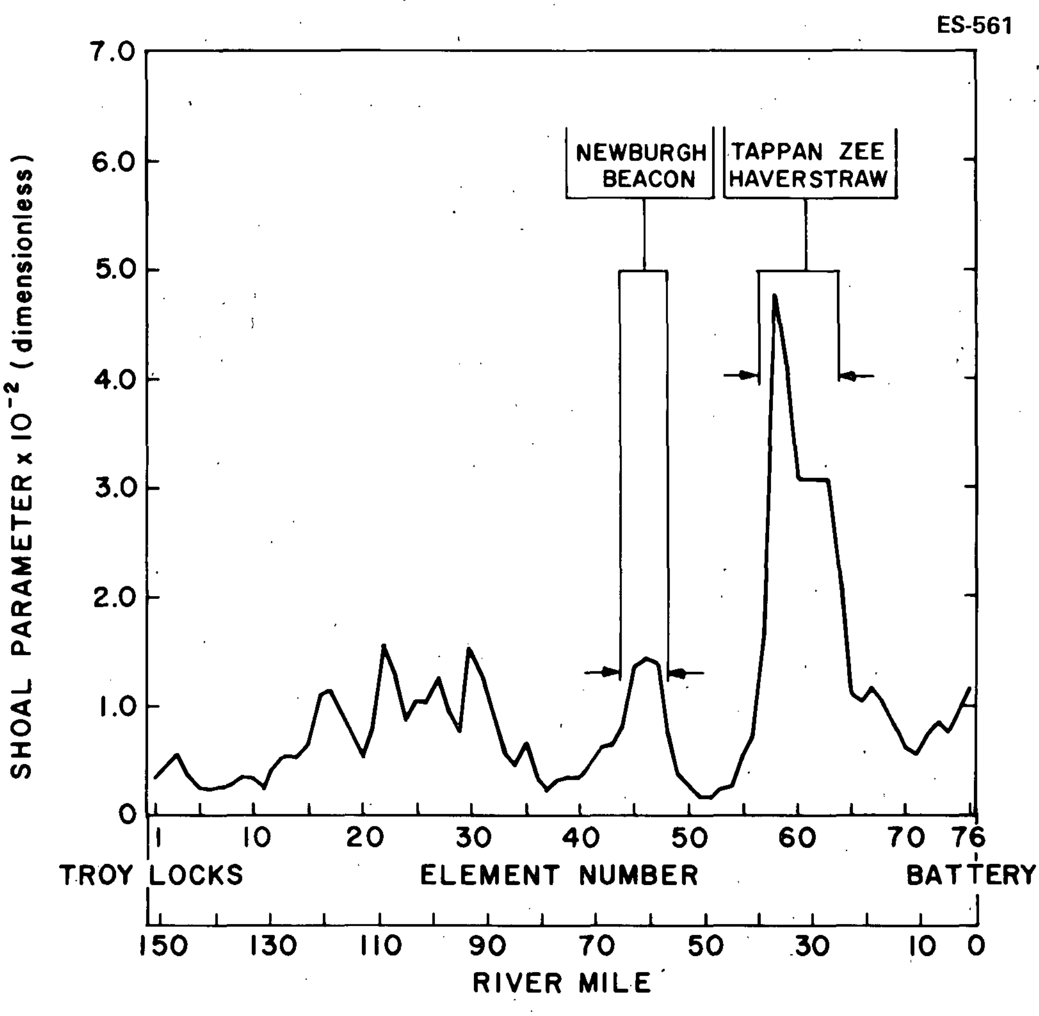

Fig. B-16. Longitudinal distribution of shoal parameter for the discrete elements along the estuary.

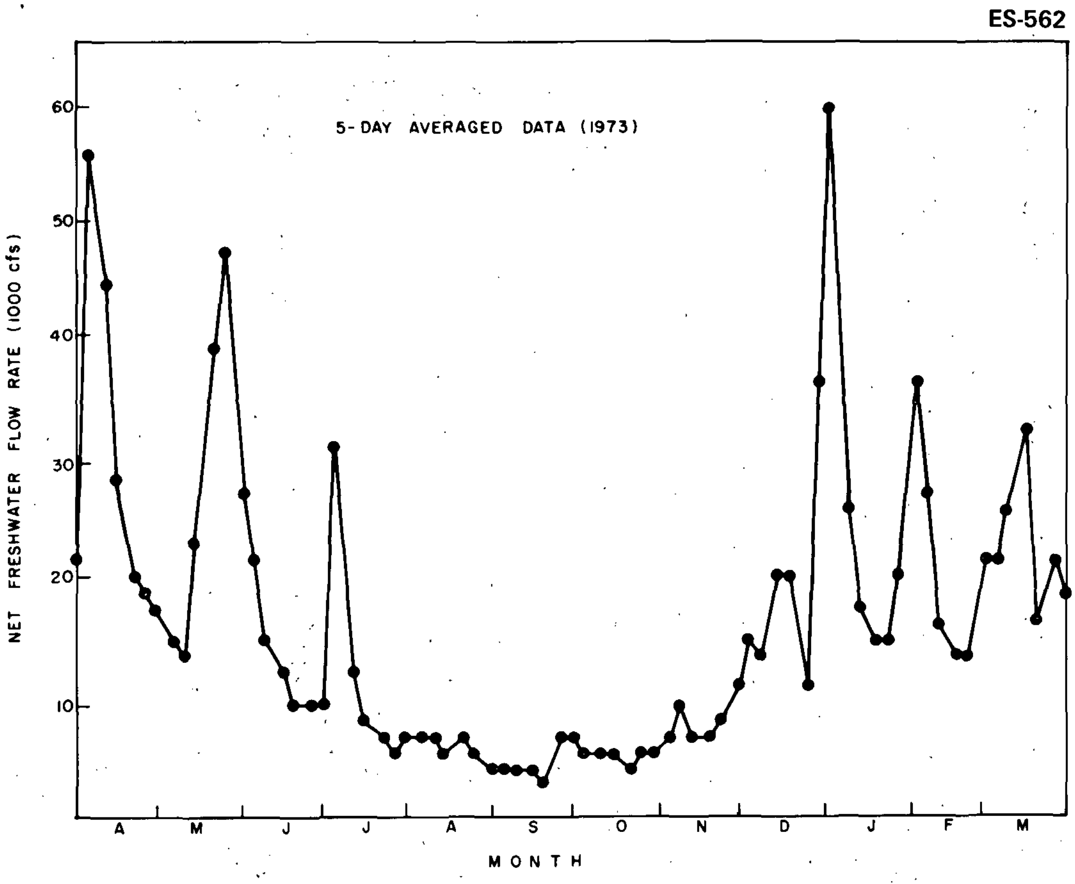

Fig. B-17. Five-day averaged daily freshwater flow rates at Green Island for April 1973 through March 1974. Source: Data supplied by U.S. Department of the Interior, Geological Survey, Albany, New York, July 1974.

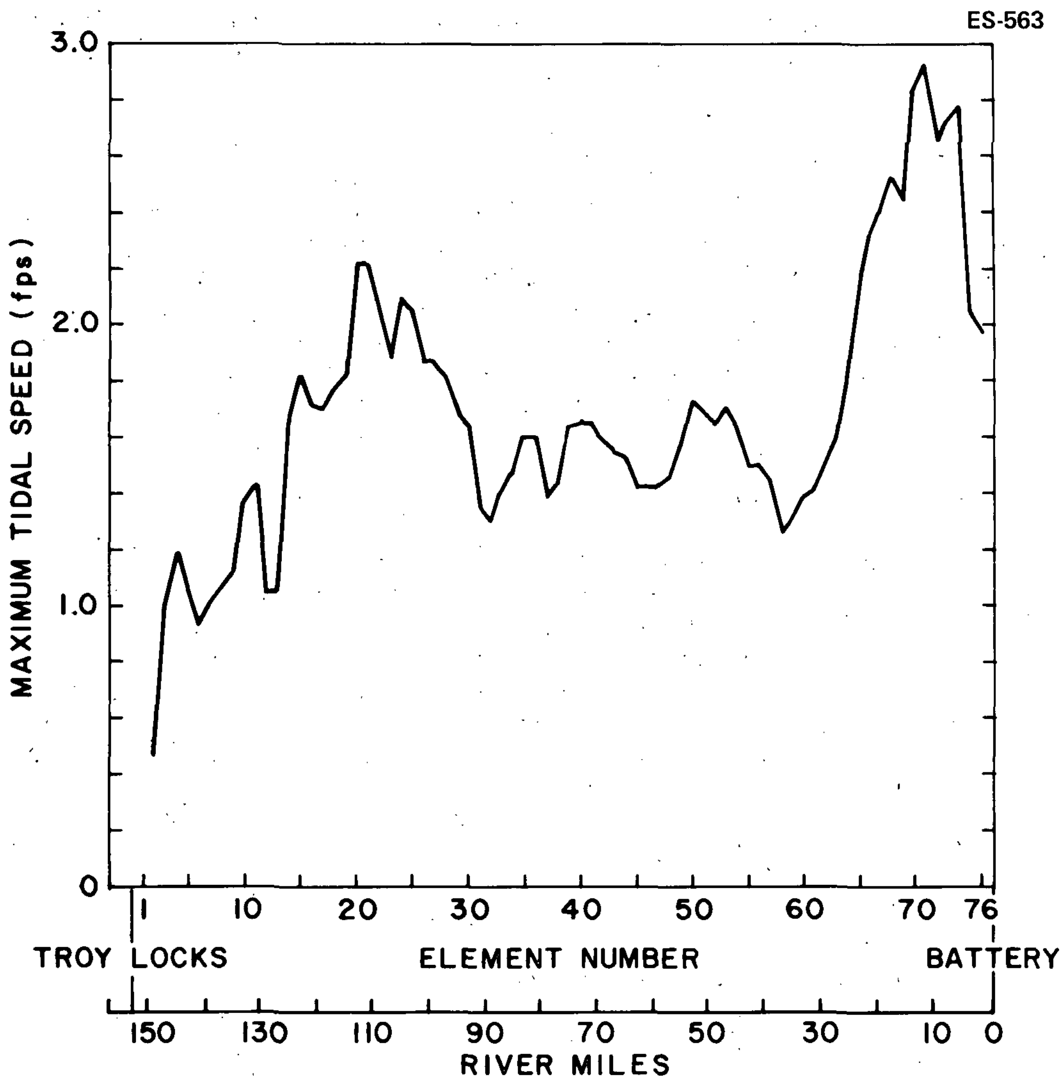

Fig. B-18. Maximum cross-section averaged tidal speed distribution along the Hudson River.

(i) Daily Mean Water Temperature of the River

Changes in daily mean water temperature during the year are based on five-day averaged data taken at Verplanck[28] as shown in Fig. B-19. For 1973 simulations, these data were assumed to approximate the longitudinally averaged daily mean water temperature of the river.

(ii) Longitudinal Variation of Water Temperature in the River

The available data (see Fig. B-20 indicate that the longitudinal variations of temperature exist throughout the year with a consistent pattern of decreasing temperature with distance upstream from the Battery. For 1973 simulations, linear variations with a 4 F° difference between the Battery and Troy Dam were employed to approximate the longitudinal temperature variations from the averaged daily mean water temperature data at Verplanck (see Fig. B-19).

(iii) Temperature Rise in the Vicinity of Thermal Discharges

The incremental temperature effects of thermal discharges are approximately included in the model, based on the standard approximate solution[4,29] of the tidal-averaged energy equation with freshwater flow convection and longitudinal transport due to tidal dispersion. The input data for the natural temperature distribution are modified according to the amount of heat added as obtained from the specified operational conditions of the power plants.

(d) Salinity Conditions in the Estuary

The concentration and mobility of juvenile striped bass, which affect the magnitude of both impingement at the intakes and migration to shoal areas, depend, in part, on the salinity distribution in the estuary, particularly on the location of the salt front.[30] Hence, an approximate method is employed in the staff's model to incorporate the salinity conditions in the estuary.

(i) Salt Intrusion Length

The salt intrusion length from the Battery is determined according to the observed salinity data[25] in the Hudson river under different freshwater flow conditions based on two empirical formulae as shown in Fig. B-21.

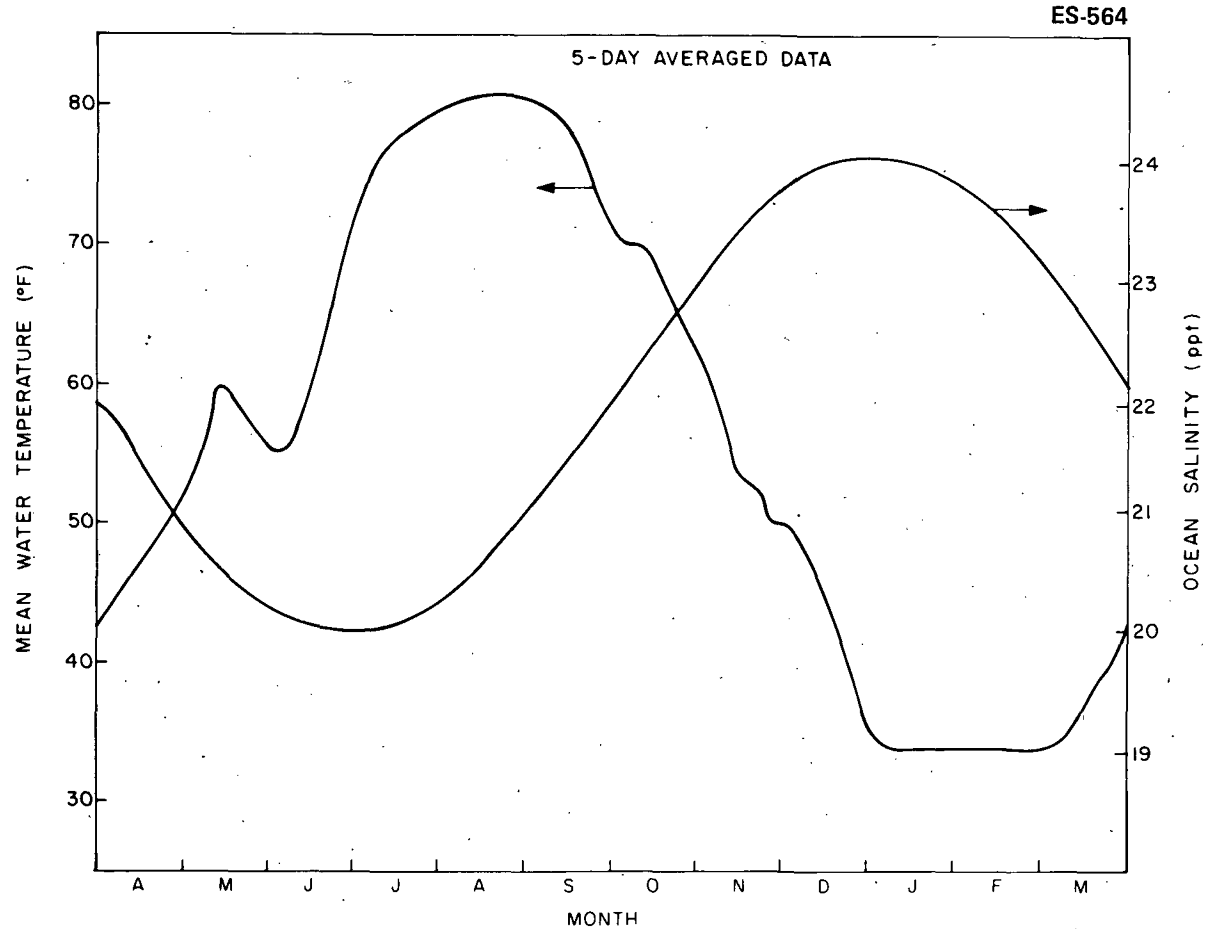

Fig. B-19. Longitudinally averaged daily mean water temperature and ocean salinity variations employed in the model. Source: Data supplied by New York State Department of Environmental Conservation, Albany, New York, August 1974.

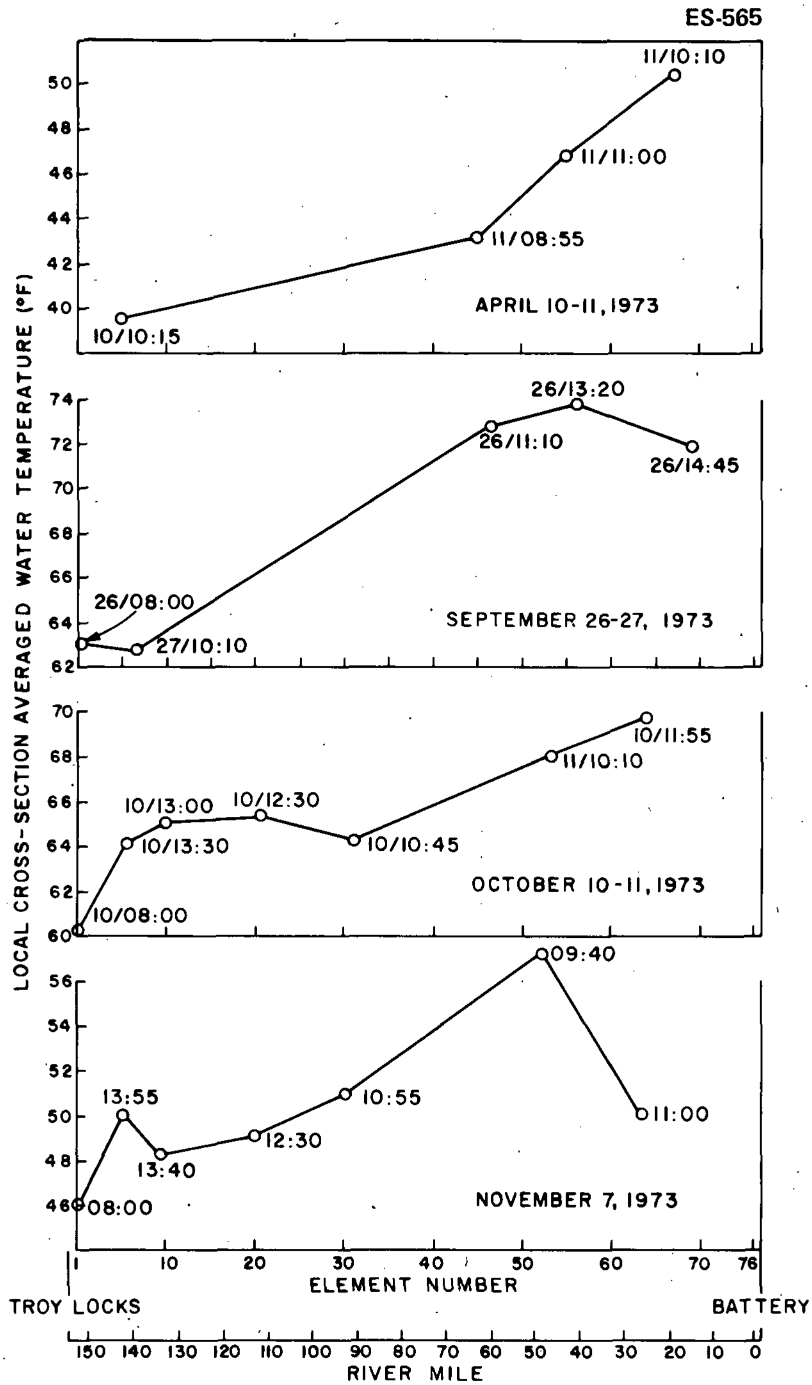

Fig. B-20. Longitudinal variations of cross-section averaged temperature in the estuary for different months in 1973.

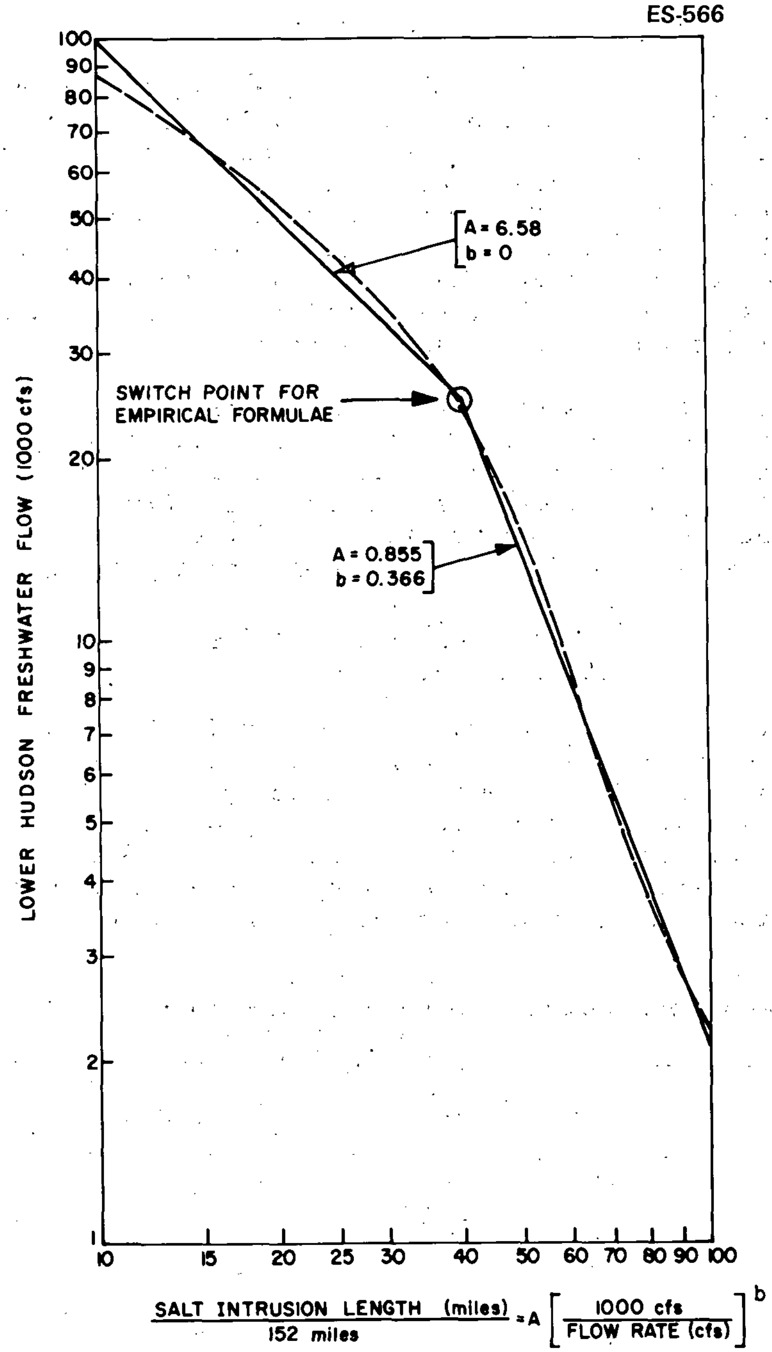

Fig. B-21. Salt intrusion length variation with freshwater flow in the Hudson River and empirical formulae for approximating this length. Source: Data supplied by U. S. Department of the Interior, Geological Survey, Albany, New York, July 1974.

(ii) Longitudinal Distribution of Mean Salinity

The longitudinal distribution of tidal-averaged mean salinity in the river is determined from a modified form of the solution of the convective dispersive constituent conservation equation,[29] based on the ocean salinity at the Battery (see Fig. B-19) and the salt intrusion length determined according to the empirical formulae in Fig. B-21. The comparison of the approximation used in the model and the observed salinity distributions at two different freshwater flow rates is shown in Fig. B-22, which indicates good agreement between the computed values and the data.

The approximate forms employed in the staff's model for the representations of the physical conditions in the estuary are considerably more accurate than the available biological data about the striped bass young-of-the-year in the Hudson River; hence, further refinement of the approximate formulae for the physical conditions has not been attempted in the computer simulation model.

(2) Biological Characteristics of Striped Bass Young-of-the-Year

The staff's computer simulation model considers six sequential life-stage age groups (i.e., eggs, yolk-sac larvae, post yolk-sac larvae, juvenile I's, juvenile II's, and juvenile III's) as well as a dummy adult spawning group. The approximate durations of these life stages, the approximate range of lengths of the fish at each life stage, and the nature and extent of their susceptibility to destruction by power plants are indicated in Table B-23.

Table B-23. Striped bass young-of-the-year life stage durations, lengths, and susceptibility to destruction at the power plants

Life stage	Duration (days)	Length (millimeter)	Destruction	
			Susceptibility	Avoidance
Egg	2.0	1.6–3.5	Entrainment	None
Yolk-sac larva	6.0	3.1–6.2	Entrainment	None
Post yolk-sac larva	22.0	6.3–15	Entrainment	None
Juvenile I	40.0	16–50	Entrainment and impingement	Low
Juvenile II	123.0	>50	Impingement	High
Juvenile III	172.0		Impingement	Medium

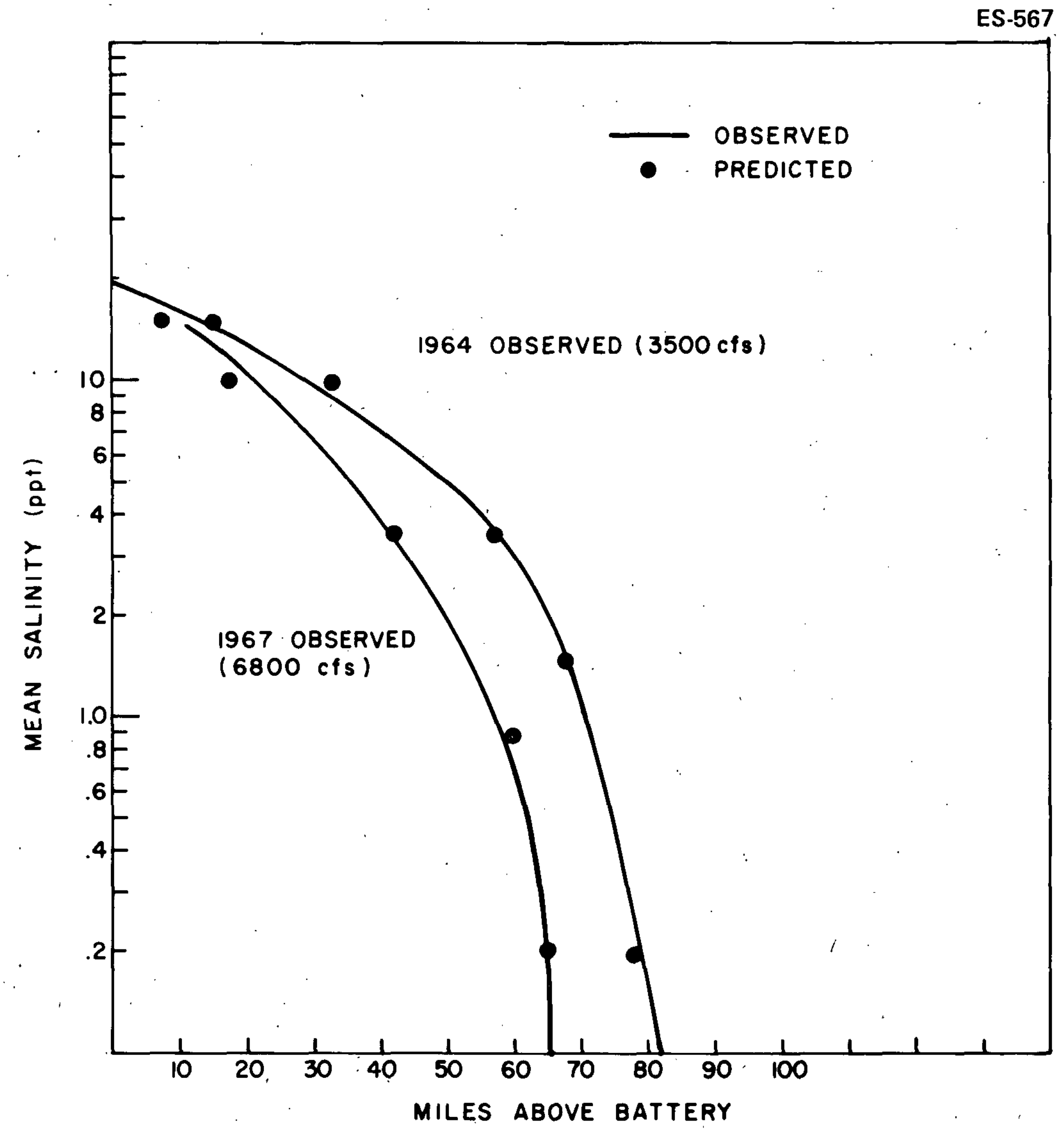

Fig. B-22. Comparisons of observed salinity distributions with the approximations used in the model.

(a) Approximate Simulations of Rate and Distribution of Egg Deposition in the Hudson River

Accurate simulation of the egg deposition in the river is extremely difficult, because definitive knowledge of the factors that control spawning does not exist. However, because distributions of the later young-of-the-year life stages are strongly dependent on the location and timing of egg production during the spawning period, it is important to simulate egg deposition rates and distribution that correspond reasonably well with actual spawning in the river.

(i) Longitudinal Distribution of Egg Deposition

The longitudinal distribution of egg deposition in the estuary is simulated by generating an appropriate distribution of a "dummy" population of spawning adult females throughout the observed spawning areas. This distribution is established by trial and error to achieve a reasonably accurate simulation of the observed weekly-averaged longitudinal distributions of egg and yolk-sac larvae in the river during the spawning period. The total number of dummy spawning adults used in the model approximates population estimates of actual female spawners in the river.[31] The choice of the distribution of dummy spawners and egg deposition rate is adjusted to simulate the observed distribution and total production of eggs. The assumed dummy spawning adult distribution, employed in applications of the staff's model with 1973 data, is presented in Fig. B-23.

(ii) Rate of Egg Deposition by Each Dummy Spawning Adult

To simulate the local rate of egg deposition in the estuary, each dummy female spawner is assumed to deposit 1,440 viable and fertilized eggs per day under optimum conditions, which corresponds to a seasonal total production of approximately 50,000 eggs per fish. The 50,000 eggs per fish per season corresponds to a realistic average deposition estimate of 1,000,000 eggs, per female per season, only 5% of which are likely to be both viable and fertilized.

(iii) Dependence of Egg Deposition Rate on Temperature

The assumed temperature dependence of the egg deposition rate is shown in Fig. B-24. Comparison of the observed egg distributions and temperature conditions for 1973 indicate that spawning occurred when temperatures were between 54 and 66°F. The peak spawning occurred during a period when temperatures varied between 58 and 62°F. Hence, to approximate the temperature dependence of spawning in the staff's model, the optimum rate of spawning (1,440 eggs per

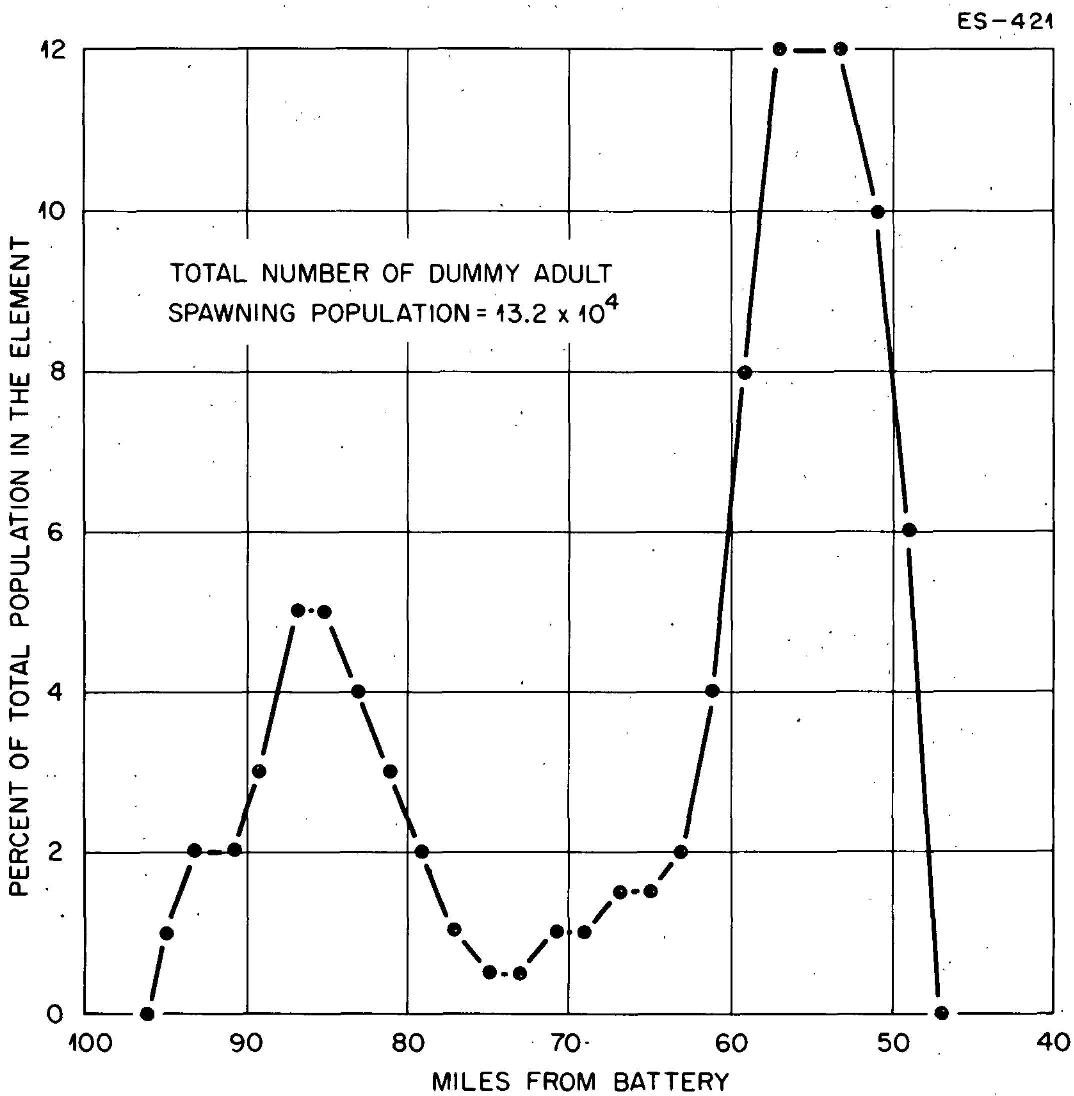

Fig. B-23. Assumed dummy spawning adult age group distribution for simulating egg deposition conditions in the estuary.

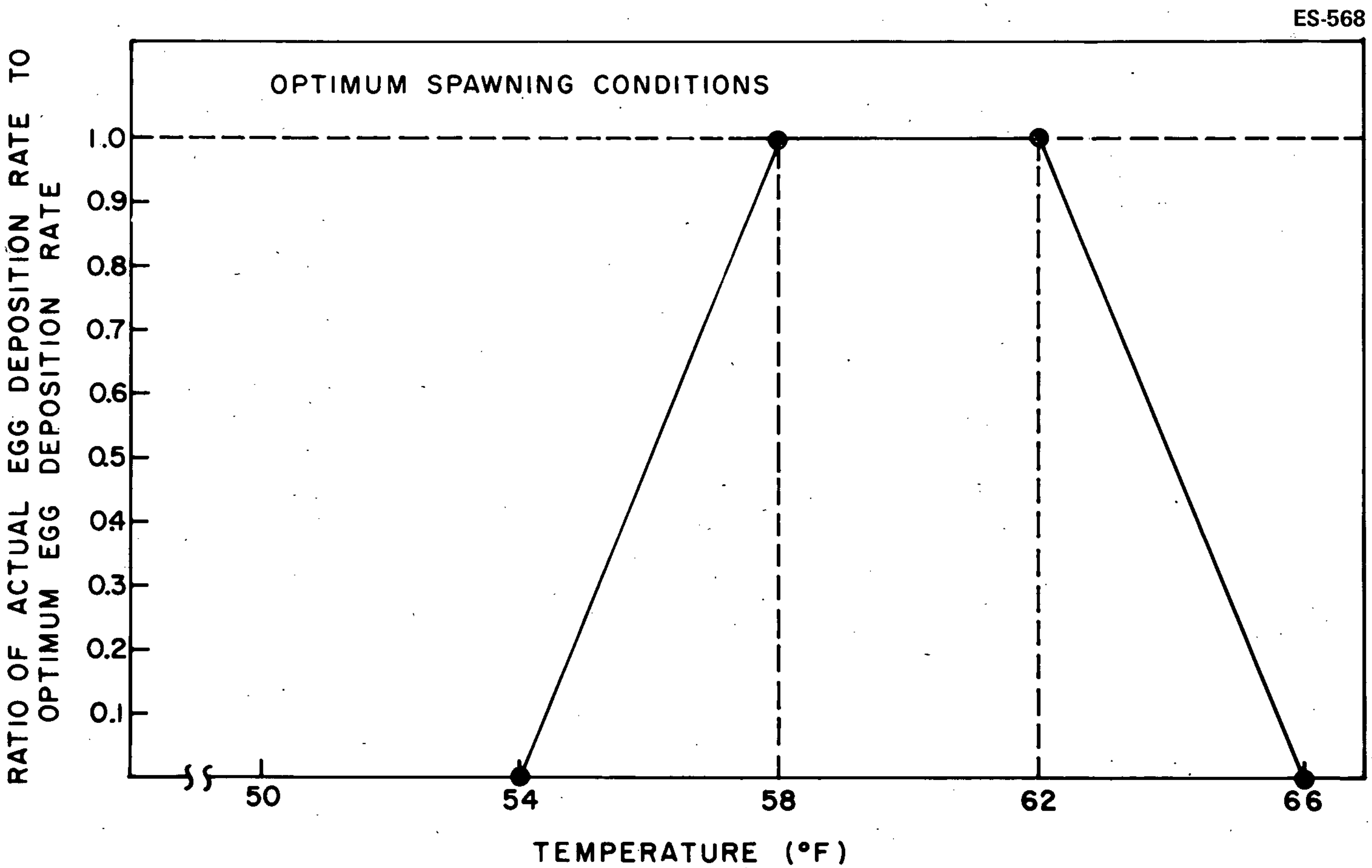

Fig. B-24. Assumed temperature dependence of egg deposition rate.

day per female) was multiplied by a factor which increased linearly from zero to one as temperature increased from 54 to 58°F, remained constant at 1.0 between 58 and 62°F, and then decreased linearly to zero as temperature increased from 62 and 66°F.

In the application of the staff's model to the simulation of 1973 data, the selected egg deposition rate and the dummy spawning adult population indicated that approximately 4.6 billion eggs were deposited in the estuary during the spawning period.

(b) Survival Conditions of Age-Group Populations

The staff's model does not employ simple decay-type variations, as does the applicant's model,[32] for calculating the local time rates of change of age group populations in the river. The net rates in the staff's model are rigorously formulated, based on instantaneous growth rates that continuously transfer populations to later life stages and on instantaneous mortality rates which continuously reduce the populations in the system. Hence, consistent with the continuous property of growth and mortality rates, the model employs instantaneous survival percentages for the age group populations, which represent, on the average, probabilities of survival of the individuals of the life stages through the minimum time period (hour) considered in the formulation of the model.

(i) Modeling of Compensatory Mechanisms

The proper modeling of the overall compensatory mechanism for the striped bass young-of-the-year in the Hudson River would require the consideration of the general ecological system with multi-species populations to include the effects of food limitation, predation, and numerous other interaction phenomena among the species. In view of the present state of the art in mathematical modeling of complex ecological systems, it is not possible to develop a model incorporating all these effects.

The available information about the striped bass does not provide direct evidence relating to the existence or the significance of possible compensatory mechanisms operating on the life stages of the young-of-the-year population. However, considering the occurrence of compensation sometime in the life cycles of biological species existing in limited environments, it is conceivable that a compensatory mechanism, in the general sense, could also be operational during the first year of life of the striped bass.

The staff's computer simulation model incorporates a generalized population-density-dependent compensatory mechanism in the formulations of the instantaneous survival percentages of the age group populations, based on the following assumptions:

1. For each life stage with an existing age group population at any given time, as instantaneous survival percentage is defined which determines the part of the population which is being continuously transferred into the next life stage based on the survival of the individuals of the population as they live through the duration of the life stage. The instantaneous survival percentage of the age group depends only on the population density of the particular life stage and not on the population densities of the other life stages considered in the analysis.

2. At low population density levels, below critical conditions, each age group population has a constant optimum survival percentage, which represents the maximum attainable survival percentage of the life stage under optimum existence conditions of the river. For population densities below the critical density of the life stage, the instantaneous survival percentage of the age group is identically equal to the optimum survival percentage; and it is independent of the population density.

3. The density-dependent compensatory mechanism becomes effective in the system when the age group population density exceeds the critical density of the life stage. For age group population densities higher than the critical value, the instantaneous survival percentage of the life stage decreases linearly from its optimum value with increasing density. This linear variation form for the instantaneous survival percentage is conceptually similar to the logistic-type relationship between the growth rate of a population and its population size.[33-35]

In the applications of the staff's model, the necessary parameter values for the assumed form of the density-dependent compensatory mechanism were determined based on the results of the model's simulation of the 1973 population data in the river. Since the determinations from the simulations of all the unknown parameters for all life stages with operational compensatory mechanisms would be extremely difficult, a simple approach was used in the analysis to limit the number of variables.

For each life stage, except egg, a constant effective value for the instantaneous survival percentage is assumed to have existed throughout the 1973 spawning period. Considering the short duration of the eggs and the limited importance of the food limitation effect for this life stage, the compensatory mechanism for the egg age group population was neglected in the analysis. Furthermore, in view of their long life stage durations, and in anticipation of possible high survival percentages, the same effective survival percentage values were assumed for the juvenile II and juvenile III age group populations.

The appropriate values for the effective survival percentages were determined by running the model without the compensatory mechanism for different combinations of the life stage survival percentage values until reasonably accurate simulations of the longitudinal distributions of all age group populations were obtained for the 1973 physical and plant operational conditions in the river.

To obtain the necessary parameters for the generalized form of the compensatory mechanism, the critical population density of each life stage was assumed to equal 90% of the maximum population density observed for the life stage during the 1973 spawning period in the river. To determine the slope of the linear variation of the instantaneous survival percentage with age group population density, the effective survival percentage value was assumed to be reached at the half point value between the critical population density and the maximum observed density for each life stage according to the 1973 data.

The parameter values for maximum observed population densities, effective survival percentages, critical population density values, and optimum survival percentages, used in the formulations of the population-density-dependent mechanisms for the specified life stages in the staff's model, are presented in Table B-24.

Table B-24. Parameter values employed in the staff's model for population density dependent compensatory mechanism for survival percentages of life stage populations

Life stage	Maximum population density (number per 1,000 ft^3)	Effective survival percentage	Critical population density (number per 1,000 ft^3)	Optimum survival percentage
Egg	No population density dependent compensatory effect			40.0
Yolk-sac larva	8.0	60.0	7.2	66.0
Post yolk-sac larva	7.0	80.0	6.3	84.0
Juvenile I	2.0	90.0	1.8	92.0
Juvenile II	1.0	98.0	0.9	99.0
Juvenile III	1.0	98.0	0.9	99.0

The schematic representations of the density dependent forms of compensatory mechanisms employed in the staff's model are shown in Figs. B-25–B-28 for the yolk-sac larva, post yolk-sac larva, juvenile I, and juvenile II and juvenile III life stages.

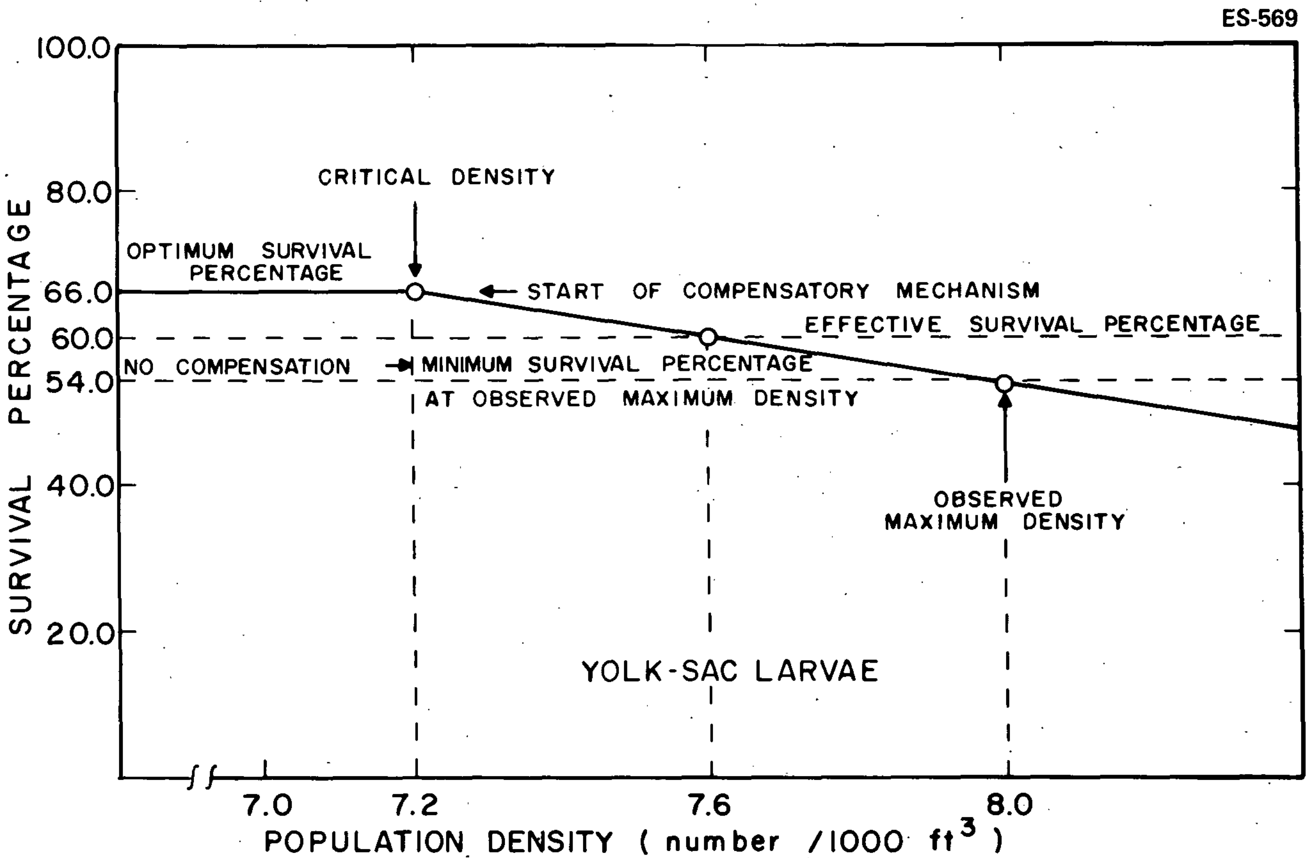

Fig. B-25. Schematic representation of survival precentage of yolk-sac larvae on population density.

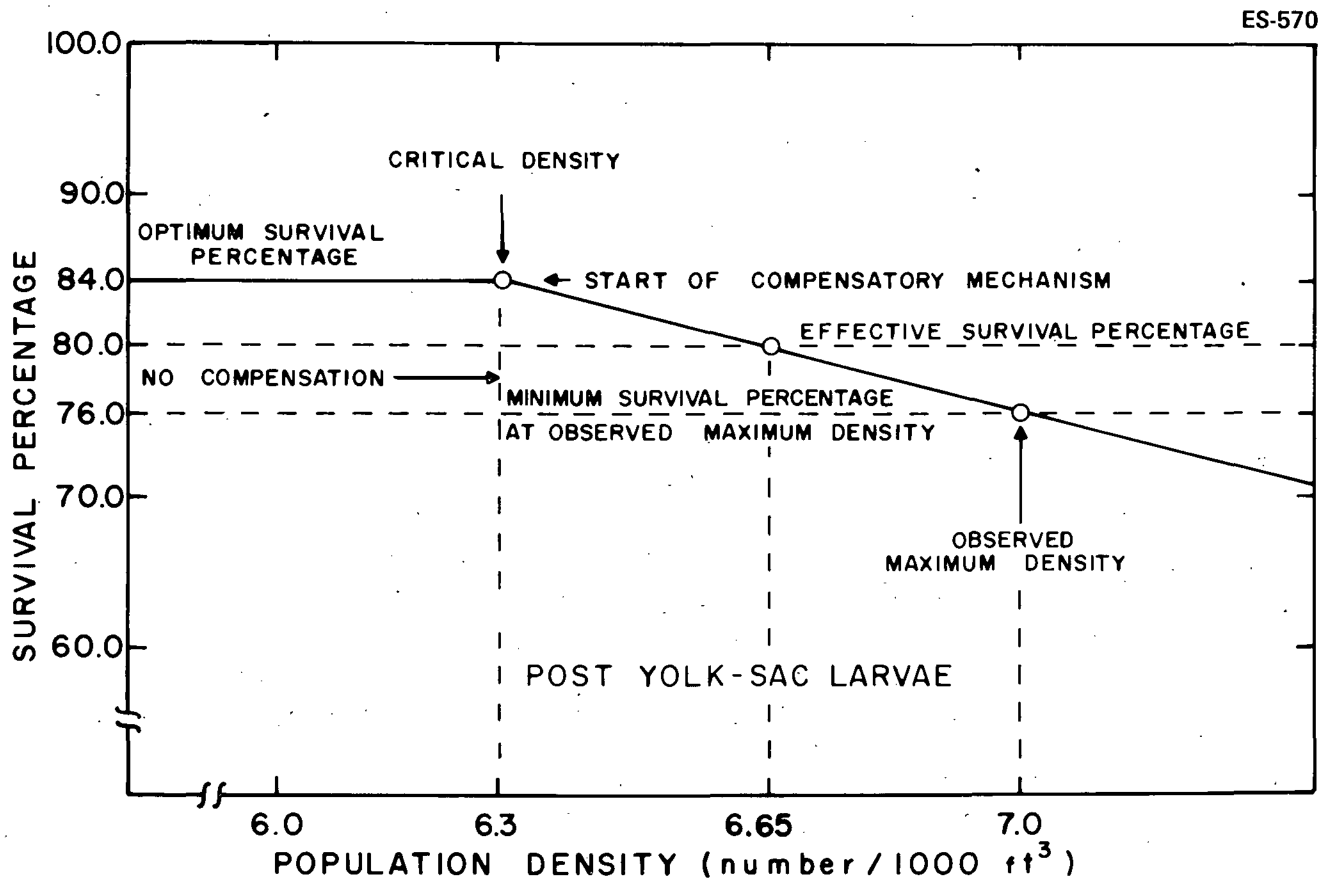

Fig. B-26. Schematic representation of survival percentage of post yolk-sac larvae on population density.

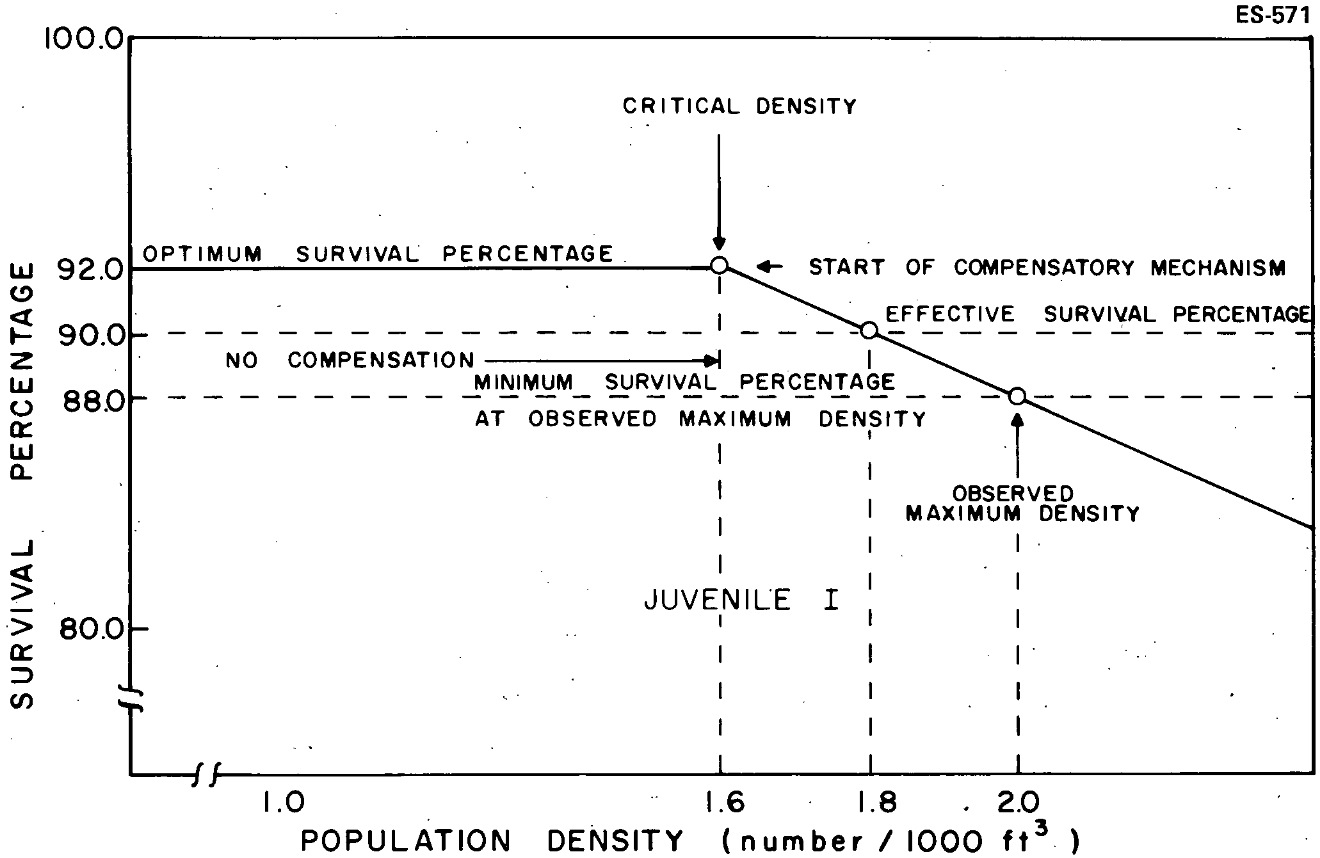

Fig. B-27. Schematic representation of survival percentage of juvenile I on population density.

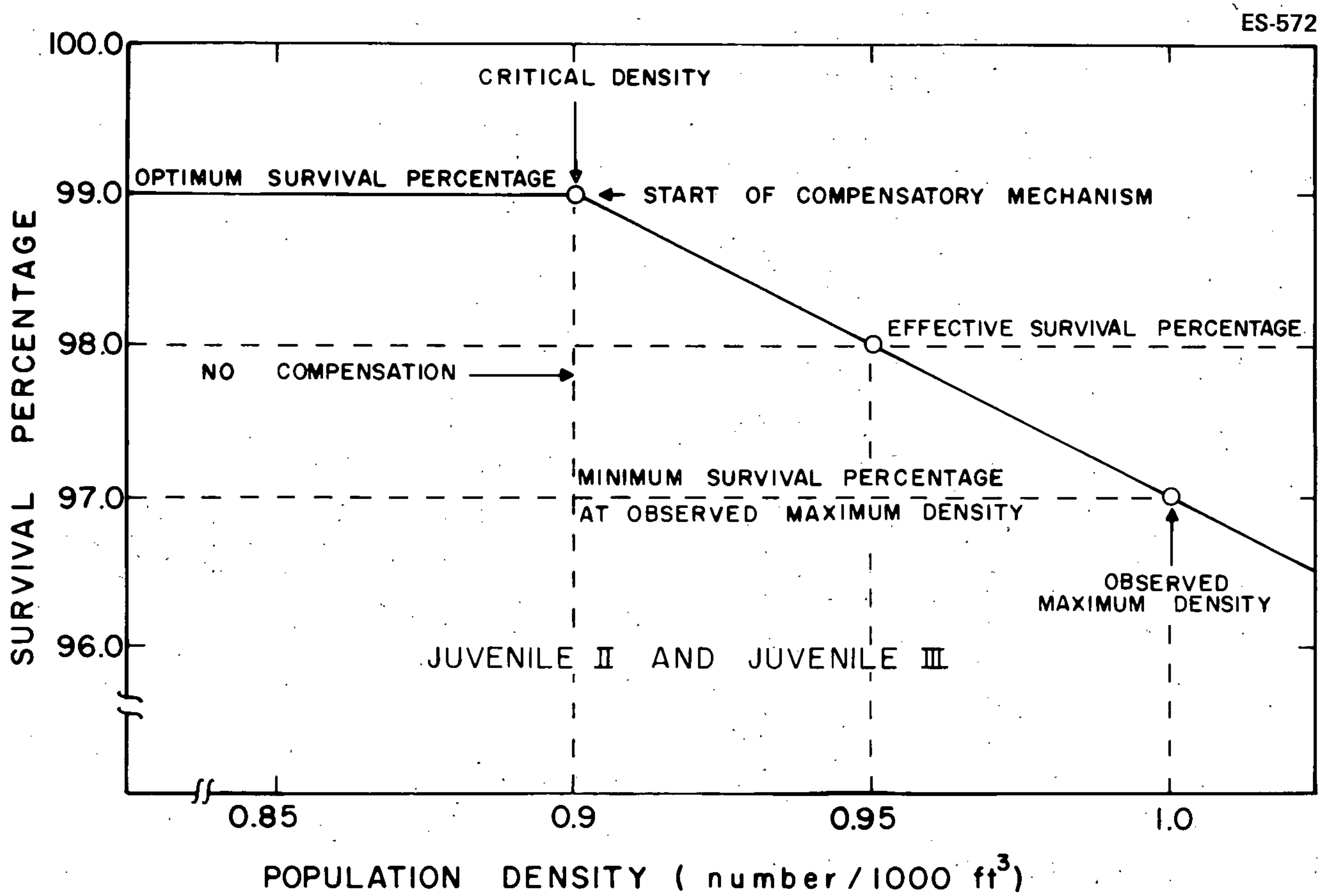

Fig. B-28. Schematic representation of survival percentage for juvenile II and juvenile III on population density.

The compensatory mechanism in the staff's model is conceptually similar to that used in the applicant's model from age group population-density-dependence considerations, with the basic difference being the linear variation in the staff's model in comparison to the cubic form in the applicant's model. Furthermore, both models consider the concept of optimum conditions (in terms of maximum survival percentages in the staff's model and in terms of minimum decay rates in the applicant's model) for the general behavior of the age group populations.

However, the operational influence of the compensatory mechanism on the age group populations is significantly different in the two models. In the applicant's model, the compensatory mechanism changes the mortality coefficient directly — hence changing the rate of decay of the age group population densities representative of the natural mortality conditions. In comparison to the formulation of the staff's model, this corresponds to simultaneously changing the survival percentage, growth rate, and mortality rate of the age group population. In the applications of the staff's model, the compensatory mechanism independently changes the instantaneous survival percentage of the life stage without directly affecting the growth and mortality rates of the age group populations.

(ii) Dependence of Survival Percentages on Temperature and Salinity Conditions

The general formulation of the staff's computer simulation model also considers the dependence of the percentage survival of the age group populations on the temperature and salinity conditions to simulate the effects of possible occurrences of severe catastrophic events in the river. However, in the applications of the model to the simulation of the 1973 data and for the assessment of the impact of the proposed power plants, this capability of the model was not used in the computations because severe physical conditions in the river were not evident.

(c) Growth Rates of the Age Group Populations

The staff's model considers continuous transfer rates for age group populations from earlier to later life stages rather than considering decaying populations that are transferred to the next life stage at the end of their durations, as does the applicant's model. The staff believes that its formulation is more realistic, because the actual ages of the individuals in any specified life stage can have an age distribution covering a wide range, depending on the time when they spawned and on the time history of physical conditions in the river.

(i) Optimum Growth Rates

In the applications of the staff's model, the optimum growth rate (transfer rate to the next life stage) of an age group population was approximated as the inverse of the minimum duration that the striped bass exists in the life stage. This assumption, together with the proper formulation of the transfer rates in the model, guarantees that, after the transfer into the life stage from the earlier life stage ends, the remaining age group population of the life stage necessarily grows into the next life stage during a period approximately equal to the specified duration of the life stage. In the staff's model the optimum growth rates are employed as hourly rates, based on the approximate durations of the life stages presented in Table B-25.

Table B-25. Life stage durations, optimum growth rates, and minimum mortality rates employed in the staff's model

Life stage	Duration (days)	Optimum growth rate (1 per hour)	Minimum natural mortality rate (1 per hour)
Egg	0 ≃ 2	0.347222×10^{-1}	0.347222×10^{-1}
Yolk-sac larva	3 ≃ 8	0.694444×10^{-2}	0.694444×10^{-2}
Post yolk-sac larva	9 ≃ 30	0.189394×10^{-2}	0.189394×10^{-2}
Juvenile I	31 ≃ 70	0.104166×10^{-2}	0.104166×10^{-2}
Juvenile II	71 ≃ 193	0.338754×10^{-3}	0.338754×10^{-3}
Juvenile III	194 ≃ 365	0.242248×10^{-3}	0.242248×10^{-3}

(ii) Effects of Temperature and Salinity on Growth Rates

The actual durations of the life stages, particularly of the egg life stage, strongly depend on the temperature conditions[36] resulting in slower growth rates early in the summer when the temperatures are below the optimum conditions of 75 to 85°F in the river. Hence, in the staff's model the appropriate correction for the temperature effect was incorporated for eggs to modify the optimum growth rate (based on the inverse of the minimum duration time) as shown in Fig. B-29. The temperature dependence was represented by a linear increase from 50 to 75°F, at which temperature the optimum conditions are reached for the growth rate.

The optimum condition was assumed to exist bwtween 75 and 85°F, followed by a rapid decrease in the rate from 85 to 95°F, at which temperature the growth of the striped bass eggs terminates.

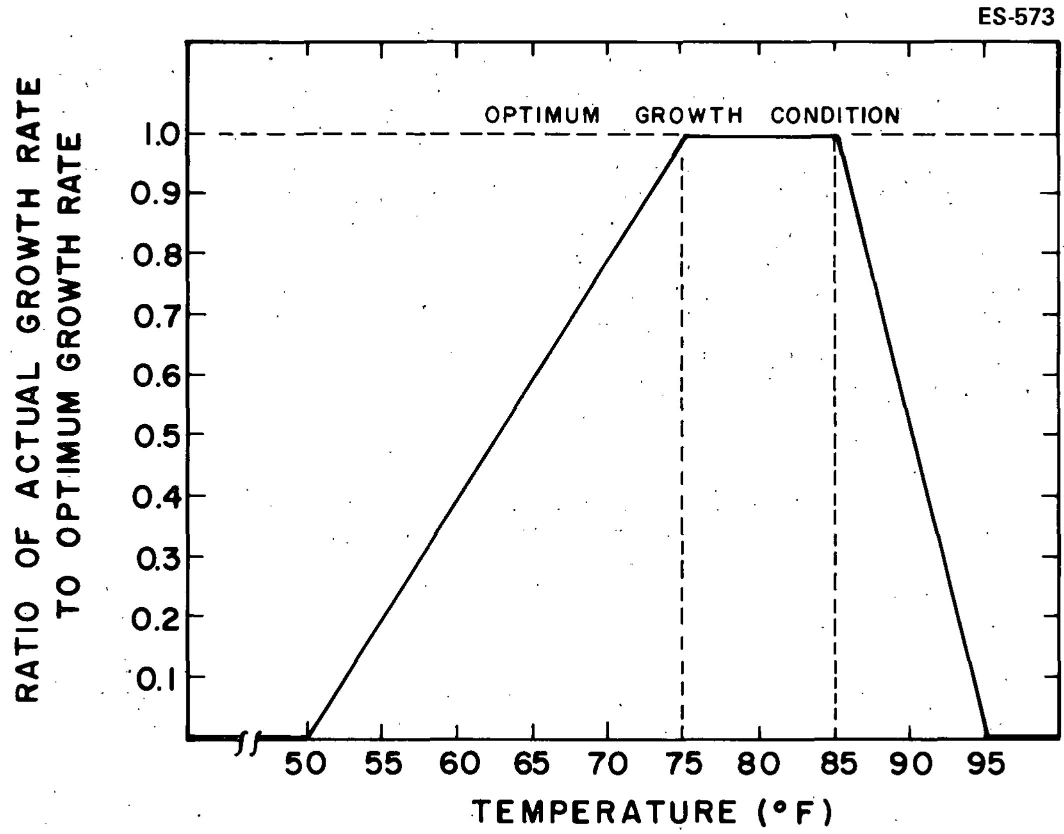

Fig. B-29. Representation of temperature dependence of growth rates for age group populations based on the minimum durations of life stages.

Although the temperature dependence of the growth rate for eggs is well documented,[36] the necessary information for the later life stages is not readily available. Hence, the same functional correction for the temperature effect as shown in Fig. B-29 was employed for all life stages in the staff's model.

The growth rates of age group populations can also depend on the local salinity conditions in the river. Hence, the staff's model was formulated with the capability for incorporating the dependence of the growth rates on salinity as functional relations similar to those used for the temperature effects. However, because the necessary data are not available, the salinity dependence option was not employed in the applications of the staff's model to the simulation of the 1973 data.

(d) Mortality Rates of the Age Group Populations

In the conceptual formulation of the staff's model, the percentage of an age group population that does not survive to grow into the next life stage must necessarily die out of the system after a certain period of existence. Hence, in a manner similar to the treatment of growth rates, the model also considers appropriate continuous, natural mortality rates for the life stages.

(i) Minimum Natural Mortality Rates

The minimum natural mortality rate of an age group population is defined as the inverse of the minimum duration that the striped bass exists in that particular life stage under optimum conditions. Hence, in the staff's model the minimum mortality rate is taken as equal to the optimum growth rate for each life stage as shown in Table B-25. This important characteristic of the model is essential in any continuous formulation, because it guarantees that, under optimum conditions, the striped bass populations are retained in a life stage not longer than the minimum duration of the life stage. Hence, the general formulation of the staff's model guarantees that, under optimum conditions, at the end of the duration of a life stage, the age group population of the particular life stage either grows into the next life stage or dies out of the system, depending on the survival percentage of the life stage.

(ii) Effects of Temperature and Salinity on the Mortality Rates

The general formulation of the staff's model also considers the dependence of the natural mortality rates on temperature and salinity. It has the capability to retain the striped bass populations in a life stage longer than the minimum duration of the life stage under non-optimum conditions, or to rapidly decrease the populations under possible catastrophic temperature conditions that might occur in the river. However, these options of the model were not employed in applications to the simulation of the 1973 data and to the assessment of the impact of the proposed power plants.

In summary, the staff's computer simulation model considers three conceptually fundamental terms (i.e., survival percentage, growth rate, and mortality rate) to realistically formulate the continuous progression of striped bass young-of-the-year populations from earlier to later life stages. These three terms can be determined individually, based on the biological characteristics of the life stage and the effects of the physical conditions in the river on these characteristics. Hence, the formulations of the local time rate of change of the age group populations in the staff's model are considerably more plausible and realistic from biological considerations than the first-order, decay-type mortality rates (similar to the ones associated with simple chemical reactions) employed in the applicant's model.

(e) Mobility Characteristic of the Age Group Populations

The later life stages of the striped bass young-of-the-year (Juvenile I, Juvenile II and Juvenile III) exhibit strong mobility characteristics. For example, migration to shoal areas can significantly influence longitudinal distributions, and the ability of juveniles to avoid the intakes reduces the susceptibility of the age group populations to entrainment and impingement at the power plants. The staff's computer simulation model considers these important effects; based on the biological characteristics of the striped bass in various life stages and the tidal flow conditions in the river rather than introducing artificial modifications in the model to simulate the initiation of shoaling and intake avoidance, as does the applicant's model.

Since, contrary to the tidal-average hypothesis of the models, the age group populations actually exist under strong, periodic tidal flow conditions in the estuary, the ultimate longitudinal effect of instinctive migratory behavior necessarily depends on ability to swim against the tidal currents. Similarly, susceptibility to entrainment and impingement also depends on swimming ability against the intake velocities and ability to identify and to avoid the intake structures.

(i) Approximate Maximum Swimming Speed and Sustained Duration

The available information about the swimming characteristics of the striped bass young-of-the-year is based on very limited experimental data[37] concerning the maximum swimming speeds and the fatigue times which were determined by observing different size fish, corresponding to different life stages, under uniform flow conditions generated in a laboratory apparatus.

In the general formulation of the staff's model, the early life stages (eggs, yolk-sac larvae, and post yolk-sac larvae) are assumed to have no mobility characteristics. Hence, these age-group populations are assumed to have no migratory influence on their longitudinal motions in the estuary and no ability to avoid the intakes. Based on the available data,[37] approximate mobility characteristics were assigned to the later life stages (Juvenile I, Juvenile II, and Juvenile III) as listed in Table B-26. These characteristics were then used for the modeling of the significantly important behavioral characteristics, such as migrations to shoal areas, which control the longitudinal distributions, and the intake avoidance capabilities, which determine the entrainment and impingement impact of the power plants.

Table B-26. Approximate data employed in the staff's model for the mobility characteristics of life stage age group populations

Life stage	Maximum swimming speed (fps)	Sustained duration (hour)	Intake avoidance parameter	Shoaling effect parameter	Crowding effect parameter
Juvenile I	0.50	2.00	0.20	0.4	0.2
Juvenile II	1.00	4.00	0.80	0.4	0.2
Juvenile III	1.00	6.00	1.00	0.4	0.2

It must be emphasized that the parameters employed in the staff's model to simulate the effects of swimming ability of the striped bass young-of-the-year cannot be considered as completely accurate representations of the actual mobility characteristics of these later life stages. However, despite the uncertainties in the river sampling data as well as the inaccuracies of other parts of the general model, the results of the simulation (discussed later) indicate that this approximate treatment is indeed sufficiently accurate to achieve simulation of the shoaling conditions that control the longitudinal distributions of the juvenile life stages in the estuary.

(ii) <u>Effects of Temperature and Salinity on Mobility Characteristics</u>

The available data[38] on the number of fish impinged on the screens at the intakes at Indian Point indicate that impingement is related to the local temperature and salinity conditions in the estuary. Hence, to incorporate the temperature and salinity effects, the approximate maximum swimming speed values used in the model for the life stages (Table B-26) were modified by temperature and salinity correction factors in the staff's model.

A schematic representation of the temperature dependence factor employed in the staff's model for the modification of the maximum swimming speeds of the juvenile life stages of the striped bass young-of-the-year is shown in Fig. B-30. Below 30°F, the fish is assumed to have no swimming ability; the swimming speed increases

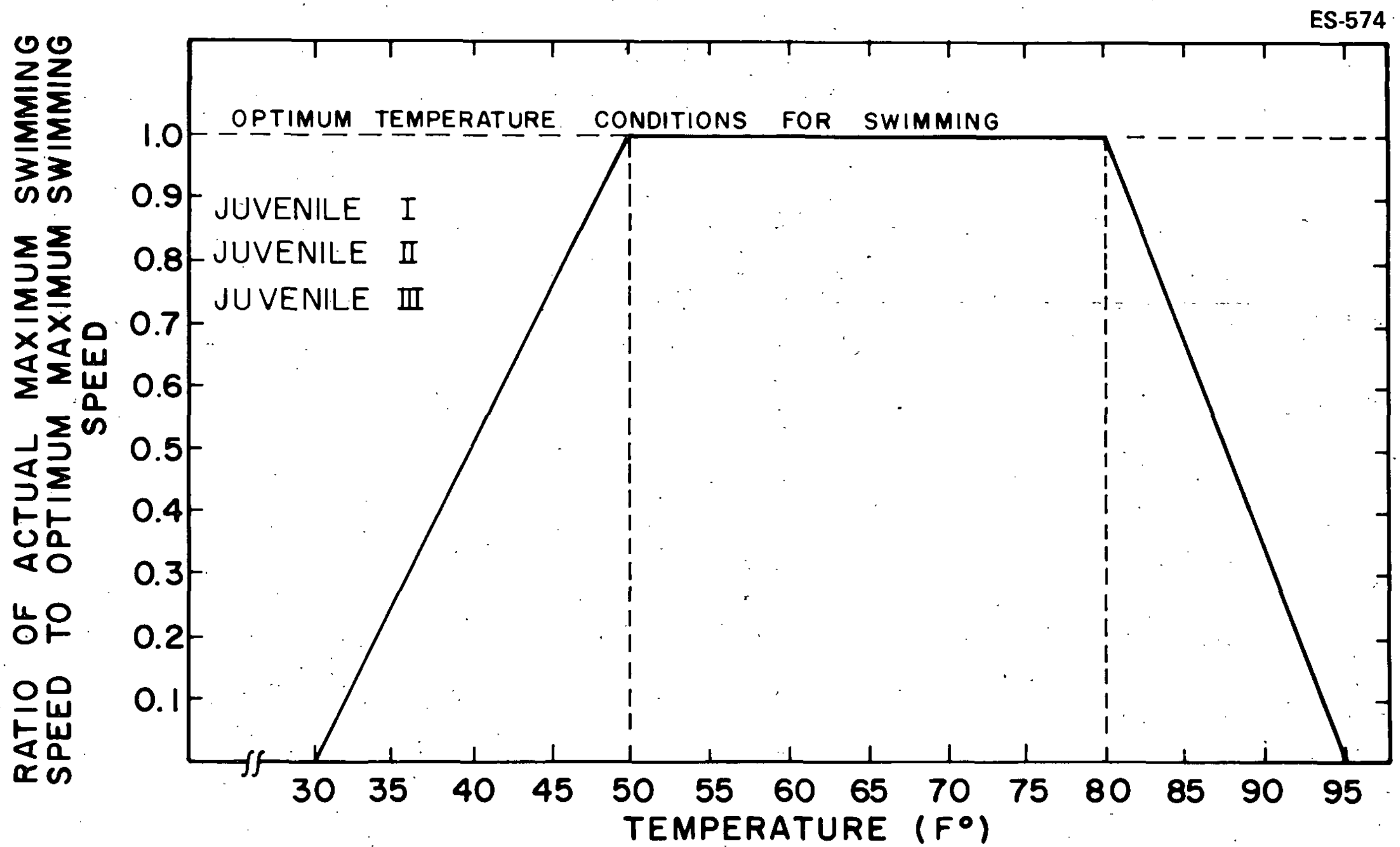

Fig. B-30. Representation of temperature dependence of the maximum swimming speeds of juvenile life stages in the staff's model.

linearly between 30 and 50°F, at which temperature it reaches the maximum speed. Swimming speed remains maximum until 70°F and then decreases linearly to zero between 70 and 90°F. The fish are assumed to lose their swimming ability completely at and above 90°F. The assumed form of the temperature dependence is sufficiently accurate to simulate higher impingement rates at the intakes during cold winter conditions in the river.

Schematic representation of the salinity dependence factor employed in the staff's model for the modification of the maximum swimming speeds of the juvenile life stages is shown in Fig. B-31. The maximum swimming speed is assumed to be unaffected by salinity for conditions below 0.15 and above 4.0 ppt in the river. The swimming ability of the fish decreases linearly between 0.15 and 1.0 ppt when the fish ceases to exhibit any migratory motion until salinity reaches 3.0 ppt; and it increases linearly between 3.0 and 4.0 ppt, at which point salinity no longer has an effect on the mobility characteristics.

The salinity dependence of the maximum swimming speed of the juvenile stages does not imply that the fish undergo physiological changes over this salinity range. The salinity dependence in the staff's model is rather employed in a more general ecological sense to simulate other phenomena (e.g., concentration of juveniles near the salt front) that are not well understood but that appear to affect impingement.

In summary, the staff's model realistically employs the swimming abilities of the juvenile striped bass life stages in formulations that enable the simulation of the important effects of shoaling behavior, that control the longitudinal distributions of these age group populations and plant avoidance ability, that affects impingement at the power plants.

(f) Migratory Behavioral Characteristics of the Age Group Populations

In addition to movement with the longitudinal convective motion due to the net freshwater flow along the estuary, it is established that some striped bass young-of-the-year life stages also exhibit various kinds of migratory behavior in all directions in the estuary.

(i) Diurnal Vertical Migratory Motions of Early Life Stage Age Group Populations

For yolk-sac larva and young juveniles, diurnal variations in densities in the ichthyoplankton samples taken at different depths

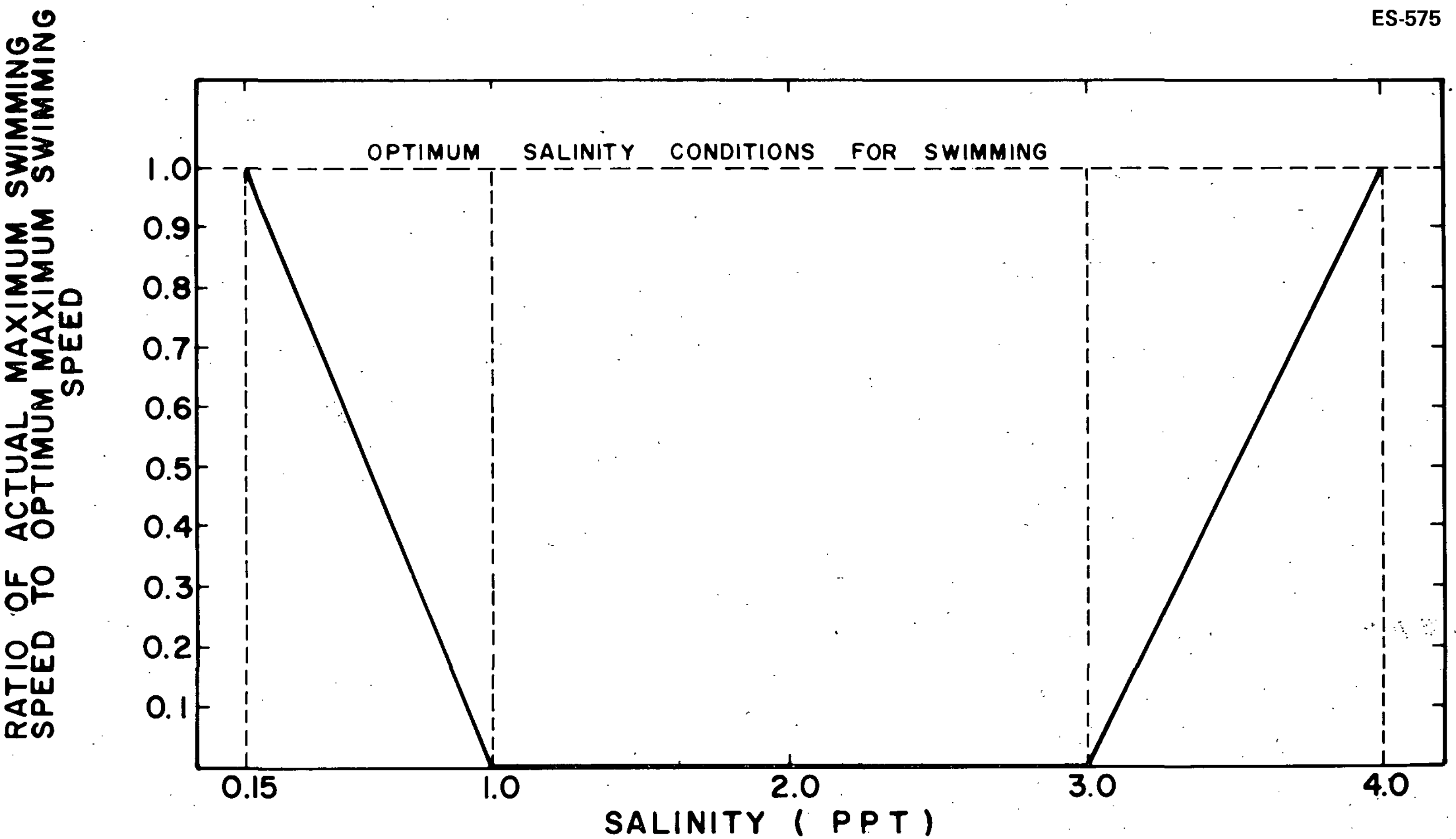

Fig. B-31. Representation of salinity dependence of the maximum swimming speeds of juvenile life stages in the staff's model.

have been observed, with higher concentrations found in samples taken near the surface during the night, and relatively higher concentrations found near the bottom during the day.[39] These indications of diurnal vertical migratory motions can be attributed to numerous potential physical, behavioral, and ecological factors, such as responses to light, flow conditions, and avoidance of predators, as well as to sampling gear avoidance, which can result in low catches in upper strata during daylight hours (see Chapter V).

Although, in the general formulation of the staff's model, provisions have been made to incorporate this behavior, in the applications of the model to the simulation of the 1973 data and to the assessments of the power plant impacts, the effects of vertical migration on the ultimate longitudinal transfer of the age group populations were not included. Because it is established that the vertical migratory motions are diurnal, the distributional effects are approximately evenly divided between the ebb and flood stages of the 12.4-hr semi-diurnal tidal flow in the estuary. Hence, a significant convective, defect-type, longitudinal transport, resulting from the changes in vertical distributions and the turbulent velocity profiles of the tidal flow conditions, cannot be expected. Furthermore, because considerably higher population densities are apparent near the bottom at most times, and the vertical migratory motions only partially alter these predominant distributions, the net convective defect transport, resulting from tidal and daily averaged distributional conditions, would be significantly greater than any possible transport due to the vertical motions. Hence, it is realistic to not include the effects of vertical migrations in the modeling of the longitudinal motions of the age group populations in the estuary.

(ii) Migrations of Juvenile Age Group Populations to Shoal Areas

The migration of the juvenile life stages into shoal areas is extremely important from modeling considerations, because this behavioral characteristic almost completely dominates the longitudinal distributions of the later juvenile age group populations. The applicant's model and the previous staff's model employed artificially introduced distributional variations, based on observed data, to simulate this effect in their formulations. However, although both models assigned plausible shoaling values to various regions in the estuary to simulate the lateral and longitudinal migration of the juveniles, they did not quantitatively identify the fundamentals of these behavioral characteristics, which can vary significantly with different population levels during different years and with different environmental effects of the power plants.

In the present computer simulation model, the ultimate longitudinal migration effect of the juvenile age group populations is formulated according to the phenomenological concept of the "potential law of migration." The migratory behavior is assumed to be influenced by the longitudinal variations (gradients) of (a) the availability of shoaling areas and (b) the crowding conditions along the estuary.

It is realized that, regardless of the continuous, downstream net freshwater flow convection hypothesis of the tidal-averaged models, the age group populations in reality can move considerable distances up and down the estuary due to the tidal excursion. Hence, in a sense, they have the ability to survey the availability of shoaling areas and the population density conditions at different locations along the estuary without expending significant effort. Consequently, if a juvenile age group population has the physiological ability to resist the tidal flow currents, they can then select an "optimum" shoal area within the tidal excursion range, in which to stay until the crowding conditions reach a level such that the food availability in the area becomes low enough to stimulate the juveniles to seek another shoal area along the estuary. Hence, in the staff's model, two dimensionless potentials were formulated to describe the longitudinal migrations of the juvenile age group populations from one element to an adjacent element along the estuary.

Potential Resulting from the Availability of Shoal Areas

This potential is based on the shoal parameter value, which represents the availability of the shoal areas along the estuary as determined from the geometrical characteristics of the cross sections of the estuary bed (see Section B.4.b(1)(a) above). It is implemented in the following form: Shoaling Potential for Migration from an Element to the Adjacent Element = [(Shoal Parameter Value in the Adjacent Element) - (Shoal Parameter Value in the Element)]/(Average Value of the Shoal Parameter for the Two Elements).

Negative Potential Resulting from Crowding Conditions

This potential is based on the juvenile age group population densities in two adjacent elements along the estuary. It is implemented in the following form:

Crowding Potential for Migration from an Element to the Adjacent Element = [(Population Density in the Element) - (Population Density in the Adjacent Element)]/(Average Population Density for the Two Elements).

This migratory behavior model for the juvenile age group populations, although novel from biological modeling considerations, is conceptually similar to well-established phenomenological transport models developed in the context of the physical sciences. The mathematical details of the model are discussed in detail in Ref. 23.

It is realized that the acceptability of a mathematical model is ultimately judged by the pragmatic test of its ability to simulate the actual observed conditions in the estuary. In the applications of the staff's model to the simulation of the 1973 data, the computed results for the juvenile life-stage age group populations were shown to agree very well with the observed distributions along the estuary, both from qualitative and quantitative considerations of the observed occurrence of high population densities in the expected shoal areas.

(3) Plant Conditions

Since the staff's model considers 2-mile-long discrete elements in the segmentation of the estuary, the intake and discharge locations were considered separately in the general formulation, because a plant's intake and its discharge could possibly be located in different segments.

The reduction rates of the age group populations by the power plants are formulated in two parts. According to the population densities of the age groups at the intakes and the specified plant flow rates, the removal rates of the populations from the elements that contain the intakes are determined. Based on the survival percentages of the life stages as they pass through the plant system, the intake population densities are reduced to obtain the population densities at the discharges. The replenishment rates of the populations are determined according to the discharge densities and plant flow rates in the elements containing the discharges. Hence, the staff's model has the capability for simulating the removal and replenishment of age group populations by the power plants at different locations along the river, depending on the locations of the intake and the discharges.

The physical operational conditions of the power plants are employed as inputs to the model, based on specifications for the existing and proposed units. The susceptibilities to entrainment and impingement and the survival percentages of the age group populations as they pass through the plant systems are determined according to the operational conditions of the power plants and the biological characteristics of the life stages.

(a) Operational Conditions of the Power Plants

In the applications of the staff's model to the simulation of the 1973 data and to the assessment of the impact of entrainment and impingement losses, 13 different cases involving combinations of existing and proposed power plants on the Hudson River, were considered. The operational conditions of these power plants and the values for various parameters employed in the modeling of entrainment and impingement losses are presented in Table B-27. In certain cases combinations of plant units were separated to enable predictions of damage associated with various scenarios (see Chapter XI) that needed to be considered in the overall assessment of power plant impact on the river.

For Indian Point Units Nos. 2 and 3, both once-through and closed-cycle cooling cases were considered by changing the plant flow rates and through plant mortality as shown in Table B-27.

The geometrical factors for the intakes and discharges of the power plants listed in Table B-27 are employed in the model to incorporate special geometric characteristics of the cooling system which might affect the population densities at the intakes and at the discharges. The intake factors were assumed as unity for all power plants, indicating no change in intake densities due to the geometries of the structures. The discharge geometry factors were used to adjust for special characteristics of the cooling systems. They were assumed as unity for all once-through cooling cases, indicating no additional reduction in survival because of the cooling system. Mortality due to once-through systems was taken into account, using plant survival factors discussed below [(Section B.4.c(3)(b)(iii)]. For closed-cycle cases, the discharge geometry factors were specified as zeros to represent total destruction by entrainment due to combined thermal, mechanical, and chemical stresses.

(b) Biological Conditions for Entrainment and Impingement Rates

The staff's computational model determines the population reduction rates due to entrainment and impingement at the power plants based on the physical operational conditions of the power plants and the biological characteristics of the striped bass young-of-the-year life stages in the estuary and in the power plant cooling water flow systems. The various factors considered in the formulations are conceptually similar to the f factors employed in the applicant's model.

Table B-27. Hudson River power plant operating data

Power plant	Unit No.	Location, mile point above Battery	In-service date	Capacity (MWe)	Intake flow rate (cfs)	Plant temperature rise (F°)	Plant thermal discharge (billion Btu/hr)	Intake velocity (fps)	Plant intake geometry factor	Plant discharge geometry factor
Albany		140		400	784	11.0	1.917		1.0	1.0
Danskammer	1	66	1951	64	89	14.5	2.250	2.5	1.0	1.0
	2		1954	64	89					
	3		1959	127	231					
	4		1967	253	277					
Roseton	1	65.4	1974	600	724	15.4	5.000	0.75	1.0	1.0
	2		1974	600	724					
Indian Point	1	43	1962	265	709	15.3	15.755	0.67	1.0	1.0
	2		1973	873	1938[a]			0.90		a
	3		1975	1033	1938[b]			0.90		b
Lovett	1	42	1949	22	32	14.8	2.375	0.77	1.0	1.0
	2		1951	22	32			0.77		
	3		1955	72	103			0.73		
	4		1966	184	263			1.6		
	5		1969	203	290			1.6		
Bowline	1	37.5	1972	620	855.5	13.5	5.167	0.5	1.0	1.0
	2		1974	620	855.5					
59th Street		5		221	374	6.0	0.500		1.0	1.0

[a] With closed-cycle cooling, the intake flow rate is 125 cfs and the discharge geometry factor is 0.0.
[b] With closed-cycle cooling, the intake flow rate is 135 cfs and the discharge geometry factor is 0.0.

(i) Intake Density Ratio (f_I)

Because the staff's model is spatially one-dimensional along the estuary, it can only simulate longitudinal variations in age group population densities. This simplifying hypothesis is common to all existing models employed in the assessment of the biological impact of the power plants on the Hudson River. Hence, the model cannot predict vertical and lateral variations in the distribution of organisms in the estuary.

Considering that the intake structures are located at the shores of the river, it is quite conceivable that the population densities in the water entering the intakes are different than the tidal-averaged mean age group population densities in the elements containing the intakes. These averaged densities are computed by the model to simulate the conditions estimated from the 1973 sampling program. To incorporate the possible difference between the intake population density and the mean population density in the discrete element that contains the intake, the staff's model employs a single intake density ratio factor (f_I) for each life stage, defined as:

$$\text{Intake Density Ratio } (f_I) = \frac{\text{Population Density in the Intake Water}}{\text{Mean Population Density in the Intake Element}}$$

This ratio corresponds to the product $f_1 \cdot f_2 \cdot f_3$ employed in the applicant's model.

The f_I values can only be determined by additional information about the vertical and lateral distributions of the age group population densities in the vicinity of the power plant intake. It should be emphasized that, if reliable information about the vertical and lateral distributions is not available, considerations of consistency in modeling dictate that the intake density ratio must be assumed as unity, because this value represents the correct theoretical one corresponding to the least prejudiced estimate in any one-dimensional formulation.

In the applicant's model, f_1, f_2, and f_3 factors are evaluated from available data concerning the vertical and lateral variations of each age group population. However, a recent f factor analysis by QLM, a consultant to the applicant,[18] which leads to extremely small values for the intake density ratios for various plants on the river, has not been accepted by the staff. As discussed in Section V.D.2.b(2)(3) and Appendix B, Section B.3, the possible inaccuracies in sampling and the conceptual error involved in using river transect data to supplant segment data (which is inconsistent with the modeling hypothesis) lead to the conclusion that the intake density ratio f_I values obtained by QLM may be significantly low.

Before elaborating further on the appropriate choice of values for the intake density ratio parameter, it is instructive to consider the effect of this parameter on the ultimate estimate of entrainment and impingement impact on the striped bass young-of-the-year populations in the estuary. To illustrate the dependence of the predicted impact on this parameter, the staff's model was applied to the hypothetical case of Indian Point Units Nos. 1, 2, and 3 alone with once-through cooling. The impact of plant operation was represented by a percentage reduction ratio (to be discussed later), based on the total standing crops of young-of-the-year without and with plant operation. The simulation results were obtained for different values of the f_I parameter in the range 0 to 2.0. A percent reduction ratio was defined as:

$$\text{Percent Reduction Ratio} = \frac{\text{Percent Reduction with a Given Intake Density Ratio Factor } f_I}{\text{Percent Reduction Ratio with } f_I \text{ of Unity}}$$

The variation of the percent reduction ratio with the intake density ratio factor is presented in Fig. B-32 for the 1973 flow conditions and for two different cases representing low and high values for the effective survival percentages of the age group populations. The results in Fig. B-32 clearly indicate that the relationship between the plant impact and the intake density ratio factor is a nonlinear one as might be expected. For f_I values below 0.3, as shown in Fig. B-32, the slope of the curve is greater than 1.0, and the actual percent reduction will increase rapidly with f_I in this range. Conversely, for f_I values greater than 0.3, the actual percent reduction will vary at a lower rate with increase in the value of f_I.

The general functional relation represented in Fig. B-32 remains approximately constant under wide ranges of transport conditions, power plant operating conditions, and age group population distributions in the estuary.[23] Hence, the indicated relationship between the percent reduction ratio and the intake density ratio f_I can be universally applied for the interpolation and/or extrapolation of percent reduction ratios associated with various f_I values from the results obtained for a single f_I value.

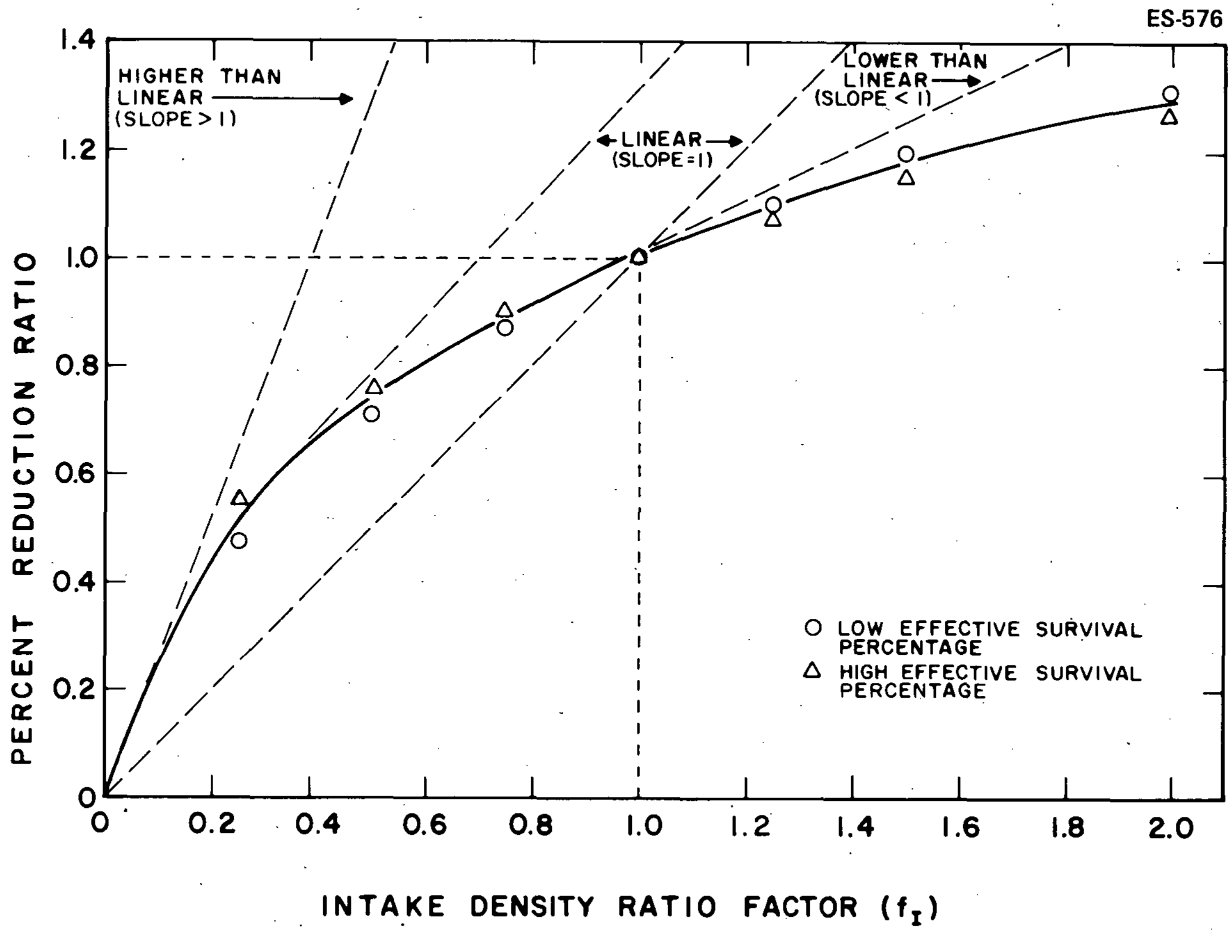

Fig. B-32. Dependence of percent reduction by plant operation on intake density ratio.

As stated earlier, in the opinion of the staff, the available data about the vertical and lateral variations of the various age group populations in the river do not justify the selection of the extremely low values[18] for f_I obtained recently by the applicant. However, there exists strong indirect evidence that the intake density ratios are indeed less than unity at the power plants. This evidence is based on the data for the longitudinal distributions of the age group populations and the results from the staff's model in simulating the 1973 conditions, as described in the following paragraph.

To achieve reasonable verifications of the staff's model based on 1973 data, it was necessary to use relatively high values of the convective defect transport factor (to be discussed later) for the early life stages (eggs, yolk-sac larvae, and post yolk-sac larvae), indicating that significant vertical and/or lateral variations in the distribution of the age group populations do indeed exist in the estuary, with high concentrations occurring near the bottom or near the shores. This results in the retardation of the convective downstream motion of the populations by the net freshwater flow. Hence, from considerations of consistency in modeling as well as from indications in the 1973 data, it is realistic to accept that the f_I values can indeed be, and likely are, less than unity. However, it should be emphasized that due caution must be exercised in the estimation of the values for the intake density ratio, and the above conclusion by no means implies that the extremely low values for the intake f factors suggested recently by the applicant[18] are realistic and acceptable for the assessment of the entrainment and impingement impact.

Although the apparent existence of significant convective defect-type transport indicates that considerable vertical and lateral variations in the distributions of the age group populations must exist, this does not automatically imply that a comparable large reduction from unity must exist for the f_I values. Considering the location of the intakes at the shores, substantial reduction in the f_I values could exist if the variations in age group population densities are predominantly in the vertical direction. Conversely, if the variations are predominantly in the lateral direction, then, in view of the shore locations of the intakes, the f_I values could be considerably greater than unity. However, considering the 1973 data, it is evident that the vertical variations of the early life stages are indeed more pronounced than are the lateral variations, although the Texas Instruments sampling in the shoal areas for these early life stages was very limited prior to August 1973. Nonetheless, it is realistic to assume that the intake density ratios of existing and proposed power plants may be less than 1.0 for eggs, yolk-sac larvae, and early post yolk-sac larvae. However, juveniles (and perhaps late post yolk-sac larvae) are found predominantly in shallow water, and thus, the intake density ratios for these life stages may be greater than unity. An indication of this result is discussed in Section B.3 for juveniles in Bowline Pond.

In the determination of a realistic value for the intake density ratio of a proposed power plant or an additional unit, it is not sufficient to consider only the natural variations of the age group distributions in the river in the absence of flow through the plant at the time intake and river transect samples are being taken. From hydrodynamic considerations, the induced flow conditions in the river due to the intake flow, can alter the observed natural distributions in the river. Furthermore, again from hydrodynamic considerations, the influence of the intake flow is not necessarily restricted to a region near the surface and in the immediate vicinity of the intake; indeed, the intake water to a power plant can be drawn from considerable distances from the intake and from various depths depending on the geometry of the riverbed and the tidal flow conditions in the vicinity of the power plant. Hence, for example, the values for f_1 and f_2 suggested by the applicant for Cornwall, based on the distributional data without the operation of the proposed unit, may not be realistic for the assessment of the impact of Cornwall.

In summary, the 1973 data for the pre-juvenile life stages indirectly indicate that the intake density ratios employed in the tidal-averaged, one-dimensional models, must have values less than unity based on the necessity to incorporate strong, convective, defect-type transport in the applications of these models to simulate the observed longitudinal distributions. However, in view of the lateral distributional effects, the hydrodynamic conditions that may be induced by the intake flows and the sampling difficulties discussed in Section V.D.2.b(2)(e), the staff's opinion is that the intake density ratio (f_I) is most likely between 0.5 and 1.0.

(ii) Intake Avoidance Factor

The staff's model considers the intake avoidance capabilities of the age group populations based on their mobility characteristics. For the juvenile life stages, appropriate intake avoidance factors are incorporated in the formulation of the model to simulate the avoidance effects, based on the ratios of the maximum swimming speeds of the age group to the intake speeds. This type of modeling realistically predicts the increase in impingement during cold winter periods and under certain critical salinity conditions as observed in the estuary. The values for the intake avoidance factor used in the applications of the staff's model are presented in Table B-28.

Table B-28. Intake avoidance factor and optimum plant survival percentage values employed in the staff's model

Life stage	Intake avoidance factor	Optimum plant survival percentage
Egg	0.00	0.20
Yolk-sac larva	0.00	0.20
Post yolk-sac larva	0.00	0.20
Juvenile I	0.20	0.00
Juvenile II	0.80	0.00
Juvenile III	1.00	0.00

(iii) Plant Survival Conditions

The reductions in the age group population densities, as they pass through the power plant system, are based on the plant percentage survival factors for the life stages. This factor represents the mean survival probability of a striped bass young-of-the-year life stage (based on physiological capabilities) after it is exposed to representative levels of mechanical and thermal stresses that generally occur in passing through the plant. The differences in the overall plant percentage survivals for different plants are readily considered in the general formulation of the model by assigning appropriate values to the intake and discharge geometric factors that incorporate the special design characteristics of the particular plants.

Because the plant survival percentage depends both on mechanical and thermal stresses, it is considered in two parts, as the optimum plant survival percentage without the thermal effects and a multiplicative factor to modify the optimum value for the cases with the thermal effects.

The optimum plant survival percentage values employed in the staff's model are presented in Table B-28. These represent the best estimate values for the optimum survival percentages for the striped bass young-of-the-year life stages based on the discussion given in Chapter V.

The thermal effect on the plant survival percentage is based on the maximum temperature that exists in the plant flow system. For condenser cooling systems, this temperature is calculated as the sum of the intake temperature and the condenser temperature rise for the power plant. The results of various experiments (see Chapter V) indicate that the survival probabilities for the early life stages of striped bass young-of-the-year decrease rapidly for temperatures higher than 85°F. Hence, in the staff's model a multiplicative temperature factor was included to represent the additional damage due to the thermal stresses, as shown in Fig. B-33. This factor was multiplied by the plant survival percentages for all age group populations, including juveniles.

In summary, the plant conditions can be realistically represented in the staff's model by considering the approximate effects of the vertical and longitudinal distributions of life stage, age group populations in the estuary, the physical operational characteristics of the power plants, and the plant survival percentages of the life stages as they pass through the plant flow system.

(4) Longitudinal Convection

The actual hydrodynamic conditions in the Hudson River are dominated by the semidiurnal tidal flow, even during periods of high net freshwater flow. Consequently, the actual motions of the striped bass young-of-the-year age group populations, and particularly those of the early life stages, are controlled by the tidal flow conditions in the estuary.

Because the staff's present model, similar to the applicant's and staff's earlier models, considers only tidal- and daily-averaged one-dimensional conditions in the river, the formulation of longitudinal convection is necessarily based on the net freshwater flow in the estuary. Hence, for each discrete element of the model, the convective transfer rates for the life stage, age group populations in and out of the element are formulated according to the freshwater flow rates across the upstream and downstream enclosure surfaces of the discrete elements.[23]

(5) Longitudinal Transport

According to the fundamental hypothesis of the tidal- and daily-averaged one-dimensional models, excluding the freshwater convective transfer, the totality of the remaining effects that could result in the displacement of the age group populations in the estuary must be incorporated into the general formulation of the overall longitudinal transport phenomenon. In the staff's computer simulation model, three of these other fundamental effects that control

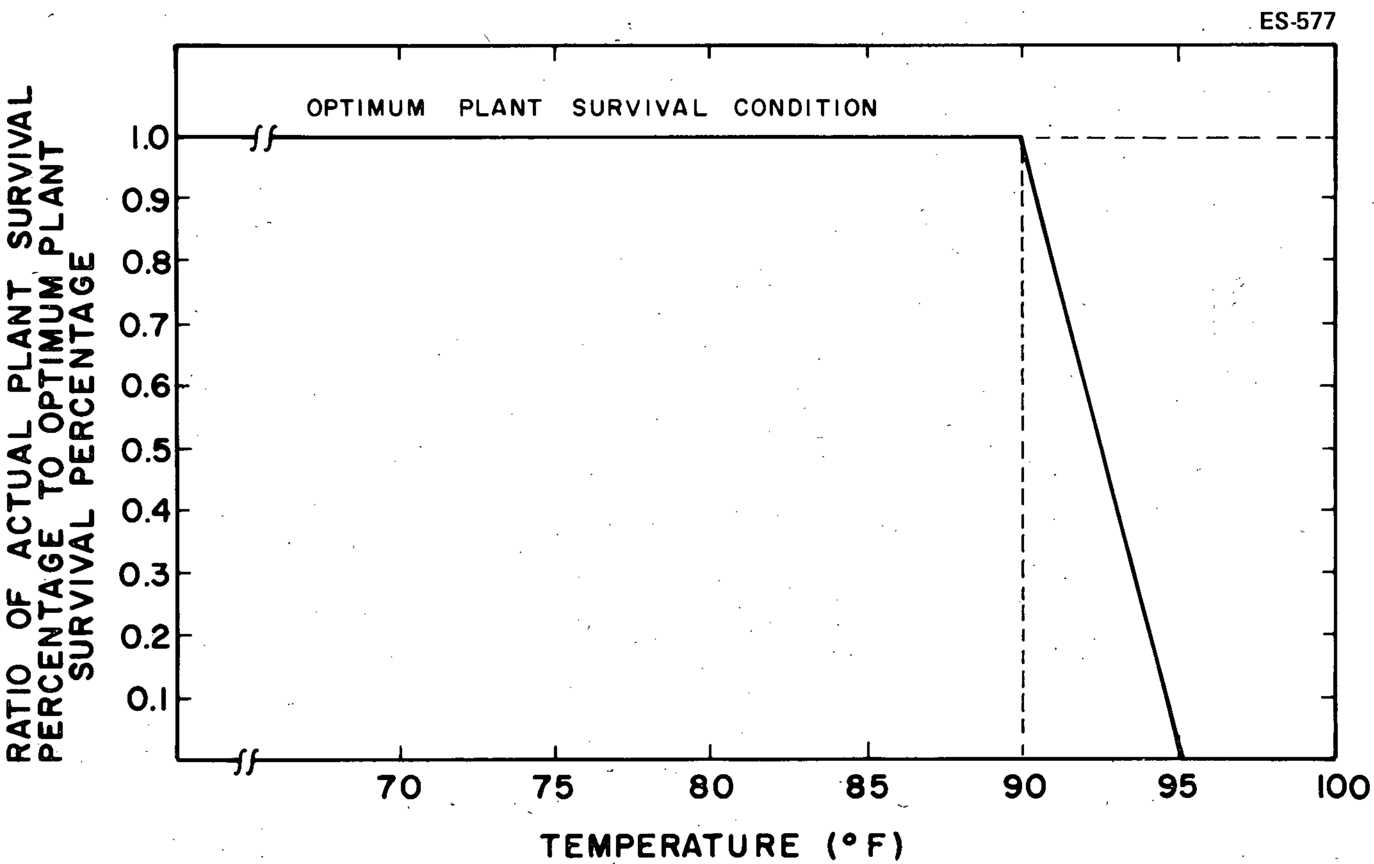

Fig. B-33. Multiplicative factor employed in staff's model for incorporating thermal effects in plant survival percentage calculations.

the longitudinal transport are individually formulated, based on (a) the tidal flow conditions, (b) vertical and lateral variations in the distributions, and (c) the migratory behaviors of the older age group populations in the estuary.

(a) Tidal Dispersion Transport

The averaging of the semidiurnal tidal conditions in an estuary over the tidal cycle results in a longitudinal mixing-type transport for passive organisms. This well-established phenomenon[40,41] occurs due to the velocity profiles and the vertical turbulent eddy diffusion in the estuary. For the early life stages (eggs, yolk-sac larvae, and post yolk-sac larvae), the tidal dispersion effect contributes considerably to the overall longitudinal transport, because these age group populations behave as passive organisms in the flow regimes of the estuary. The tidal dispersion effect is formulated in the staff's model according to Bowden's[42] analysis based on a constant dispersion coefficient value of 0.6, a maximum local tidal speed, and local depth.

The formulation of tidal dispersion transport employed in the applicant's model is based on a longitudinally varying dispersion coefficient that was previously determined for the modeling of the salinity intrusion phenomenon in the Hudson River. The use of the applicant's salinity dispersion coefficient results in longitudinal transport fluxes that are approximately an order of magnitude higher than the ones computed according to the staff's model near the downstream end of the estuary. It should be realized that the salinity intrusion dispersion coefficient is strictly limited to salinity intrusion in the Hudson River, because it includes the totality of stratification effects, two-layer conditions, and the timewise, discontinuous, semidiurnal ocean salinity conditions in an imbedded form in its definition.

The striped bass young-of-the-year age group populations in the estuary do not behave like salt concentrations. Although there exists evidence[38] that the longitudinal distributions of various later age group populations depend on the location of the salt front, the three dominant phenomena which are essential for the justification of the high salinity dispersion coefficient values (stratification, two-layer conditions, and discontinuous ocean salinity variations) do not have similar counterparts associated with the striped bass young-of-the-year populations. Hence, one must conclude that the tidal dispersion transport model employed in the applicant's analysis is not correct for the representation of the tidal transport phenomenon for the age group populations. However, it should also be pointed out that the inappropriate values of the dispersion coefficient used may not introduce significant error in the results of the applicant's model. Because the salinity intrusion dispersion coefficient starts at the correct tidal dispersion coefficient value at large distances upstream of the Battery and reaches the high values only in the vicinity of the Battery, the fact that the early age group population distributions are concentrated at large distances from the Battery produces the result that the effective values of the salinity intrusion dispersion coefficients, used in the evaluation of the transport fluxes, do not deviate significantly from the correct tidal dispersion coefficient values. Furthermore, by the time the striped bass young-of-the-year population reaches the vicinity of the ocean end of the estuary in substantial numbers, the migratory behavior, as shoal preference, of the juveniles dominates the overall longitudinal phenomenon and overcomes the effect introduced by the applicant's parameterization of the tidal dispersion transport. Nevertheless, this error of using high values for the dispersion coefficient could conceivably result in excessive longitudinal spreading of the age group populations along the downstream end of the estuary and could thus cause undesirable discrepancies in the simulation of the actual conditions by the applicant's model.

(b) Convective Defect Transport

Since the convective transfer rates are based on the tidal-averaged and cross-sectional-averaged mean values of the age group population densities, the actual existence of cross-sectional and tidal variations in the population densities and the turbulent velocity profiles along the vertical and lateral directions result in a significant longitudinal transport effect due to the defect in the formulation of the convective transfer rates in a tidal-averaged one-dimensional model. Although the proper formulation of this effect was included in the staff's model to enable the evaluation of the associated transport fluxes based on the observed vertical and lateral distributions of age group populations, this mechanism was not used in applications because of the very limited and inadequate information about such distributions existing in the summarized data. Rather, the overall effect of the vertical and lateral variations in the age group population densities was assumed to result in longitudinal convective defect-type transport fluxes similar to the ones for the net freshwater convective transfer. A negative convective defect factor CDF* was introduced as a parameter for each age group population to be determined from the results of simulation of the 1973 data. The staff's model was applied, with the 1973 physical data and the plant operational conditions in the estuary, in successive runs using values for the CDF of 0.0, 0.9, 0.4, and 0.8 to determine the particular value for this convective defect transport coefficient, which produced the best simulations of the 1973 longitudinal distributions of the age group populations in the river. The results showed that the CDF values of 0.0

*The convective transport defect factor has been abbreviated in the text as CDF or CTDF.

(indicating no convective defect transport) and 0.4 (moderate convective defect transport) caused rapid flushing of the young-of-the-year populations out of the river with poor simulations of the 1973 distributions. The results with 0.8 and 0.9 values for CDF both produced acceptable simulations of the longitudinal age group population distributions within the accuracy bounds of the observed data. The final choice of 0.8 for the value of this parameter for the life stages — egg, yolk-sac larvae, and post yolk-sac larvae — was made because its use produced a slightly better simulation of the weekly averaged values for both the longitudinal distributions and the standing crops for all age group populations in the river for the period of May 1 to October 15, 1973.

Although the 0.4 value for the convective defect factor produced unacceptable simulations, giving lower than observed age group population densities according to the 1973 data, this parameter value was also used for all the investigated cases of power plant impact to illustrate the relative insensitivity to the absolute numbers of the age group populations in the river of the appropriately defined percentage population reduction caused by the power plant.

It should be pointed out that the 0.8 value employed in the staff's model for the convective defect transport factor for all life stages corresponds to the 0.2 value for the "transport avoidance factor" for larvae used in the applicant's model. However, the value of 0.58 used in the applicant's model for the "transport avoidance factor" for eggs approximately corresponds to the 0.4 value of the convective defect transport factor employed in the staff's analysis; hence, the freshwater convection of eggs in the applicant's analysis is considerably higher than the values used in the staff's model. Because the applicant has not presented any simulations of the 1973 data using the stated values of the particular parameter, it would be speculative at this time to elaborate on the appropriate values of this parameter for the applicant's model. The staff's application of the model with CDF value of 0.4 indicated that the longitudinal distributions of egg population density did not deviate significantly from the result obtained with the 0.8 value for CDF, because the duration of egg life stage is relatively short in comparison to the duration of the later life stages. However, it must be pointed out that, depending on how one defines the percent population reduction due to the power plants, overemphasis of the convective transfer in the model can cause an appreciable decrease in the value of the percent reduction. This is due to reduced residence times in the vicinity of the plants; hence, this error tends to underestimate the impact due to the entrainment and impingement damage.

(c) Migratory Transport

The later life stages (Juvenile I, Juvenile II, and Juvenile III) of the striped bass young-of-the-year tend to migrate to and remain in shoal areas in the river. Hence, after July, juvenile age group populations start concentrating in Newburgh-Beacon, and particularly in Tappan Zee-Haverstraw Bay regions where ample shoal areas exist for the populations. The available data[39] conclusively indicate that, regardless of the freshwater flow convection and tidal dispersion transport, juvenile populations tend to stay in these areas by resisting the hydrodynamic conditions in the river. Consequently, as a result of their physiological ability to swim and because of their behavioral preference for shoal areas, an additional longitudinal transport effect becomes dominant in controlling the longitudinal distributions of the populations.

The staff's computer simulation model incorporates this effect by means of formulations based on the previously discussed gradient-type laws for shoaling and crowding potentials. The net driving potential for the migration is determined as a linear combination of the two potentials with their associated weighting coefficients (shoaling effect parameter and crowding effect parameter, respectively). The values employed in the applications of the staff's model are presented in Table B-26 for the three juvenile life stages.

The transport rates across the enclosure surfaces of the discrete elements are determined by considering the cross-sectional areas, the net driving potentials, the distances between the elements, tidal excursion length, maximum swimming speeds, and sustained durations of swimming speed ability to resist the tidal flows in the estuary. The details of the formulation of the migratory transport model are presented in Ref. 23. The simulations of the 1973 data by the staff's model, employing the gradient law of migratory transport, resulted in simulated longitudinal distributions of the juvenile age group populations which both qualitatively and quantitatively agreed with the distributions indicated by the beach-seine data. The model was particularly successful in identifying the areas of high population density in the river.

In summary, the formulation of the overall longitudinal transport phenomenon in the staff's model uses the fundamental contributions due to tidal dispersion and convective defect transport (due to vertical and lateral variations in population densities) also considered in the applicant's model. Furthermore, the model realistically simulates the essential phenomenon of migration as an additional transport effect in terms of the geometrical and hydrodynamic conditions of the estuary and the capabilities and behavioral characteristics of the striped bass young-of-the-year populations, without resorting to the artificial redistribution of populations to the shoal areas employed in both the staff's previous model and the applicant's model.

(6) Age Group Population Generation (Transfer) Rates

As discussed earlier, the staff's computer simulation model employs continuous formulations for the transfer of populations between the life stage. Hence, the local age group population generation rate of a life stage is defined as the net effect of the instantaneous survival percentage, continuous growth, and mortality rates that influence the time rate of change of the age group population in a discrete element, excluding the contributions of convection and transport phenomena. It is defined for different life stages as:

Egg Population Generation Rate in the Element
= Egg Deposition Rate in the Element - (Survival Percentage)(Egg Growth Rate in the Element) - (1 - Survival Percentage)(Egg Mortality Rate in the Element)

and for the yolk-sac larva to Juvenile III life stages:

Age Group Population Generation Rate of a Life Stage in an Element
= (Survival Percentage of the Previous Life Stage) (Growth Rate of the Age Group Population of the Previous Life Stage in the Element) - (Survival Percentage of the Life Stage)(Growth Rate of the Age Group Population of the Life Stage in the Element) - (1 - Survival Percentage of the Life Stage)(Mortality Rate of the Age Group Population of the Life Stage in the Element).

The effects of temperature and salinity conditions in the estuary and the dependence of the percentage survival of the age group populations on the local density of the particular life stage (the density-dependent compensatory mechanisms) are incorporated in the evaluations of the egg deposition rate and the growth and mortality rates according to the descriptions presented in Section B.4.b(2) above.

(7) Plant Reduction Rates

The staff's model considers the plant reduction by entrainment and impingement, based on separate considerations of the intake, plant flow system, and discharge conditions according to the following procedure:

1. Age group population densities at the intake of the power plant are determined by multiplying the existing age group population densities in the discrete element that contains the intake by the specified intake density ratios (f_I's) for the life stages.

2. The intake densities thus obtained are multiplied by the intake geometry factor for the power plant to include the possible geometrical effect of the intake configuration.

3. For the existing conditions of temperature and salinity in the discrete element containing the intake, the maximum swimming speeds are calculated for all age group populations. The intake densities are multiplied by the appropriate intake density avoidance factors based on the ratios of the swimming speeds to the intake velocity to determine the reduced values of intake densities due to avoidance for all age group populations.

4. Based on the final values of intake densities obtained in Item 3 and the plant flow rate specified by the operational conditions, the rates of removal of all age group populations from the discrete element containing the intake are determined.

5. Based on the temperature conditions in the element of the intake and specified plant temperature rise, the maximum temperature in the plant flow system is determined. Based on the maximum temperature value and the optimum survival percentages, the adjusted plant survival percentages for all age group populations are calculated. The intake densities obtained in Item 3 are multiplied by the plant survival percentages to determine the discharge densities for all age group populations.

6. The discharge densities obtained in Item 5 are multiplied by the discharge geometry factor for the power plant to determine the final (reduced relative to the intake) values for the age group population densities (of live organisms) at the discrete element containing the discharge.

7. Based on the final values of discharge densities obtained in Item 6 and the plant flow rate specified by the operational conditions, the rates of replenishment of each age group population is determined for the discrete element containing the discharge.

The calculated removal and replenishment rates for the discrete elements containing the intakes and discharges of all the power plants are employed in the general formulation of the staff's model to calculate the age group population distributions in the estuary.

(8) Operational Procedure of the Computer Simulation Model

The staff's computer simulation model is based on the simple number conservation principle for each age group population in each discrete element. The associated computer code of the model systematically computes the following steps for determining the age group population densities in the estuary:

1. Starts the calculations either at the beginning of the spawning period, without any striped bass young-of-the-year in the river; or at any specified time with given initial values for all age group population densities in all the elements.

2. According to the input data, determines the natural physical conditions in each element in the estuary.

3. According to the input plant operational conditions data, corrects the temperature distributions based on the plant temperature rise values.

4. According to the specified biological input parameters, calculates the egg deposition rates in all the elements.

5. According to the specified biological input parameters, calculates the survival percentage, growth, and mortality rates for each age group population in each element.

6. According to the specified net freshwater flow rates and based on the geometric properties of the elements and the age group population densities, calculates the net rates of convective transfer of life stage, age group populations between the adjacent elements.

7. According to the input physical data, employs the local maximum tidal speed and depth values to determine the tidal dispersion coefficients on the enclosure surfaces; and based on the densities at the element surfaces, calculates the net transfer rates of the age group populations due to tidal dispersion between the adjacent elements.

8. According to the specified convective defect transport coefficient and the input physical data, calculates the net transfer rates of the age group populations due to convective defect transport between the adjacent elements.

9. According to the input biological data and the physical data about the estuary, employs the densities and calculates the net transfer rates of the age group populations due to migratory transport between the adjacent elements.

10. According to the methodology in Section B.4.b(7) calculates the net removal rates from the elements containing the intakes and replenishment rates at the elements containing the discharges for the age group populations.

11. Sums all the rates for the life stage, age group populations (calculated in Items 4 to 10) to determine the net time rate of change of each age group population in each element.

12. According to the specified time step of computation, advances the time; and based on the net time rates of change of age group populations (calculated in Item 11), computes the net changes that occurred in each age group population in each element during the time step of the computation period.

13. Adds the net changes (calculated in Item 12) to the populations from the previous time step to determine the new age group populations and the densities in all the elements at the end of the computational period.

14. If the new time values correspond to a new day, prints, stores, or plots the computed age group population densities depending on the output form specified; if the new time value does not correspond to a new day, repeat steps 2 through 13 above.

This outline of the computational model represents an overly simplified presentation of the actual procedure, which is rigorously described in Ref. 23.

Although the staff's model is capable of predicting daily distributions of age group population densities in all 76 elements of the estuary, the detailed results were averaged over weekly periods and groups of five adjacent elements to render the computer simulations consistent with QLM's reduction of the 1973 data.

(9) Definition of Percent Reduction to Represent the Impact of Power Plant Operation

The assessment of the entrainment and impingement impact of a power plant on the striped bass young-of-the-year population in the Hudson River requires careful consideration of the definition of the reduction in populations by the power plant. In the staff's calculations of predicted reductions, the computer simulation model was employed twice for each set of input parameters to predict the populations both without and with the power plant(s), under the same natural physical conditions in the estuary. The computations were extended until October 15, when the juvenile populations were assumed to be sufficiently mature to avoid severe entrainment and impingement at the power plants under normal physical conditions in the estuary. In other words, the major damage to the young-of-the-year populations was assumed to have already occurred before the date by the operational conditions of the power plant(s) under consideration. Although short periods of notable levels of impingement do indeed occur after October 15 (particularly during cold winter conditions), this additional reduction by impingement was not included in the preliminary assessments of the power plant impacts. Furthermore, after October 15, both the 1973 data and the simulations by the staff's model indicated that the migratory transport to shoal areas dominate the longitudinal distributions in the estuary; this minimized the possibility of occurrence of significant changes in the longitudinal distributions due to convection and tidal dispersion in the river.

The net reduction by entrainment and impingement due to power plant operation is defined as the difference (on October 15) between the standing crop (total number of juveniles) for the simulation without the plant and the standing crop for the simulation with the power plant. The staff points out that this number does not necessarily represent the actual physical reduction of organisms at any particular power plant site, because the depletion caused by other existing plants, the possible effects of density-dependent compensatory mechanisms, and, most important, the natural mortality, will affect the number left at any time after the entrainment period has ended. However, although the net reduction depends on the date when it is calculated, the percent reduction will remain relatively constant after the period of entrainment and impingement, provided residual density-dependent effects are not operative.

The definition of the percent reduction also requires careful consideration in the choice of the denominator for the ratio. Significantly different percent reduction values can be calculated dependent on the base conditions chosen for use in the assessments of the impact of the power plants. In the staff's analyses, three fundamental percent reduction definitions were employed: (a) percent reduction based on hypothetical "clean river" conditions, (b) percent reduction based on existing 1973 conditions, and (c) percent reduction based on operation of all units at Bowline, Lovett, and Roseton-Danskammer.

(10) <u>Simulation of the 1973 Striped Bass Data</u>

The staff's model was first employed to simulate QLM's reduction of the 1973 data, which provided longitudinal distributions of the striped bass young-of-the-year age group populations in the Hudson River. The 1973 data was selected for two reasons: (a) the applicant has indicated that the new data was significantly more extensive and reliable than the existing 1967 and 1968 data, (b) the staff's previous model (DES, IP-3, Appendix B, Section 3.6) was already extensively applied to the 1967 and 1968 data.

As discussed in the earlier sections, the appropriate parameter values in the staff's model were determined by the simulations of the 1973 data. The model was first employed without the density-dependent compensatory mechanism to determine the values for the constant effective survival percentages and the convective defect transport factors (CDF) for the life stages which produced the best fit simulations of the 1973 data for the longitudinal distributions of the age group populations in the river. The parameters for the density-dependent compensatory mechanism were determined based on the observed maximum density values of the age group populations according to the 1973 data as discussed in Section B.4.b(2). The computational simulations were repeated with compensatory mechanism operational with the selected parameter values. The operational power plants in 1973 were included in the simulations with intake density ratios of unity for all age group populations. The results of the staff's model (i.e., daily averaged age group population densities in 2-mile long discrete elements) were averaged by week and by 10-mile segment for comparison of the simulations with the distributions of age group populations according to the 1973 data.

Some of the representative cases with successful simulation are presented in Fig. B-34, which shows egg, yolk-sac larvae, post yolk-sac larvae and juvenile (as the sum of Juvenile I's, Juvenile II's, and Juvenile III's) life stage population distributions, respectively. Although reasonable agreement between the simulations and the 1973 data was achieved for the majority of the weekly averaged distributions, it was impossible to attain consistent agreement for all weekly distributions, particularly for the early life stages. Some of the representative cases with unsuccessful simulation are presented in Figs. B-35 and B-36 for the four age group populations.

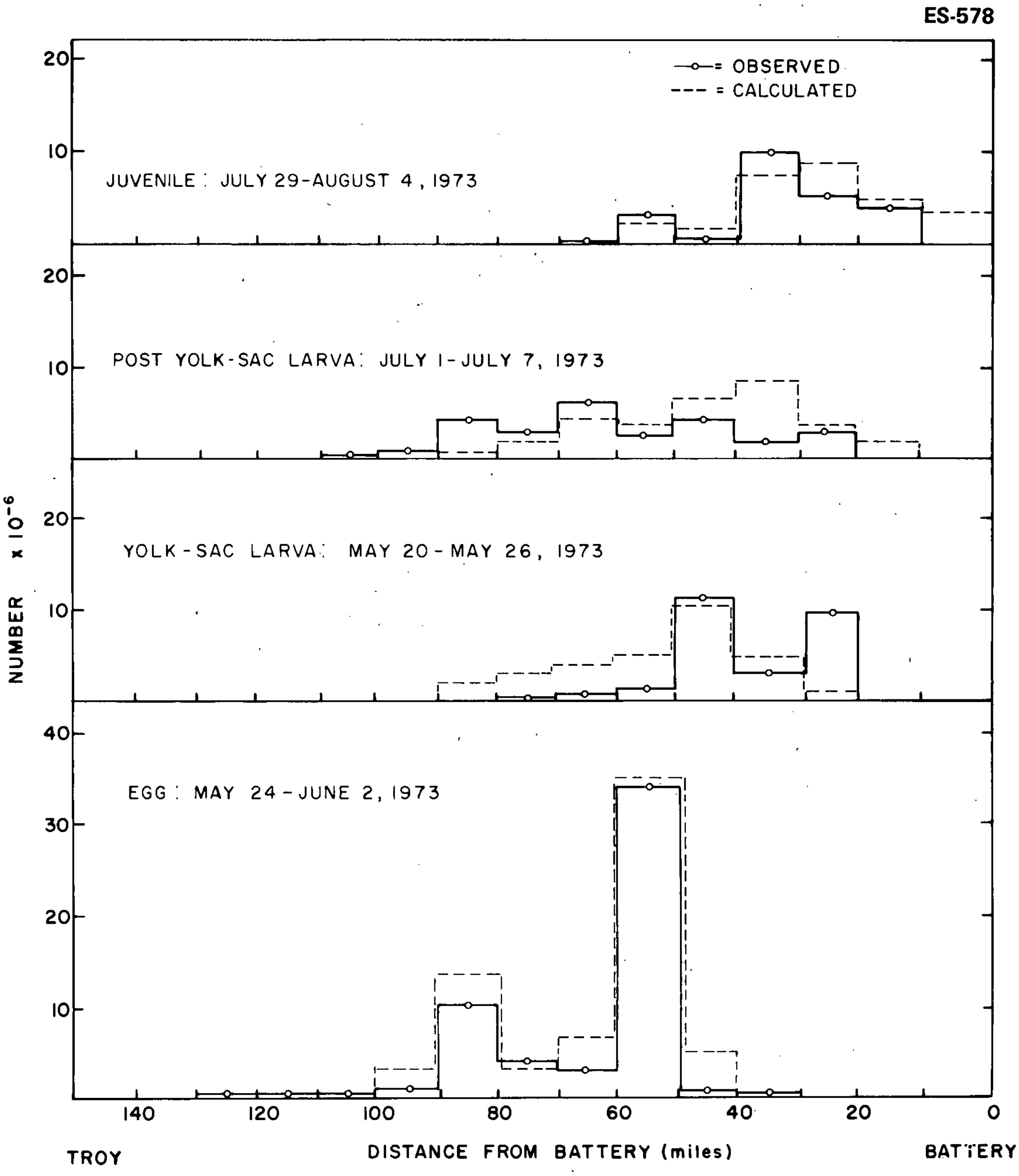

Fig. B-34. Representative good comparison cases for young-of-the-year population distribution.

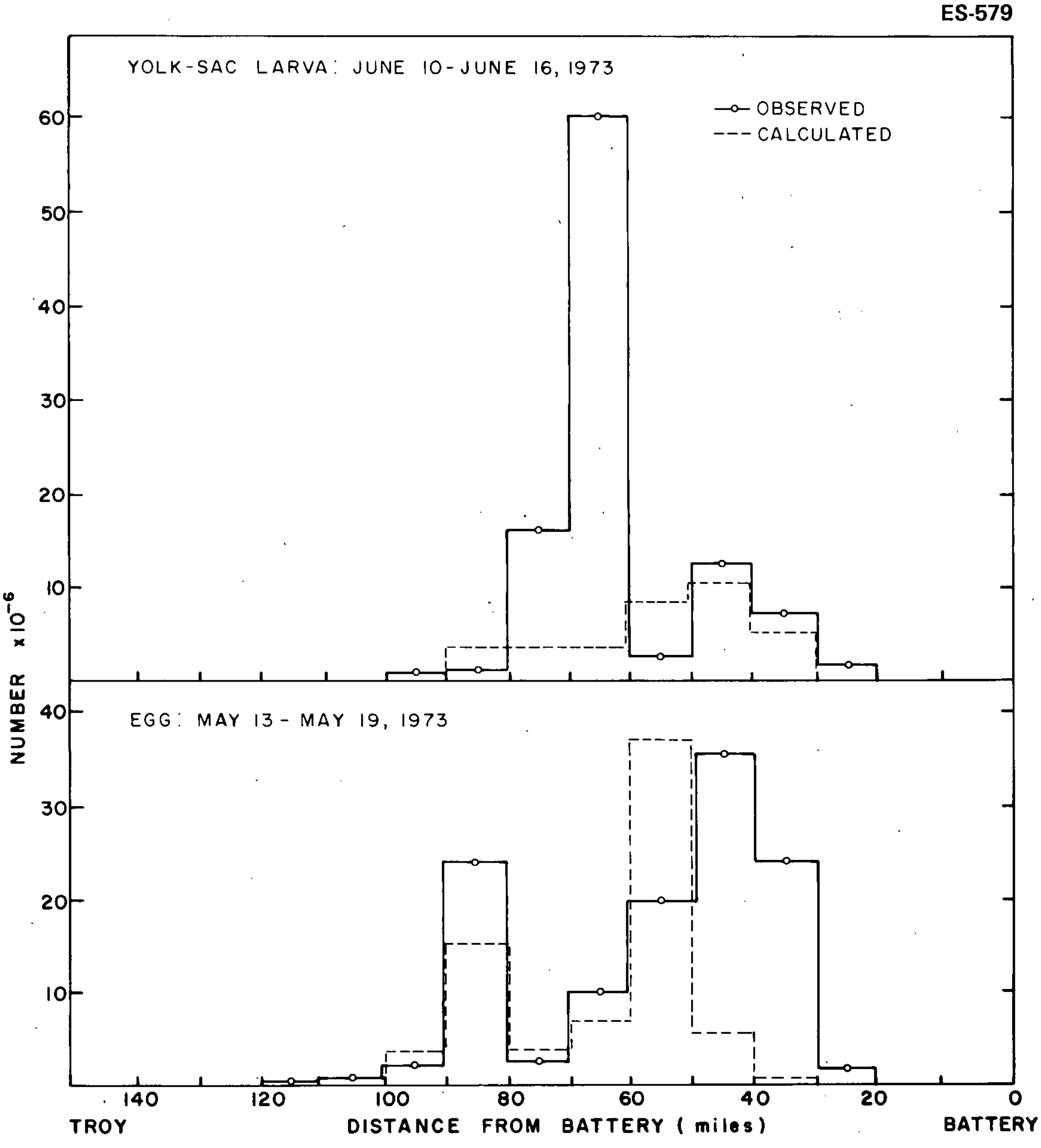

Fig. B-35. Representative bad comparison cases for young-of-the-year population distribution (egg and yolk-sac larvae).

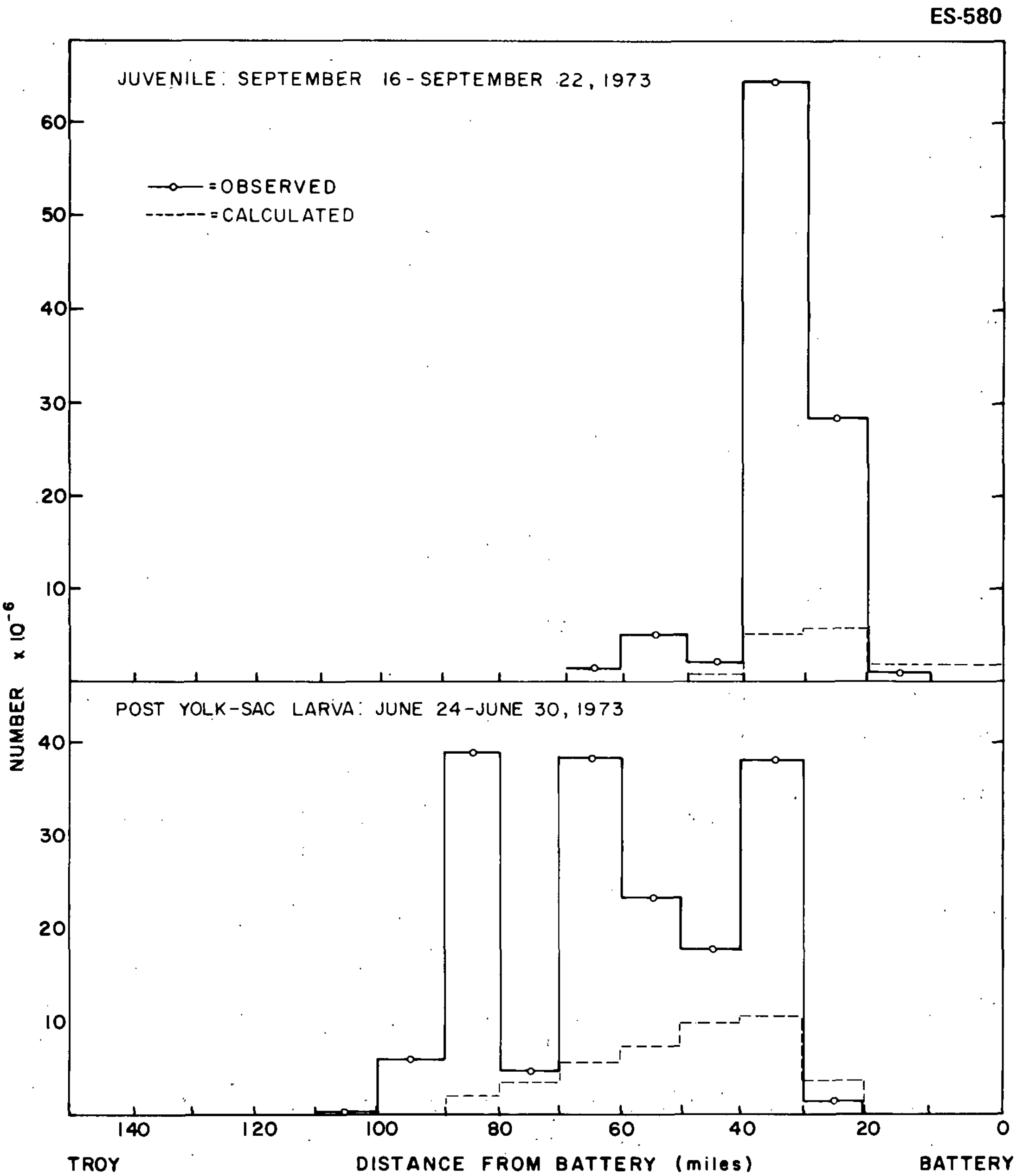

Fig. B-36. Representative bad comparison cases for young-of-the-year population distributions (post yolk-sac larvae and juveniles).

It should be emphasized that the discrepancies between the simulations and the 1973 data are by no means solely the fault of the model, considering the problems relating to the 1973 sampling program (see Chapter V). However, for the assessment of the impact of the proposed power plants, it is neither necessary nor possible to achieve exact simulation of the longitudinal distributions of the age group populations for all the weeks for which 1973 sampling data are available. Interestingly enough, except for two weeks, the best agreement between the computer simulations and the data was achieved for the juvenile age groups with respect to both qualitative and quantitative distributions. This result indicates the probable validity of the potential law of the migratory transport model. An alternate and less detailed comparison of the simulations and the 1973 data is presented in Fig. B-37 for the weekly standing crop values for the age group populations in the estuary.

The general agreement between the simulations and the 1973 data is quite acceptable except for the various peaks that occur, particularly in post yolk-sac larvae and juvenile distributions (Fig. B-37); these peaks, in turn, lead to the occurrence of the same peaks in the total standing crop distribution in Fig. B-38. Considering that the egg deposition had already stopped before the occurrence of the earliest peak, it is biologically impossible for the total standing crop to increase in the estuary. Hence, the two peaks that appear in the post yolk-sac larva and the juvenile distributions are obviously due to sampling variation. If the errors in the sampling are eliminated in the data, the simulations by the staff's model of the weekly standing crop distributions are very acceptable, particularly for the later life stages (post yolk-sac larvae and juvenile age group) populations.

As discussed earlier, in the formulation of the compensatory mechanisms in the staff's model, the parameter values for the critical densities were selected based on the observed maximum densities of the age group populations. These observed maximum values unfortunately corresponded to the particular data points which are suspect due to sampling errors. Consequently, the choice of the critical density parameters based on these apparently ambiguous data resulted in model runs which did not show the intended effect of the population density dependent compensatory mechanism in the simulation. Since the computed age group population densities never exceeded the assumed critical density values, the computer runs with the compensatory mechanism operational actually resulted in simulations using constant "optimum survival percentage" values. These corresponded to increases in the effective survival percentage values from 60 to 66% for yolk-sac larvae, from 80 to 84% for post yolk-sac larvae, from 90 to 92% for Juvenile I, and from 98 to 99% for Juveniles II and III. Hence, the staff's analysis resulted in two

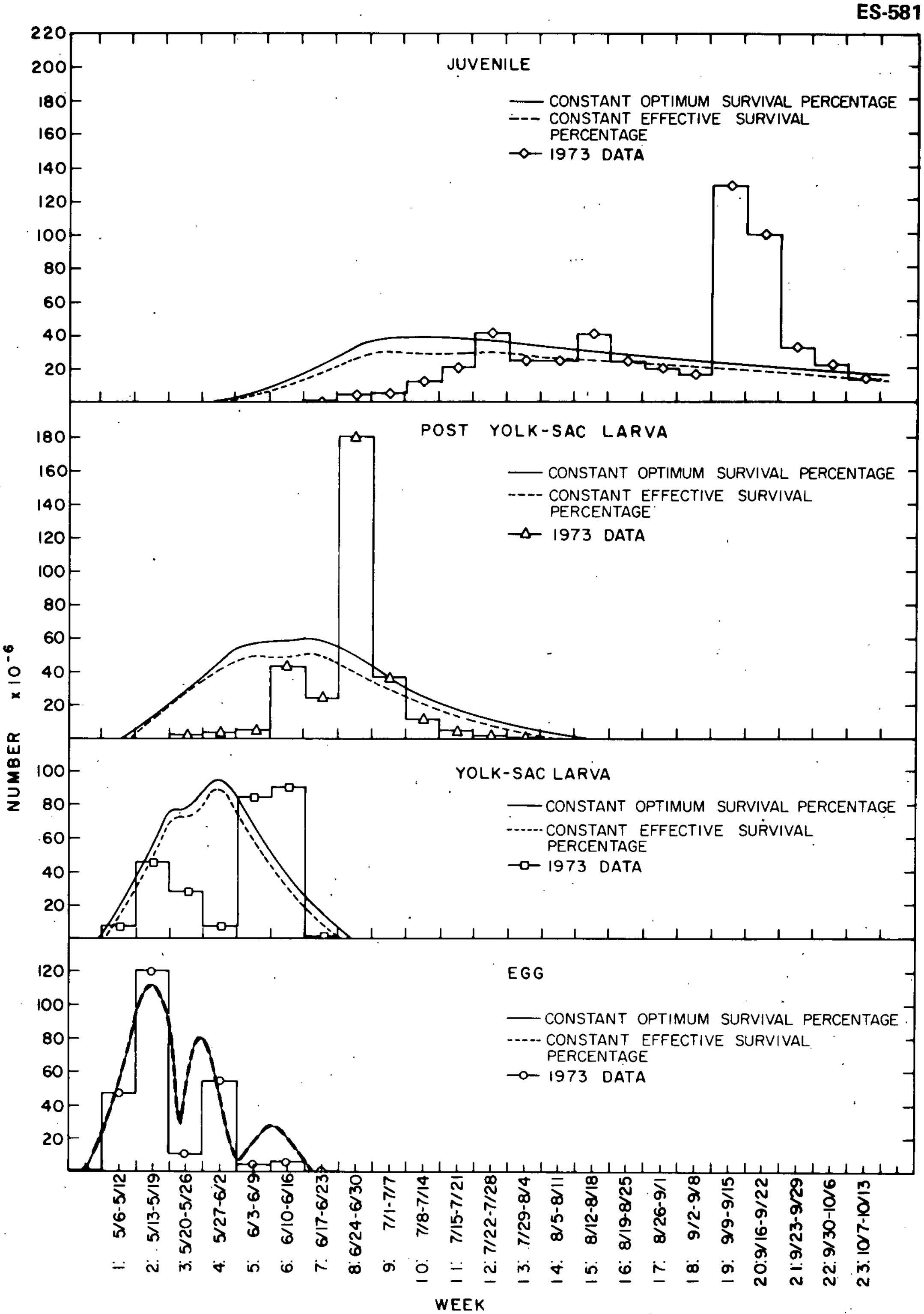

Fig. B-37. Comparisons of simulated and observed weekly standing crop values for young-of-the-year life stages.

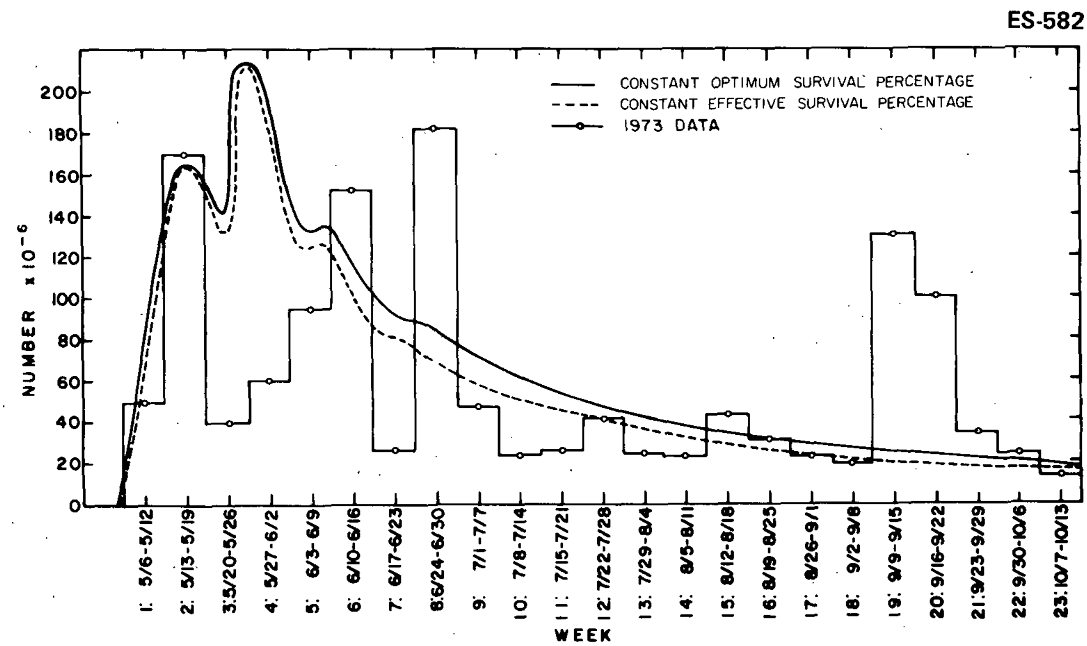

Fig. B-38. Comparison of simulated and observed weekly standing crop values for combined young-of-the-year life stages.

sets of simulations — one corresponding to survival percentage equal to "effective survival percentage" and the other to survival percentage equal to "optimum survival percentage" computer runs. The staff has recently rerun the simulation for a few cases with more realistic parameters and the results are given in Section V.D.2.d(3)(c)iii.

(11) Application of the Model to the Assessment of Power Plant Impact

The staff's computer simulation model was applied to the assessment of the entrainment impact of the existing and proposed power plants on the Hudson River by considering the 12 cases for other plants on the river and alternatives at Indian Point given in Table B-29.

As discussed earlier, the best verification of the 1973 data was achieved by selecting a value of approximately 0.8 for the convective defect transport factor (CDF), indicating slow, downriver convection of early life stages by the net freshwater flow. The lower value of 0.4 for CDF resulted in rapid downriver convection and loss of organisms out of the estuary, a result that is in poor agreement with the observed distribution data. Nonetheless, the results obtained using a CDF value of 0.4 are presented to indicate some of the important properties of the simulations when residence time in the Hudson River of striped bass young-of-the-year is assumed to be less in the model than indicated by field observations.

Three base cases were considered: (1) the hypothetical clean river, (2) 1973 conditions, (3) all power plants except Indian Point Units Nos. 1, 2, and 3 and Cornwall. These cases were, respectively, the first 3 of the 12 cases in Table B-29.

Model predictions of standing crops, reduction in standing crops, and percent reduction in standing crops of the young-of-the-year striped bass for the entire estuary on October 15 for two convective defect transport factor values (0.8 and 0.4), for two intake density ratio factor values (0.5 and 1.0), and with effective survival percentage and optimum survival percentage values are given in Tables B-30 to B-33. Results are presented using each of the three base cases as a reference for each combination of convective defect transport factor, intake density ratio factor and survival percentage.

Table B-29. Description of the 12 cases for other power plants on the river and alternatives at Indian Point used in runs of the staff's young-of-the-year striped bass model

Case	Other plants[a]	Cornwall	Indian Point Unit[b] No. 1	No. 2	No. 3	Total intake flow (cfs)
1	–[c]	–	–	–	–	0
2	1973	–	–	–	–	3,419
3	+	–	–	–	–	5,723
4	+	–	OT	OT		8,370
5	+	–	OT	OT	OT	10,308
6	+	–	OT	CT	OT	8,495
7	+	–	OT	CT	CT	6,692
8	+	+	OT	OT	OT	14,308
9	+	+	OT	CT	OT	12,495
10	+	+	OT	CT	CT	10,692
11	–	–	OT	OT	OT	4,585
12	–	+				4,000

[a]The other plants are Albany, Danskammer (four units), Roseton (two units), Lovett (five units), Bowline (two units), and 59th Street. The 1973 conditions (Case 2) included Albany, Danskammer (four units), Lovett (five units), Bowline (one unit), and 59th Street.

[b]OT = once-through cooling; CT = cooling tower.

[c]A minus sign indicates plants not included in the calculation, and a plus sign indicates plants included in the calculation.

Certain properties of the simulations warrant special consideration:

1. Comparison of the "Total Number" columns in Tables B-30 to B-33, which give the standing crop of striped bass in the estuary on October 15, show that the absolute numbers are approximately 30% higher with optimum survival percentage values than with effective survival percentage values. Considering that the optimum survival percentage values are at most only 10% higher than the effective survival percentage values (66% compared with 60% for yolk-sac larvae), the results indicate that the final total standing crop numbers for the juveniles on October 15 are quite sensitive to the values of the survival percentages of the life stages. However, no appreciable changes in the percent reduction values are evident for the cases with effective survival percentage and optimum survival percentage computer runs. Hence, these results suggest that with respect to

Table B-30. Relative impact in absolute standing crop numbers and in percent reduction forms for the 12 operational cases with convective defect transport coefficient = 0.8 and with effective survival percentages

	Intake density ratio = 0.5							Intake density ratio = 1.0						
		Reduction for case 1		Reduction for case 2		Reduction for case 3			Reduction for case 1		Reduction for case 2		Reduction for case 3	
Case	Total number (10^{-6})	Number (10^{-6})	Percent	Number (10^{-6})	Percent	Number (10^{-6})	Percent	Total number (10^{-6})	Number (10^{-6})	Percent	Number (10^{-6})	Percent	Number (10^{-6})	Percent
1	18.1680							18.1680						
2	15.3865	2.7815	15.31					13.2005	4.9675	27.34				
3	14.3777	3.7903	20.86	1.0088	6.55			11.2036	6.9644	38.33	1.9968	15.12		
4	12.3058	5.8622	32.27	3.0807	20.02	2.0719	14.41	8.7743	9.3937	51.70	4.4262	33.53	2.4293	21.68
5	11.1422	7.0258	38.67	4.2443	27.58	3.2355	22.50	7.6525	10.5155	57.87	5.5480	42.02	3.5511	31.69
6	12.1117	6.0563	33.33	3.2748	21.28	2.2660	15.76	8.5939	9.5741	52.69	4.6066	34.89	2.6097	23.29
7	13.5768	4.5912	25.27	1.8097	11.76	0.8009	5.57	10.1874	7.9806	43.92	3.0131	22.82	1.0162	9.07
8	8.5228	9.6452	53.08	6.8637	44.60	5.8549	40.72	4.9356	13.2324	72.83	8.2649	62.61	6.2680	55.94
9	9.4034	8.7646	48.24	5.9831	38.88	4.9743	34.59	5.6901	12.4779	68.68	7.5104	56.89	5.5135	49.21
10	10.5728	7.5952	41.80	4.8137	31.28	3.8049	26.46	6.8035	11.3645	62.55	6.3970	48.46	4.4001	39.27
11	13.4186	4.7494	26.14	1.9679	12.79	0.9591	6.67	11.3041	6.8639	37.78	1.8964	14.36		
12	13.8927	4.2753	23.53	1.4938	9.70	0.485	3.37	11.8730	6.2950	34.64	1.3275	10.05		

Table B-31. Relative impact in absolute standing crop numbers and in percent reduction forms for the 12 operational cases with convective defect transport coefficient = 0.8 and with optimum survival percentages

Case	Intake density ratio = 0.5							Intake density ratio = 1.0						
	Total number (10^{-6})	Reduction for case 1		Reduction for case 2		Reduction for case 3		Total number (10^{-6})	Reduction for case 1		Reduction for case 2		Reduction for case 3	
		Number (10^{-6})	Percent	Number (10^{-6})	Percent	Number (10^{-6})	Percent		Number (10^{-6})	Percent	Number (10^{-6})	Percent	Number (10^{-6})	Percent
1	23.4500							23.4500						
2	19.8448	3.6052	15.35					17.0671	6.3829	27.21				
3	18.5475	4.9025	20.90	1.2973	6.55			14.4456	9.0044	38.39	2.6215	15.35		
4	15.8434	7.6066	32.43	4.0014	20.17	2.7041	14.57	11.3073	12.1427	51.78	5.7598	33.74	3.1383	21.72
5	14.3461	9.1039	38.82	5.4987	27.72	4.2014	22.65	9.8616	13.5884	57.94	7.2055	42.21	4.5840	31.73
6	15.6071	7.8429	33.44	4.2377	21.36	2.9404	15.85	11.0810	12.3690	52.74	5.9861	35.07	3.3646	23.29
7	17.5147	5.9353	25.31	2.3301	11.75	1.0328	5.56	13.1310	10.3190	44.00	3.9361	23.06	1.3146	9.10
8	10.9748	12.4752	53.19	8.8700	44.70	7.5727	40.82	6.3525	17.0975	72.91	10.7146	62.77	8.0931	56.02
9	12.1279	11.3221	48.28	7.7169	38.89	6.4196	34.61	7.3233	16.1267	68.77	9.7438	57.09	7.1223	49.30
10	13.6300	9.8200	41.87	6.2148	31.33	4.9175	26.51	8.7618	14.6882	62.63	8.3053	48.66	5.6838	39.34
11	17.3499	6.1001	26.01	2.4949	12.58	1.1976	6.45	14.5931	8.8569	37.76	2.4740	14.49		
12	17.9443	5.5057	23.47	1.9005	9.59	0.6032	3.25	15.3475	8.1025	34.55	1.7196	10.07		

Table B-32. Relative impact in absolute standing crop numbers and in percent reduction forms for the 12 operational cases with convective defect transport coefficient = 0.4 and with effective survival percentages

Case	Intake density ratio = 0.5							Intake density ratio = 1.0						
	Total number (10^{-6})	Reduction for case 1		Reduction for case 2		Reduction for case 3		Total number (10^{-6})	Reduction for case 1		Reduction for case 2		Reduction for case 3	
		Number (10^{-6})	Percent	Number (10^{-6})	Percent	Number (10^{-6})	Percent		Number (10^{-6})	Percent	Number (10^{-6})	Percent	Number (10^{-6})	Percent
1	2.7332							2.7332						
2	2.4273	0.3059	11.19					2.1694	0.5638	20.62				
3	2.3045	0.4287	15.68	0.1228	5.05			1.8906	0.8426	30.82	0.2788	12.85		
4	2.0594	0.6738	24.65	0.3679	15.15	0.2451	10.63	1.5697	1.1635	42.56	0.5997	27.64	0.3209	16.97
5	1.8928	0.8404	30.75	0.5345	22.02	0.4117	17.86	1.3863	1.3469	49.27	0.7831	36.09	0.5043	26.67
6	2.0309	0.7023	25.70	0.3964	16.33	0.2736	11.87	1.5408	1.1924	43.62	0.6286	28.97	0.3498	18.49
7	2.2194	0.5138	18.80	0.2079	8.56	0.0851	3.69	1.7738	0.9594	35.09	0.3956	18.23	0.1168	6.17
8	1.6075	1.1257	41.19	0.8198	33.77	0.6970	30.24	1.0329	1.7003	62.20	1.1365	52.38	0.8577	45.36
9	1.7387	0.9945	36.38	0.6886	28.37	0.5658	24.55	1.1642	1.5690	57.40	1.0052	46.33	0.7264	38.41
10	1.8963	0.8369	30.62	0.5310	21.87	0.4082	17.71	1.3358	1.3974	51.12	0.8336	38.42	0.5548	29.34
11	2.1986	0.5346	19.55	0.2287	9.42	0.1059	4.59	1.9006	0.8326	30.46	0.2688	12.38		
12	2.2685	0.4647	17.0	0.1588	6.54	0.036	1.56	1.9676	0.7656	28.01	0.2018	9.30		

Table B-33. Relative impact in absolute standing crop numbers and in percent reduction forms for the 12 operational cases with convective defect transport coefficient = 0.4 and with optimum survival percentages

Case	Intake density ratio = 0.5							Intake density ratio = 1.0						
	Total number (10^{-6})	Reduction for case 1		Reduction for case 2		Reduction for case 3		Total number (10^{-6})	Reduction for case 1		Reduction for case 2		Reduction for case 3	
		Number (10^{-6})	Percent	Number (10^{-6})	Percent	Number (10^{-6})	Percent		Number (10^{-6})	Percent	Number (10^{-6})	Percent	Number (10^{-6})	Percent
1	3.4815							3.4815						
2	3.0877	0.3938	11.31					2.7577	0.7238	20.78				
3	2.9278	0.5537	15.90	0.1599	5.18			2.4003	1.0812	31.05	0.3574	12.96		
4	2.6141	0.8674	24.91	0.4736	15.33	0.3137	10.71	1.9941	1.4874	42.72	0.7636	27.69	0.4062	16.92
5	2.4010	1.0805	31.03	0.6867	22.23	0.5268	17.99	1.7575	1.724	49.51	1.0002	36.26	0.6428	26.77
6	2.5791	0.9024	25.91	0.5086	16.47	0.3487	11.90	1.9543	1.5272	43.86	0.8034	29.13	0.4460	18.57
7	2.8208	0.6607	18.97	0.2669	8.64	0.1070	3.65	2.2508	1.2307	35.35	0.5069	18.38	0.1495	6.22
8	2.0397	1.4418	41.41	1.0480	33.94	0.8881	30.33	1.3085	2.1730	62.41	1.4492	52.55	1.0918	45.48
9	2.2080	1.2735	36.57	0.8797	28.49	0.7198	24.58	1.4767	2.0048	57.58	1.2810	46.45	0.9236	38.47
10	2.4064	1.0751	30.87	0.6813	22.06	0.5214	17.80	1.6941	1.7874	51.34	1.0636	38.56	0.7062	29.42
11	2.7965	0.6850	19.67	0.2912	9.43	0.1313	4.48	2.4211	1.0604	30.45	0.3366	12.20		
12	2.8894	0.5921	17.00	0.1983	6.42	0.0384	1.30	2.5025	0.9790	28.12	0.2552	9.25		

forecasts of percent reduction, the staff's young-of-the-year computer simulation model is not very sensitive to the values assumed for the overall probability of survival from egg to juvenile.

2. The results in Tables B-30 to B-33 also indicate that percent reduction is clearly a relative concept, depending on the base case employed in the assessment of impact. For the most drastic conditions (Case 8) of all plants operating, including Cornwall, with once-through cooling at Indian Point Units Nos. 1, 2, and 3 and with (CDF, f_I) = (0.8, 1.0), the percent reductions become: 73% based on the hypothetical clean river conditions (Case 1), 63% based on 1973 conditions (Case 2), and 56% based on the condition of all plants in operation except Indian Point Units Nos. 1, 2, and 3 and Cornwall (Case 3). Hence, depending on the base case used, the percent reduction value can vary appreciably.

3. The results for the low convective defect transport factor (CDF) of 0.4 (Tables B-32 and B-33) indicate that the absolute numbers for the standing crop of juveniles on October 15 and the absolute numbers for reduction by the power plants are generally 5 to 10 times lower than the corresponding numbers for the 0.8 CDF value (Tables B-30 and B-31). This significant difference illustrates that overestimation of convection by the freshwater flow results in rapid movement of the striped bass young-of-the-year down the river and out of the estuarine system. However, the percent reduction values for the 0.4 CDF value (Tables B-32 and B-33) are generally 30% less than the values for the 0.8 CDF value (Tables B-30 and B-31). Thus, the percent reduction values are relatively insensitive to the size of the standing crop, which supports the argument that the assessment of the entrainment impact on a relative scale does not necessarily require very accurate knowledge of the absolute standing crops in the river.

4. Although the percent reduction values are less sensitive to the value of CDF than are the standing crop values, the decrease in corresponding percent reduction values in going from Tables B-30 and B-31 to Tables B-32 and B-33 is not trivial. These decreases indicate the importance of adjusting the convective defect transport factor (CDF) until the simulated longitudinal and temporal distributions approximately correspond to the observed distributions. Again, for the staff's model the correspondence was much better with a CDF value of 0.8 than 0.4.

5. The staff's sensitivity analysis (Tables B-30 to B-33) indicates that the single most important parameter influencing the model

predictions of percent reduction is the intake density ratio (f_I). Table B-34 gives approximate percent reduction values for the 12 cases of other power plants on the river and alternatives at Indian Point, for CDF values of 0.4 and 0.8, for each of the three base cases as the reference, and for f_I values of 0.2, 0.4, 0.6, 0.8, and 1.0. The percent reduction values in the body of the table were estimated by interpolation from Fig. B-32. As was pointed out previously in discussing Fig. B-32, and as is indicated by the values in Table B-34, the sensitivity of the percent reduction values to f_I increases as f_I decreases.

In summary, the application of the staff's model (relying on the 1973 data to fix a number of the parameters) to the assessment of the entrainment impact of the power plants on the striped bass young-of-the-year population results in percent reduction values that are largely insensitive to modest variations in overall survival probabilities, which are somewhat more sensitive to changes in the assumed susceptibility to convective transport and which are primarily controlled by the value of the intake density ratio.

Table B-34. Effect of intake density ratio parameter on relative percent reduction

Case	Convective defect transport coefficient = 0.8														
	Percent reduction for case 1					Percent reduction for case 2					Percent reduction for case 3				
	Intake density ratio					Intake density ratio					Intake density ratio				
	0.2	0.4	0.6	0.8	1.0	0.2	0.4	0.6	0.8	1.0	0.2	0.4	0.6	0.8	1.0
1															
2	12	18	22	24	27										
3	16	25	31	35	38	6	10	12	14	15					
4	22	34	41	47	52	14	22	27	31	34	9	14	17	20	22
5	24	38	46	53	58	18	28	34	39	42	13	21	25	29	32
6	22	35	42	48	53	15	23	28	32	35	10	15	19	21	23
7	18	29	35	40	44	10	15	18	21	23	4	6	7	8	9
8	31	48	58	66	73	26	41	50	58	63	24	37	45	51	56
9	29	45	55	63	69	24	38	46	52	57	21	33	40	45	49
10	26	41	50	57	63	20	32	39	45	49	17	26	31	36	39
11	16	25	30	34	38	6	10	12	13	14	4[a]	6[a]	7[a]	9[a]	
12	15	23	28	32	35	4	7	8	9	10	2[a]	3[a]	4[a]	4[a]	

Case	Convective defect transport coefficient = 0.4														
	Percent reduction for case 1					Percent reduction for case 2					Percent reduction for case 3				
	Intake density ratio					Intake density ratio					Intake density ratio				
	0.2	0.4	0.6	0.8	1.0	0.2	0.4	0.6	0.8	1.0	0.2	0.4	0.6	0.8	1.0
1															
2	9	14	17	19	21										
3	13	20	25	29	31	5	9	10	12	13					
4	18	28	34	40	43	12	18	22	26	28	7	11	14	16	17
5	21	33	40	46	50	15	24	29	33	36	11	18	22	25	27
6	18	29	35	40	44	12	19	23	27	29	8	13	15	17	19
7	15	23	28	32	35	8	12	14	17	18	3	4	5	6	6
8	26	41	50	57	62	22	35	42	49	53	19	30	36	41	45
9	24	38	46	53	58	19	30	37	42	46	16	25	30	35	38
10	21	34	41	47	51	16	26	31	36	39	12	19	23	27	29
11	13	20	24	28	30	5	8	10	11	12	3[a]	4[a]	5[a]	6[a]	
12	12	18	23	26	28	4	6	7	8	9	1[a]	1[a]	1[a]	2[a]	

[a]Evaluated from intake density ratio = 0.5 values instead of 1.0.

c. Striped Bass Life-Cycle Population Model

(1) Introduction

The life-cycle population model is based on Leslie's[43,44] deterministic, discrete-time model, which incorporates age-dependent fecundity and survival.[45,46] The staff has assumed that the population has a constant sex ratio and that there are always sufficient males to fertilize the eggs spawned by the females. Under these assumptions the model needs to deal only with female striped bass. Similar techniques were used by Sommani[47] in a population model for striped bass in the San Francisco Bay estuary. The time and age intervals both have a duration of a year. Aging (i.e., formation of the annulus or annual growth ring on the scales) and recruitment to the fishery (i.e., attaining a size large enough that the fish are included within that component of the population that legally can be fished) are assumed to occur immediately prior to spawning at the start of each striped bass year, which runs from one May 15 to the next.

The female striped bass population is divided into 16 annual age groups, with the oldest age group including all fish 15 years and older. The age distribution vector for year t, $n(t)$, gives the number of females in each of the 16 age groups (Fig. B-39).

The survival-fecundity matrix for year t, $A(t)$, is a 16 x 16 matrix having fecundity values in the first row, survival probabilities along the subdiagonal and in position (16,16), and all other elements equal to zero (Fig. B-39). The element f_i denotes the average number of mature "female eggs" in the ovaries of a female upon entering age class i at the beginning of year t. The element p_i denotes the probability that a female in age class i at the start of year t will survive to the start of year t+1. The age distribution vector, $n(t+1)$, for year t+1 is calculated by matrix multiplication (Fig. B-39).

Figure B-40 is an alternative representation of this matrix equation. Aging transfers occur yearly and are represented by the transfer arrows down the diagonal. As females become sexually mature (e.g., as 4-year-olds), they add to the complement of eggs spawned at the start of each year, as represented by the upward-directed arrows to the egg compartments. The total complement of eggs represents the input to the 0-year-olds at the start of the year. Natural mortality losses (e.g., mortality due to predation, disease, and parasites) occur for each age group. In addition, there is mortality of 0-year-olds due to entrainment and impingement by power plants and there is mortality of older fish due to fishing. Mortality losses and aging transfers occur first, followed by spawning.

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$$\boldsymbol{n}(t+1) = \begin{bmatrix} n_{0,t+1} \\ n_{1,t+1} \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ n_{15,t+1} \end{bmatrix} = \begin{bmatrix} p_0 f_1 & p_1 f_2 & \cdots & p_{14} f_{15} & p_{15} f_{15} \\ p_0 & 0 & \cdots & & 0 \\ 0 & p_1 & \cdots & & 0 \\ \cdot & \cdot & & & \cdot \\ \cdot & \cdot & & & \cdot \\ \cdot & \cdot & & & \cdot \\ 0 & 0 & \cdots & p_{14} & p_{15} \end{bmatrix} \begin{bmatrix} n_{0,t} \\ n_{1,t} \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ n_{15,t} \end{bmatrix} = A(t) * \boldsymbol{n}(t)$$

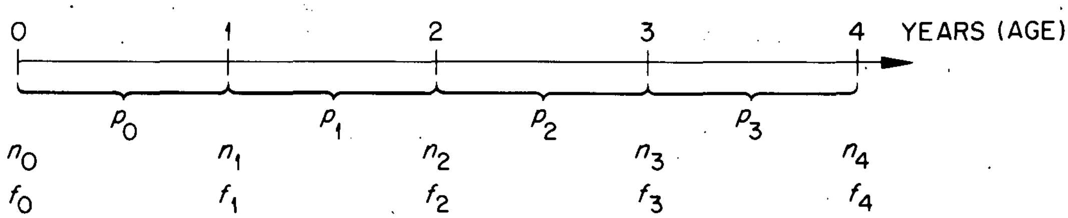

Fig. B-39. Formulation of the life-cycle model as a deterministic, discrete-time model incorporating age-dependent fecundity and survival. The diagram at the bottom defines the age and times associated with the elements of the age vector, n(t), and the Leslie matrix, A(t). The first subscript on the elements of the age vectors denotes age and the second subscript denotes year.

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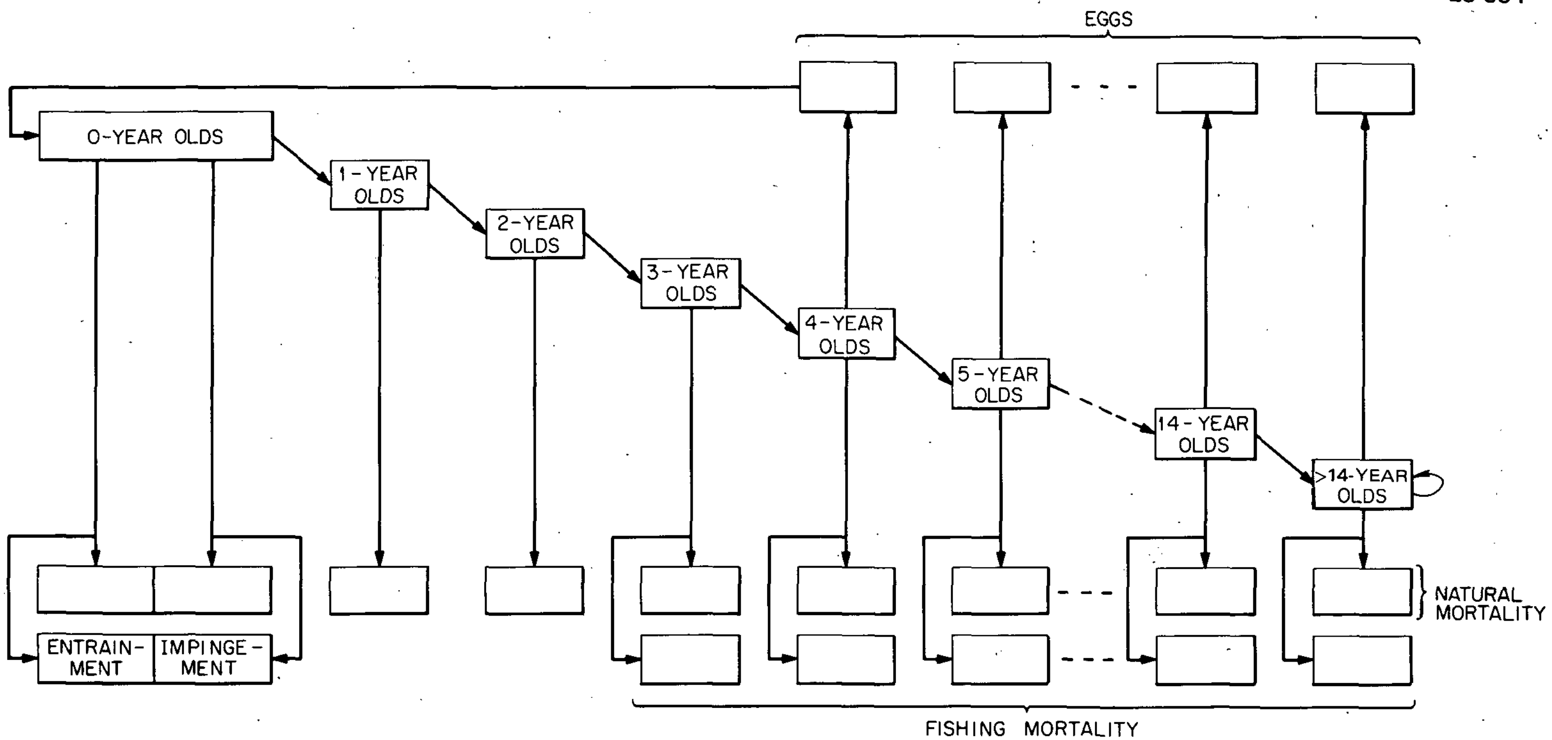

Fig. B-40. Box and arrow diagram illustrating aging transfers, production of eggs by mature females and losses due to natural mortality, fishing mortality, and entrainment and impingement.

All fish population sizes are controlled, in part, by density-dependent mechanisms whose proportionate effectiveness in reducing population growth increases or decreases as the size of the population increases or decreases.[48] The striped bass populations of the Atlantic Coast and the San Francisco Bay estuary appear to be controlled primarily by density-dependent fishing mortality.[49] However, the possibility that natural, density-dependent mechanisms may play some role in controlling the populations (or more likely, would play some role in controlling the populations at higher population densities) cannot be discounted. On the basis of data available for other fish populations (e.g., the striped bass in the San Francisco Bay Estuary[47]) and in line with the thinking of Ricker,[48,50] Backiel and LeCren,[51] and others, the staff envisions natural, density-dependent mechanisms operating primarily on the fish in age class 0.

Detailed discussion of the elements of the fecundity-survival matrix is given in the following subsections.

(2) Fecundity

The quantities f_i (i=1,15) in the first row of the matrix A(t) (Fig. B-39), where f_i is the average number of mature "female eggs" in the ovaries of a striped bass upon entering age class i at the beginning of year t, are calculated as:

$$f_i = FF * FMAT_i * EGGS_i \text{ *}, \qquad (1)$$

where FF, a constant parameter, is the probability that a fertilized egg will develop into a female; $FMAT_i$, a constant parameter for each age class, is the probability that a female is sexually mature as she enters age class i; and $EGGS_i$ is the average number of mature eggs in the ovaries of a sexually mature female upon entering age class i.

The average number of mature eggs in the ovaries of a sexually mature female upon entering age class i is calculated as:

$$EGGS_i = B_1 + [B_2 * (WT_i - WTMEAN)] , \qquad (2)$$

where WT_i is the average weight of a female at the ith annulus formation, WTMEAN is the sample mean weight of the females from all age classes upon which the regression analysis is based, and B_1 and B_2 are the intercept and slope, respectively, of the straight line equation.[52]

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*The star symbol (*) denotes multiplication.

The average weight of a female at the ith annulus formation, WT_i, is estimated using the allometric relationship:

$$LOG_{10}(WT_i) = B_3 + [B_4 * LOG_{10} (LENGTH_i)] \quad , \qquad (3)$$

where $LENGTH_i$ is the mean total length of a female at the ith annulus formation and B_3 and B_4 are the intercept and slope, respectively, of the straight line equation.[53]

The mean total length of a female at the ith annulus formation, $LENGTH_i$, is estimated as:

$$LENGTH_i = ACON + (B * AGE_i) + [C * (AGE_i^2)] \quad , \qquad (4)$$

where AGE_i is the age in years of a fish at the ith annulus formation and ACON, B, and C are the coefficients of the quadratic regression model, which was selected because it adequately characterized available data.

(3) Probability of Survival for Age Classes 1 to 15+

The elements p_i (i=1,15) in the matrix A(t) (Fig. B-39), where p_i is the probability of survival from all causes of mortality for female striped bass in age class i, are calculated as:

$$p_i[TOTP(t)] = PNS_i * PSF_i[TOTP(t)] \quad , \qquad (5)$$

where PNS_i is the probability of survival from death by natural causes for a female striped bass in age class i, and PSF_i is a function of the total female biomass legally available to the fishery at the start of the current year, TOTP(t), and represents the probability of survival from death by fishing for a female in age class i during year t.

(a) Natural Mortality

The probability of survival from death by natural causes for a female striped bass in age class i, PNS_i, is:

$$PNS_i = e^{-M_i} \quad , \qquad (6)$$

where M_i is the instantaneous natural mortality rate. The term instantaneous (natural, fishing, or total) mortality rate is used throughout this paper in a manner consistent with the fisheries literature[50] but confusing to many. These "rates" have the dimensions of 1/time and not number of fish dying per unit time.

These "rates" are analogous to the rate constants or rate coefficients commonly encountered in first-order rate equations, e.g., $N(t) = N(t_o) * e^{-r(t-t_o)} = N(t_o)e^{-r}$ when $t - t_o = 1$ year, where N is number of organisms and r is the rate constant. PNS_i is assumed to be a constant from year to year within each age class from 1 to 15+, although it may vary from age class to age class. More explicitly, the staff has assumed that for age classes 1 to 15+, sources of natural mortality are not significantly density-dependent under typical field conditions.

(b) Biomass Available to the Fishery

The total female biomass legally available to the fishery at the start of the current year, TOTP(t), is calculated as:

$$TOTP(t) = \sum_{1}^{15} WT_i * CATCH_i * n_{i,t} , \qquad (7)$$

where WT_i is the average weight of a female as she enters age class i [Eq. (3)]. $CATCH_i$, a constant parameter for each age class, is the effective fraction of fish in age class i at the beginning of the year legally available to the fishery; it is approximated as the fraction of the year for which the average length of fish in age class i is greater than or equal to the minimum legal length, LEGAL. The notation, $n_{i,t}$, denotes the number of females in age class i at the start of year t. The female biomass is assumed to be a constant proportion of the total biomass for both sexes. For the pivotal age class (i.e., i such that $LENGTH_i < LEGAL \leq LENGTH_{i+1}$), WT_i is set equal to the weight corresponding to the length LEGAL as calculated using Eq. (3).

(c) Fishing Mortality

The probability of survival from fishing, $PSF_i[TOTP(t)]$, is calculated as:

$$PSF_i\ [TOTP(t)] = 1.0 - \left[CATCH_i * VULN_i * \left(1.0 - e^{-FOFB[TOTP(t)]}\right)\right] \qquad (8a)$$

$CATCH_i$ is defined in Eq. (7); FOFB[TOTP(t)] is the instantaneous fishing mortality rate without reference to age class; and $VULN_i$, a constant parameter for each age class, is the relative vulnerability to the fishery of a female in age class i. Although adequate data are lacking, fishermen's comments indicate that striped bass run in schools according to age and that there is relatively little variability in the size of fish in a school.

As a result, because there are more younger striped bass, larger schools tend to consist of younger striped bass. Since fishermen tend to be more aware of larger schools, $VULN_i$ is assumed to depend primarily on school size and decreases with increasing age according to the number of fish in each age class. However, due to the lack of adequate data, the staff is unable to evaluate the validity of these statements and to translate them into mathematical terms. Thus, $VULN_i$ has been set equal to 1.0 for each age class and has not been included in the computer program. Further assessment of this parameter is much needed.

For all but the pivotal age class (i.e., i such that $LENGTH_i$ < $LEGAL \leq LENGTH_{i+1}$), Eq. (8a) reduces to

$$PSF_i\ [TOTP(t)] = e^{-FOFB[TOTP(t)]} \, , \qquad (8b)$$

because $CATCH_i = 1.0$, and $VULN_i$ is assumed to equal 1.0.

The following assumptions might be made with respect to the dependence of fishing mortality on the size of the legally fishable striped bass population:

1. Fishing mortality may be divided into two components, a density-independent component and a density-dependent component.

2. The density-independent component, which by definition is not strongly influenced by the size of the fishable striped bass population, constitutes a background fishing mortality. This background fishing mortality arises from two sources:

   (a) Fishing effort not directed just at striped bass (i.e., both commercial and sport fishing effort directed at whatever species are available, be they shad, bluefish, weakfish, or striped bass).

   (b) Striped bass directed fishing effort that is not overly sensitive to the number of striped bass available (i.e., the hard-core and habitual striped bass fisherman). The temporal and spatial distribution of the striped bass migratory stocks are commonly known (e.g., October and November are generally the best time for striped bass fishing along the south shores of Long Island), and thus, fishing effort will be high at that location and time over a broad range of sizes of the striped bass population.

3. The density-dependent component of the total fishing mortality is a function of the size of the fishable population, primarily in terms of its weight rather than the number of fish and primarily in terms of the size of the fishable population for the current year. Conversations with sport fishermen on Long Island indicate that the response time to news of good striped bass is a matter of hours to days. The following assumptions have been made with respect to this density-dependent component:

   (a) for population sizes greater than some minimum (below which the fishing is not good enough to significantly influence the fishing effort directed at striped bass), the individual fish's probability of surviving fishing steadily decreases with increasing population size. This relationship exists because high density in striped bass populations is associated with increased vulnerability to the fishery due to larger scale schooling and because high levels of abundance of striped bass cause increased fishing effort, which in turn increases fishing mortality.

   (b) a minimum probability of surviving fishing is approached asymptotically and depends on the maximum effort that can be expended, which in turn depends on the number of fishermen and boats available.

One function which incorporates these assumptions is Eq. (9) (Fig. B-41):

$$\mathrm{FOFB}[\mathrm{TOTP}(t)] = \begin{cases} \mathrm{FMIN}, \text{ if } \mathrm{TOTP}(t) \leq \mathrm{BMIN} \\ \dfrac{\mathrm{FMIN} * \mathrm{FMAX}}{\mathrm{FMIN} + (\mathrm{FMAX} - \mathrm{FMIN}) * e^{-\mathrm{PFCON}*[\mathrm{TOTP}(t)-\mathrm{BMIN}]}}, \\ \qquad \text{if } \mathrm{TOTP}(t) > \mathrm{BMIN} \end{cases} \tag{9}$$

TOTP(t) is defined by Eq. (7); BMIN is the minimum biomass available to the fishery below which striped bass directed fishing is assumed to be independent of TOTP(t), and its effects on fishing mortality are included in FMIN; PFCON is a measure of the sensitivity of the striped bass directed fishing effort to changes in available biomass; FMIN is the minimum instantaneous fishing mortality rate; and FMAX is the maximum instantaneous fishing mortality rate.

Graphs of the instantaneous fishing mortality rate and the probability of survival from fishing for age group i during year t versus the biomass available to the fishery at the start of year t are given in Figs. B-41 and B-42. The maximum probability of survival, PMAX, corresponds to the background or minimum instantaneous fishing mortality rate, FMIN, and the minimum probability of survival, PMIN, corresponds to the maximum instantaneous fishing mortality rate, FMAX.

The parameters FMIN and FMAX in the fishing control function (Eq. 9) are determined by specification of PMAX and PMIN, respectively. PFCON and BMIN are uniquely determined by requiring that the fishing survival function pass through the two points, (TOTP1, PSF1) and (TOTP2, PSF2) (Fig. B-43).

TOTP1 is the minimum biomass actually available to the fishery within, for example, the last 10 years; if estimates of the size of the fishable population are not available, this parameter may be estimated as some function of the yield to the fishery.

TOTP2 is calculated from TOTP1 as:

$$\mathrm{TOTP2} = \mathrm{RATIO} * \mathrm{TOTP1} \tag{10}$$

where RATIO is the average ratio of the maximum to the minimum biomass available to the fishery within, for example, 10- to 20-year periods. PSF1 and PSF2 are determined by specifying the parameter D, which defines the middle fraction (or percentage) of the interval PMIN to PMAX corresponding to the interval TOTP1 to TOTP2 on the X axis (Fig. B-43). The interval PSF1 to PSF2 is centered about the average of PMIN and PMAX; that is,

$$\mathrm{PSF1} = (\mathrm{PMAX} + \mathrm{PMIN})/2 + D * (\mathrm{PMAX} - \mathrm{PMIN})/2 \ , \tag{11a}$$

$$\mathrm{PSF2} = (\mathrm{PMAX} + \mathrm{PMIN})/2 - D * (\mathrm{PMAX} - \mathrm{PMIN})/2 \ . \tag{11b}$$

Equation (8b), after substituting Eq. (9) for FOFB[TOTP(t)], is solved for PFCON and BMIN by setting up two simultaneous equations, one for the point (TOTP1, PSF1) and the second for the point (TOTP2, PSF2). The equations for PFCON and BMIN are:

$$\mathrm{PFCON} = -Z2 * (Z2 - Z1)/[\mathrm{TOTP2} * (Z2 - Z1) - (\mathrm{TOTP1} * Z2 - \mathrm{TOTP2} * Z1)] \ , \tag{12a}$$

$$\mathrm{BMIN} = (\mathrm{TOTP1} * Z2 - \mathrm{TOTP2} * Z1)/(Z2 - Z1) \ , \tag{12b}$$

where Z1 and Z2 are intermediate variables defined as:

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$$FOFB[TOTP(t)] = \frac{FMIN * FMAX}{FMIN + (FMAX - FMIN) * e^{-PFCON * [TOTP(t) - BMIN]}}$$

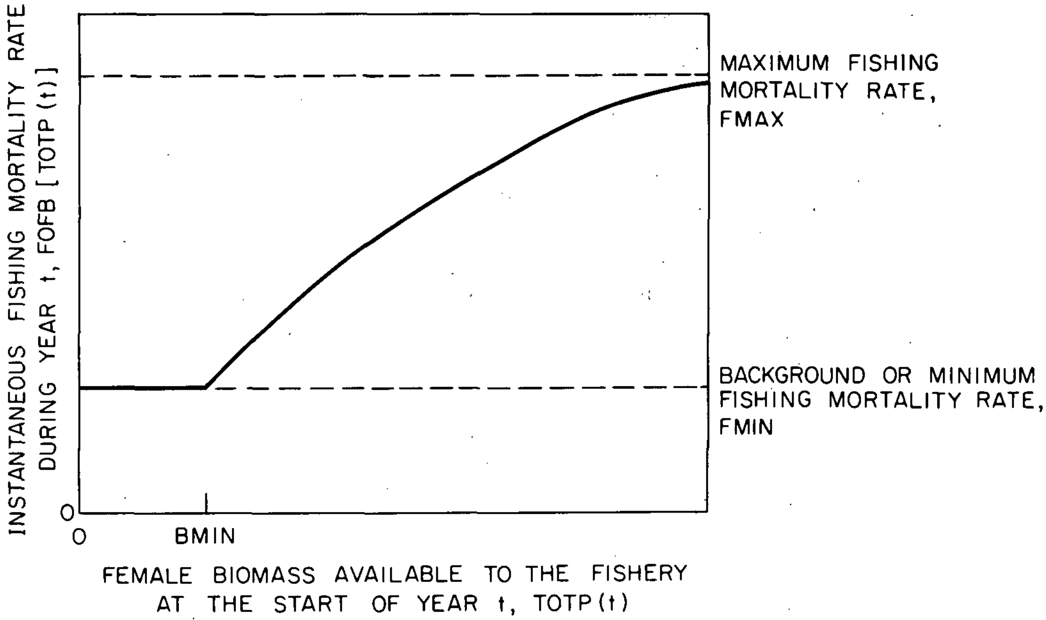

Fig. B-41. Curve for the instantaneous fishing mortality rate during year t as a function of the female biomass available to the fishery at the start of year t. A logistic relationship has been assumed.

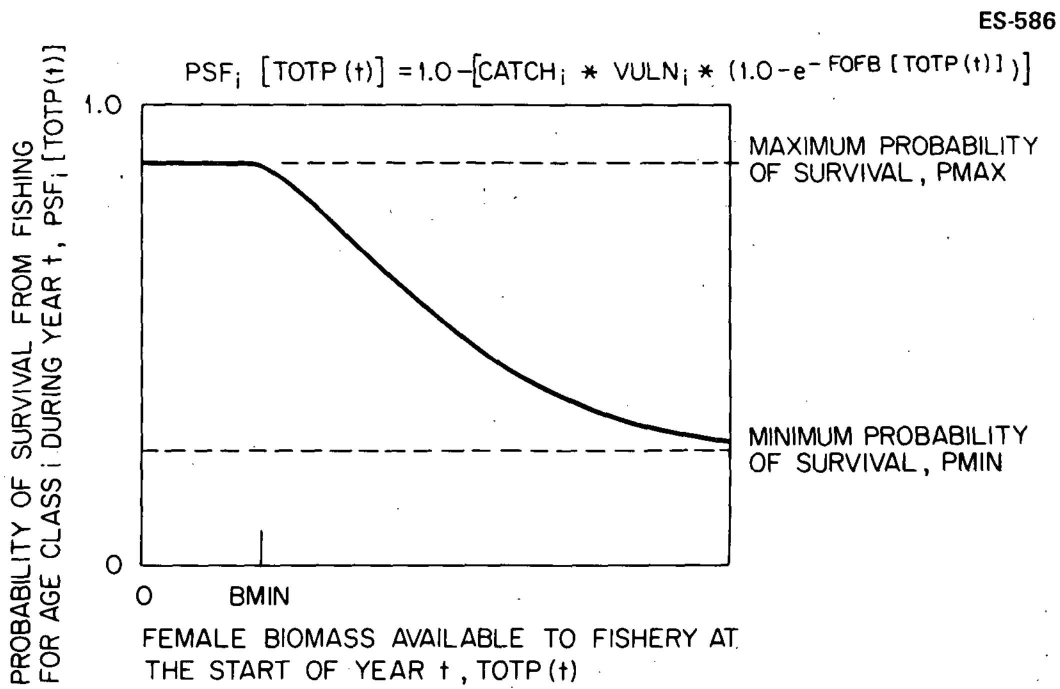

Fig. B-42. Curve for the probability of survival from fishing for age class i during year t as a function of the female biomass available to the fishery at the start of year t.

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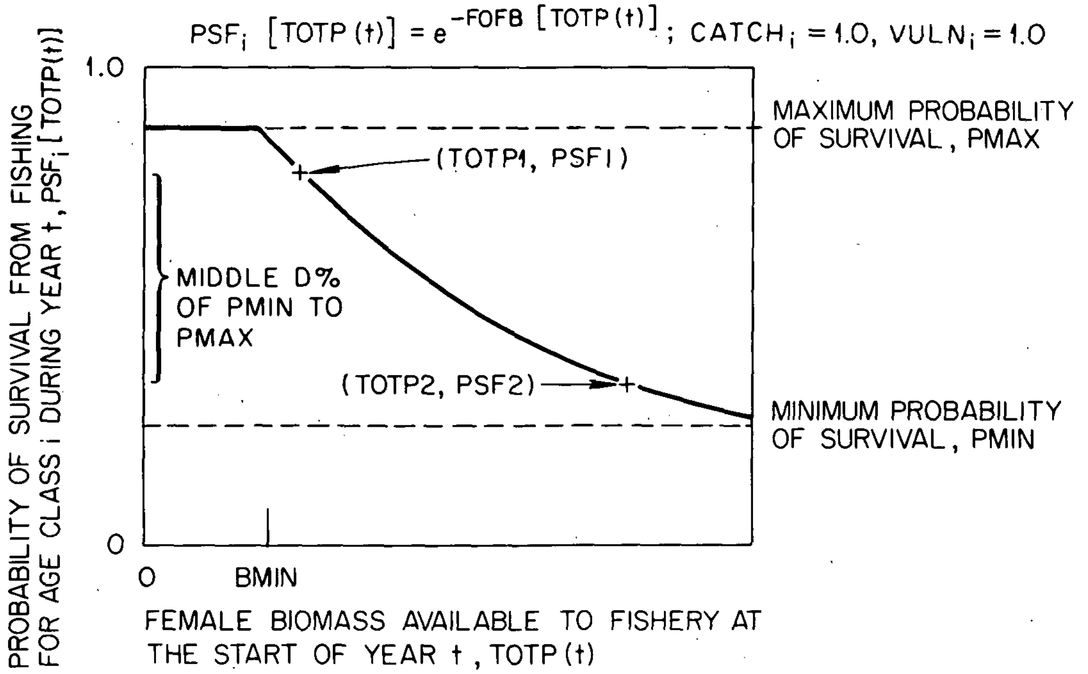

TOTP2 = RATIO * TOTP1

PSF1 = (PMAX + PMIN)/2 + D*(PMAX - PMIN)/2

PSF2 = (PMAX + PMIN)/2 - D*(PMAX - PMIN)/2

Fig. B-43. Illustration of the approach used to determine the parameters PFCON and BMIN by requiring that the fishing survival curve pass through the two points (TOTP1, PSF1) and (TOTP2, PSF2).

$$Z1 = LOG_e \{(FMIN * FMAX - FMIN * FOFB1)/[(FMAX - FMIN) * FOFB1]\} , \quad (13a)$$

$$Z2 = LOG_e \{(FMIN * FMAX - FMIN * FOFB2)/[(FMAX - FMIN) * FOFB2]\} . \quad (13b)$$

FOFB1 and FOFB2 are the instantaneous fishing mortality rates corresponding to PSF1 and PSF2, that is,

$$FOFB1 = -LOG_e(PSF1) , \quad (14a)$$

$$FOFB2 = -LOG_e(PSF2) . \quad (14b)$$

In summary, the four parameters in Eq. (9), FMIN, FMAX, PFCON, and BMIN, are determined by specifying the five parameters PMAX, PMIN, TOTP1, RATIO, and D.

The fishing mortality function acts as follows (Figs. B-41 and B-42). If the available biomass, TOTP(t), increases over the years, the instantaneous fishing mortality rate increases, and the probability of survival from fishing decreases because of an increase in striped bass directed fishing. When the mortality rate becomes high enough, the size of the population and the biomass available to the fishery decrease, which in turn leads to a decrease in striped bass directed fishing and in the fishing mortality rate and an increase in the probability of survival from fishing. The reduction in striped bass directed fishing allows the population to recover, and the available biomass increases again.

In summary, the number of i+1-year-old fish at the start of year t+1, $n_{i+1,t+1}$, is calculated from the number of i-year-old fish at the start of the year t, $n_{i,t}$, as follows:

$$n_{i+1,t+1} = n_{i,t} * p_i[TOTP(t)] = n_{i,t} * PNS_i * PSF_i [TOTP(t)] . \quad (15)$$

The independent variable in this feedback control function is TOTP(t), the female biomass available to the fishery at the start of the current year. Alternative independent variables were considered that made the instantaneous fishing mortality rate a function not of the available biomass for the current year but of the yield to the fishery over the previous 1, 2, or 3 years.

Conversations with striped bass fishermen and researchers at the New York Ocean Science Laboratory at Montauk, Long Island, have convinced the staff that the commercial and sport fisheries respond to changes in availability of striped bass in a matter of days and that the previous years' yields have little to do with the current years' striped bass directed fishing effort. The commercial fishermen fish for what is available, be it bluefish, weakfish, or striped bass; the fishermen's boats and nets are not idle just because the availability of striped bass is low.

(d) Yield to the Fishery

Although the yield to the fishery is not a variable in the fishing mortality function just described, yield is a variable of considerable interest, which the staff estimates as follows:

$$YIELD[TOTP(t)] = \sum_{1}^{15} CATCH_i * n_{i,t} * \left(1-e^{-Z_i[TOTP(t)]}\right)$$

$$* (SBF_i[TOTP(t)]/Zi\ [TOTP(t)]) * AVWT_i \ , \tag{16a}$$

where

$$Z_i[TOTP(t)] = -LOG_e\{PNS_i * PSF_i\ [TOTP(t)]\} \ , \tag{16b}$$

and

$$SBF_i[TOTP(t)] = -LOG_e\{PSF_i\ [TOTP(t)]\} \ . \tag{16c}$$

YIELD[TOTP(t)] is the yield of female striped bass to the fishery during year t; $CATCH_i * n_{i,t}$ is the number of fishable females in age class i during year t; and $1-e^{-Z_i[TOTP(t)]}$ is the probability of mortality, considering all causes, for a female in age class i during t, where Z_i[TOTP(t)] is the instantaneous total mortality rate. Thus, the product $CATCH_i * n_{i,t} * (1-e^{-Z_i[TOTP(t)]})$ is the number of fishable females in age class i that die during year t. Multiplication of this number by the ratio of the instantaneous fishing mortality rate, SBF_i[TOTP(t)], to the instantaneous total mortality rate (i.e., SBF_i[TOTP(t)]/Z_i [TOTP(t)]) gives the number of fishable females in age class i that die during year t because of fishing. As Ricker[50] points out, this ratio of instantaneous mortality rates as an estimate of the fraction of fish that die due to fishing "pertains, strictly speaking, only to the situation where fishing and natural mortality are distributed proportionately within the year" (p. 26).

$AVWT_i$ in Eq. (16a) is the weight of fish in age class i corresponding to the average age, $AGEMID_i$, of fish in age class i susceptible to the fishery. For AGE_i greater than the pivotal age class, JYR, $AGEMID_i = AGE_{i+1} - 0.5$. For the pivotal age class $AGEMID_i = AGE_{i+1} - CATCH_i/2$; that is, the age at the end of the year minus one half the fraction of the year for which the average length of fish in age class i is greater than or equal to the minimum legal length, LEGAL. $AGEMID_i$ values are used in Eq. (4) to calculate $MIDLEN_i$ values (the length of fish in age class i corresponding to the average age of fish in age class i susceptible to the fishery), which in turn are used in Eq. (3) to calculate $AVWT_i$ values.

(e) Spawners and Recruits

Two variables of interest in evaluating the dynamics of a fish population are the number (or weight) of spawners and recruits. The staff estimates the number of spawners, RSN(t), as

$$RSN(t) = \sum_{1}^{15} FMAT_i * n_{i,t} , \qquad (17a)$$

and the weight of spawners, RSWT(t), as

$$RSWT(t) = \sum_{1}^{15} WT_i * FMAT_i * n_{i,t} , \qquad (17b)$$

where $FMAT_i$ and WT_i are the probability of being sexually mature and the average weight, respectively, of a female striped bass as she enters age class i.

Recruitment to the fishery is continuous throughout the year due to the fish in the pivotal age class (i.e., i such that $LENGTH_i < LEGAL \leq LENGTH_{i+1}$) having a distribution of lengths. The staff has approximated continuous recruitment in its discrete-time model by assuming that an effective fraction of the females, $CATCH_i$, entering the pivotal age class can be considered recruited at that time. The fish in the nonrecruited fraction, $(1.0-CATCH_i)$, that survive to enter the next age class, i+1, are assumed to be recruited upon entering age class i+1. Thus, the staff estimates the number of recruits, RCRTN(t), as

$$RCRTN(t) = [CATCH_i * n_{i,t}] + [PNS_i * (1-CATCH_i) * n_{i,t}], \qquad (18a)$$

and the weight of recruits, RCRTWT(t), as

$$RCRTWT(t) = [WT_i * CATCH_i * n_{i,t}] + [WT_{i+1}$$

$$* PNS_i * (1.0-CATCH_i) * n_{i,t}] , \qquad (18b)$$

where i is the pivotal age class; $CATCH_i$ is the effective fraction of fish in the pivotal age class at the beginning of the year legally available to the fishery; PNS_i is the probability of survival from death by natural causes for the pivotal age class; WT_i is the weight of a female corresponding to the legal length, LEGAL, as calculated using Eq. (3); and WT_{i+1} is the average weight of a female at the i+1th annulus formation.

(4) <u>Probability of Survival for Age Class 0</u>

The staff has estimated the element p_o in the matrix A(t) (Fig. B-40) without density-dependent mechanisms. See Section V.D.2.d(3)(c)(ii) for a discussion of possible density-dependent mechanisms for young-of-the-year striped bass.

The probability that a female egg in age class 0 at the start of year t will survive to the start of year t+1, denoted p_o, is calculated as:

$$p_o = PPO * PNS_0 . \qquad (19)$$

PNS_0, the probability of survival from causes of natural mortality for a female striped bass in age class 0, is presumed constant from year to year, independent of $n_{o,t}$ and of the number of striped bass in any other age class. PPO is an adjustable constant used to change p_o by specifying a fractional change in PNS_0. Alternatively, PPO is the probability of surviving (or not experiencing) entrainment and impingement at power plants. A range of PPO values is used in order to evaluate what happens to the fishery and to the striped bass population when density-independent sources of mortality that act on the zero age class, such as power plant entrainment and impingement, are introduced at different levels.

(5) <u>Estimation of Parameters</u>

Estimates for the 47 input parameters in the staff's striped bass life-cycle model are given in this section. In some cases a single estimate (best estimate) is given. In the majority of cases, however, three estimates are given: best estimate, minimum, and maximum. Best estimates reflect the staff's best judgment based on presently available information; in some instances, best estimates have a relatively sound basis in a least squares fit to observed data, while in other instances best estimates are more indirectly based on data. The minimum and maximum estimates reflect the staff's degree of uncertainty in the corresponding best estimate. The parameter estimates are discussed under three headings: Fecundity Parameters, Probability of Survival for Age Classes 1 to 15+, and Probability of Survival for Age Class 0.

(a) Fecundity Parameters

(i) FF

A value of 0.5 for the probability that a given fertilized egg will develop into a female has been used for all runs.

(ii) $FMAT_i$

Estimates of the probability that a female striped bass in the Hudson River is sexually mature as she enters age class i are given in Table B-34. The most reliable criterion for classifying a female striped bass as sexually mature or immature proved to be the ratio of the weight of the ovaries to total body weight.[39] Unfortunately, the sample size of three for 6-year-old fish is not adequate to accurately estimate the percentage mature of this pivotal age class. Perhaps of even greater significance for accurately estimating the $FMAT_i$ values is that the percent of females in each age class in the Hudson River in the spring that are mature may be greater than the percent of females in the corresponding age class in the total population. This is because of a greater tendency for mature females to migrate upriver in the spring and, therefore, to be caught in gill nets. Data are not available to quantify this possible bias in $FMAT_i$ values. Minimum, maximum, and best estimates of the $FMAT_i$ parameters are given in Table B-36; the best estimates correspond to those in Table B-35.

(iii) B_1, B_2, and WTMEAN

Estimates of the three parameters in the regression model relating average number of eggs produced and presumed to be spawned by a sexually mature female after entering age class i, $EGGS_i$, and the average weight of a female at the ith annulus formation, WT_i, are given in Fig. B-44. The staff has not examined the consequences of changing these three parameters independently of changing B and C in the LENGTH-AGE regression.

Table B-35. Ovary/total body weight ratios and percent mature of age groups 3–14 for 57 striped bass collected March–May, 1973, in the Hudson River

Age (years)	Month	Sample size	Ovary/total body weight ratio	Percent mature
3	April	1	1/215	0
4	March April	7	1/258 1/96, 1/119, 1/121, 1/179, 1/182, 1/195	0
5	March April	9	1/106, 1/157 1/101, 1/119, 1/128, 1/154, 1/155, 1/162, 1/182,	0
6	March May	3	1/86, 1/139 1/16	67
7	April May	8	1/10, 1/18, 1/21 1/11, 1/16, 1/18, 1/37, 1/37	100
8	March April May	15	1/90 1/7, 1/10, 1/9, 1/9, 1/11, 1/11, 1/13, 1/15, 1/23 1/10, 1/11, 1/11, 1/12, 1/14	100
9	April May	9	1/8, 1/9, 1/9, 1/11, 1/11, 1/14 1/7, 1/8, 1/8	100
10	April May	3	1/10 1/6, 1/11	100
11				
12	May	1	1/20	100
13				
14	April		1/10	

Source: "Hudson River Ecological Study," Texas Instruments, Second Semiannual Report, November 1973, Table V-15.

Table B-36. Minimum, maximum, and best estimates of FMAT and PNS for age classes 0 to 15

Age class	FMAT[a]			PNS[b]		
	Best estimate	Minimum	Maximum	Best estimate	Minimum	Maximum
0	0.0	0.0	0.0	*c*	*c*	*c*
1	0.0	0.0	0.0	0.4	0.2	0.6
2	0.0	0.0	0.0	0.6	0.4	0.8
3	0.0	0.0	0.0	0.8	0.6	0.9
4	0.0	0.0	0.0	0.8	0.6	0.9
5	0.0	0.0	0.5	0.8	0.6	0.9
6	0.67	0.0	1.0	0.8	0.6	0.9
7	1.0	0.5	1.0	0.8	0.6	0.9
8	1.0	1.0	1.0	0.8	0.6	0.9
9	1.0	1.0	1.0	0.8	0.6	0.9
10	1.0	1.0	1.0	0.8	0.6	0.9
11	1.0	1.0	1.0	0.8	0.6	0.9
12	1.0	1.0	1.0	0.8	0.6	0.9
13	1.0	1.0	1.0	0.8	0.6	0.9
14	1.0	1.0	1.0	0.8	0.6	0.9
15	1.0	1.0	1.0	0.8	0.6	0.9

[a]Probability that a female is sexually mature as she enters the given age class.
[b]Probability of survival from causes of natural mortality.
[c]See Section B.4.C.(4).

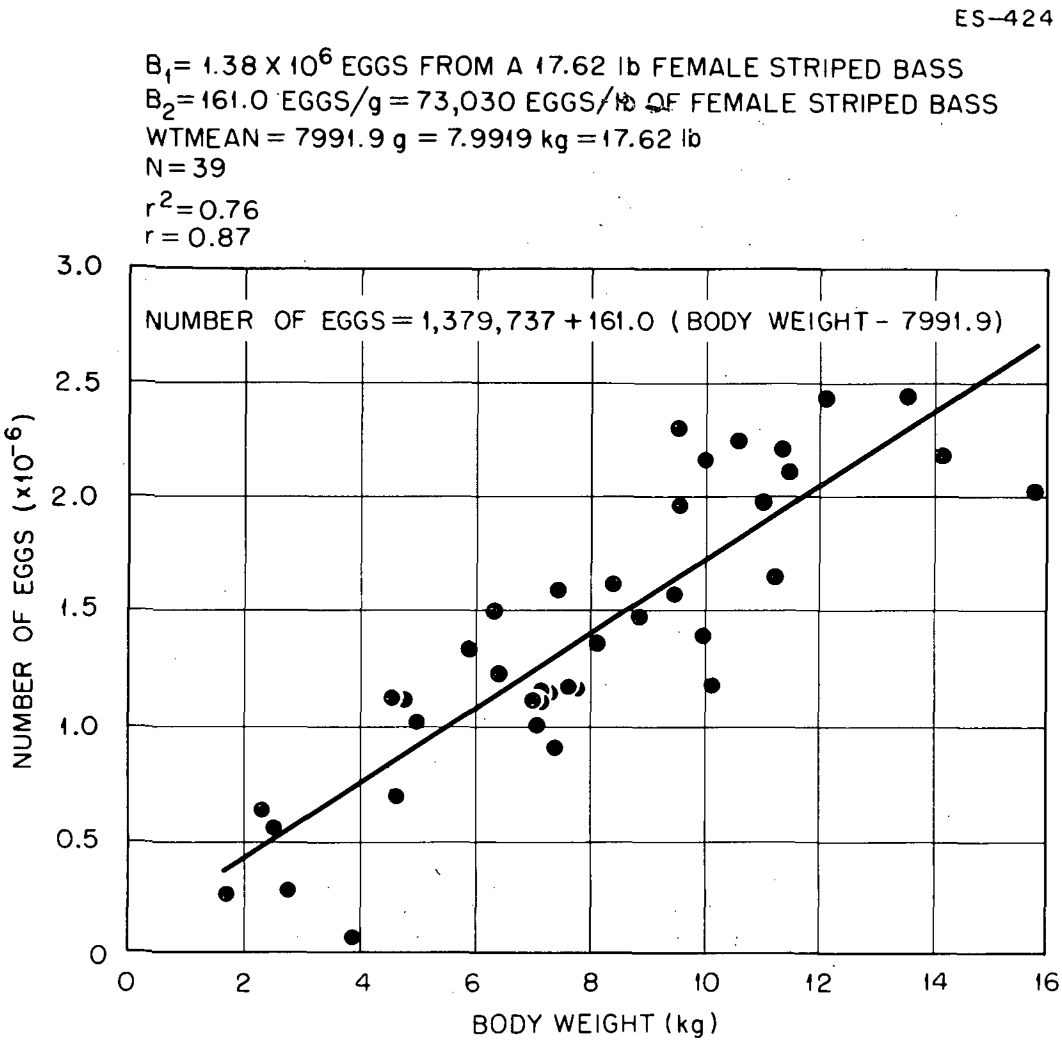

Fig. B-44. Relationship between total body weight (kg) and estimated number of eggs for 39 striped bass collected in Hudson River, 1973. $B_1 = 1.38 \times 10^6$ eggs from a 17.62-lb female; $B_2 = 161.0$ eggs/g = 73,030 eggs/lb of female; WTMEAN = 7.9919 kg = 17.62 lb; N = 39; $r^2 = 0.76$; and r = 0.87. This figure corresponds to Fig. V-14 in "Hudson River Ecological Study," Texas Instruments, Second Semiannual Report, November 1973.

(iv) B_3 and B_4

Estimates of the two parameters in the regression model relating average weight of a female at the ith annulus formation, WT_i, and mean total length of a female at the ith annulus formation, $LENGTH_i$, are given in Table B-37. The staff used the estimates given for females in running the model; the staff has not examined the consequences of changing B_3 and B_4 independently of changing B and C in the LENGTH-AGE regression.

Table B-37. Total length/weight relationships of striped bass in the Hudson River, April–September 1972

Note: $\log_{10}$ weight = B_3 + B_4 ($\log_{10}$ length), a = intercept, c = slope, and r = correlation coefficient; length is in millimeters and weight is in grams.

Sex	Region	Sample size	B_3	B_4	r
Male	Combined	51	−4.880	2.956	0.993
Female	Combined	31	−5.340	3.130	0.995
Young-of-the-year	1	816	−4.956	2.978	0.953
	2	179	−4.653	2.821	0.987
	3	125	−4.723	2.847	0.984
Total		1120	−4.886	2.940	0.960

Source: Modified from Table V-59 in "Hudson River Ecological Study," Texas Instruments, First Annual Report, April 1973.

(v) ACON, B, and C

Mean calculated total lengths (mm) at annulus formation, based on a composite sample of male, female, and immature striped bass collected in the Hudson River during April to September 1972, are given in Table B-38. The staff fitted a quadratic regression model to these data. Because the estimate of the intercept parameter, ACON, did not differ significantly from zero, this parameter was dropped from the model and a second regression analysis was performed. The quadratic model was selected because it adequately characterized the data (r^2 = 0.998). The staff used the data from the composite sample of male, female, and immature striped bass because of the small sample sizes (≤4 fish) for females more than three years old and the variability among these older females.

Table B-38. Mean calculated total lengths (mm) of male, female, and immature striped bass at annuli formation, Hudson River, RM 40 to RM 60, April–September 1972

Age group	Year class	Sample size	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14
I	1971	44	115.8													
II	1970	62	129.7	239.6												
III	1969	18	123.5	237.3	324.8											
IV	1968	3	130.9	233.0	332.7	419.5										
V	1967	3	129.9	263.2	331.9	422.4	487.7									
VI	1966	1	122.4	248.7	341.6	403.5	484.5	524.9								
VII	1965	6	141.1	245.1	346.5	443.1	517.8	582.0	633.3							
VIII	1964	1	117.2	287.7	398.5	477.3	526.3	600.9	632.9	662.7						
IX	1963	1	134.8	276.1	321.1	406.8	531.7	631.7	721.7	828.8	916.6					
X	1962	1	153.1	333.8	410.9	507.9	556.3	600.4	657.7	701.7	726.0	734.8				
XI	1961	0	0	0	0	0	0	0	0	0	0	0	0			
XII	1960	0	0	0	0	0	0	0	0	0	0	0	0	0		
XIII	1959	1	137.4	214.1	274.0	343.5	401.0	472.9	523.2	583.1	631.0	669.4	714.9	741.3	777.2	
XIV	1958	1	113.4	231.6	344.0	446.8	578.6	696.8	803.4	881.0	948.8	993.4	1028.3	1059.3	1076.6	1092.2
Weighted mean			119.7	241.6	333.6	431.7	509.9	585.0	649.0	731.5	805.6	799.2	871.6	900.3	927.0	1092.2
Two standard errors			0.71	1.30	1.98	2.78	2.86	3.10	3.12	4.71	5.14	5.59	*a*	*a*	*a*	*a*
Weighted-mean increment			119.7	121.9	92.0	98.1	78.2	75.1	64.0	82.5	74.1	−6.4	72.4	28.7	26.7	165.3
Sample size			342	98	36	18	15	12	11	5	4	3	2	2	2	1

[a]Not calculated.

Source: "Hudson River Ecological Study," Texas Instruments, First Annual Report, April 1973, Table V-57.

However, the regression coefficients for females only (i.e., B = 117.0 and C = -3.191) are approximately the same as those for the composite sample (i.e., B = 115.1 and C = -3.090).

The results of the regression analysis are summarized in Fig. B-45, which illustrates the best-estimate, minimum, and maximum growth curve used in the model. The minimum growth curve corresponds to values of B and C that are two standard errors less than the best estimates of B and C; the maximum growth curve corresponds to values of B and C that are two standard errors more than the best estimates of B and C.

(b) Probability of Survival for Age Classes 1 to 15+

(i) Natural Mortality

Instantaneous natural mortality rates for striped bass in the San Francisco Bay Estuary have been estimated by Sommani[47] (Table B-39). These estimates are for fish 3 years old and older; however, in the absence of data to the contrary, Sommani used the same estimate of natural mortality for age classes 1 and older in his model. The staff has used Sommani's estimates as a guideline in choosing 0.8 as the best estimate, 0.6 as the minimum, and 0.9 as the maximum probability of survival from sources of natural mortality for striped bass 3 years old and older. Somewhat lower estimates have been used for 1-year and 2-year-old striped bass.

(ii) Fishing Mortality

TOTP1

Data are not available to accurately estimate the minimum biomass available to the fishery, as distinct from the yield to the fishery, within the last 10 years. The minimum annual commercial landings of striped bass in New York between 1963 and 1972 was 673,000 lb in 1963; these landings, of course, include both females and males. The sport landings, which also include both males and females, substantially exceed the commercial landings in both number and weight of striped bass caught [see Section V.D.2.d(3)(c)(v)]. Based on this information and consideration of an Inner Zone and Outer Zone of influence for the Hudson River striped bass population [see Section V.D.2.d(3)(c)(v)], the staff's minimum, best estimate, and maximum values for TOTP1 (Table B-40) are 10^5, 10^6, and 10^7 pounds per year, respectively. As will be illustrated, since the forecasts of impact on the Hudson River striped bass population are on a relative scale, the forecasts are completely independent of the value of TOTP1.

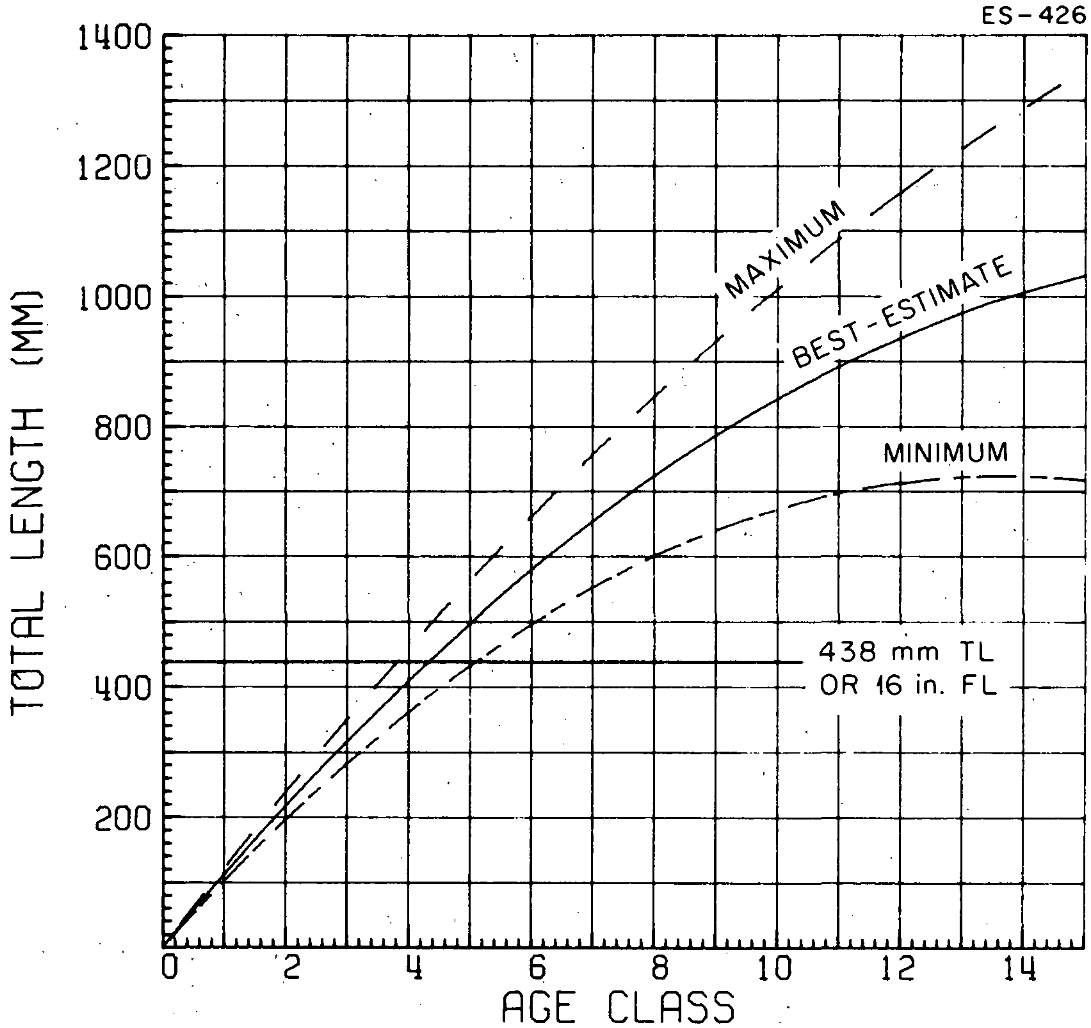

Fig. B-45. Best-estimate, minimum and maximum growth curves used in the staff's life-cycle model. The minimum legal length for the sport and commercial fisheries is 16 in. fork length (or 438 mm total length) in New York and the New England states except Maine. Fork length (in millimeters) = 4.60 + 0.903 [total length (in millimeters)]; N = 74, r = 0.99. (Source: Texas Instruments, Inc., "Hudson River Ecological Study in the Area of Indian Point, First Annual Report," prepared for Consolidated Edison Company of New York, Inc., April 1973.)

Table B-39. Instantaneous natural mortality rates (M) and the corresponding probabilities of survival from sources of natural mortality (PNS) estimated from data of tagged striped bass released and recovered during 1958 to 1968 in the San Francisco Bay Estuary

Year	M	PNS
1958	0.526	0.591
1959	0.282	0.754
1960	0.202	0.817
1961	0.152	0.859
1962	0.152	0.859
1963	0.152	0.859
1964	0.152	0.859
1965	0.244	0.783
1966	0.177	0.838
1967	0.177	0.838
1968	0.177	0.838
Average		
without 1958	0.187	0.830
with 1958	0.214	0.809

Source: P. Sommani, "A Study on the Population Dynamics of Striped Bass in the San Francisco Bay Estuary," Ph.D. Thesis, University of Washington, Seattle, Washington, Table 4.

Table B-40. Best estimate, minimum, and maximum values of the model parameters related to fishing mortality

Parameter	Best estimate	Minimum	Maximum
TOTP1 (lb)	10^6	10^5	10^7
RATIO	3.0	2.0	5.0
PMAX	0.85	0.75	0.95
PMIN	0.60	0.50	0.70
D	0.6	0.4	0.8
LEGAL (mm)	438	338	538

RATIO

The normal range of fluctuations in recruitment to the total fishery can be approximated by analyzing the fluctuations in commercial landings. The staff has done such an analysis using Hudson River landings, New York landings, Middle Atlantic landings, and Chesapeake Bay landings over 10-year periods starting with 1963-1972 and going backwards in 5-year increments to 1933-1942 (Table B-41). The average ratio of maximum to minimum yield to the commercial fishery is 4.2 for the Hudson River, 2.8 for New York (including Hudson landings) and the Middle Atlantic, and 2.1 for Chesapeake Bay. The mimimum, best estimate, and maximum values for RATIO are 2.0, 3.0, and 5.0 (Table B-40).

PMAX and PMIN

Data are not available to estimate PMAX and PMIN, the maximum and minimum probability of survival from fishing as accurately as the staff would like. However, Chadwick[54] comments:

> "In Chesapeake Bay actual tag returns in several studies in the 1930's ranged from about 30 to 40% in less than a year after tagging (Raney, 1952). More recently 38% of a group tagged in Maryland were returned (Mansueti, 1961) and 27% of a group tagged in Virginia were returned (Massmann and Pacheco, 1961). Most of these were recaptured within a year after tagging. The mortality rate indicated by these returns is difficult to determine because some tags increased the vulnerability of tagged fish to the commercial fishery (Lewis, 1961), tagging procedures varied, and nonresponse was not estimated. However, Mansueti (letter, 1962) believed that they indicate annual expectations of deaths from fishing ranging from 30 to 60%."

On the basis of this information and other tag-recapture data, which indicate somewhat lower annual expectations of deaths from fishing outside of Chesapeake Bay (TI, 2nd Annual Report;[39] Schaefer,[55] 1968), the best-estimate, minimum, and maximum values for PMAX and PMIN given in Table B-40 were selected.

D

Best-estimate, minimum, and maximum values for the parameter D, the middle fraction of the interval PMIN to PMAX, are given in Table B-40. These values were chosen to represent a range of sensitivities to changes in population size, while still satisfying the constraint that the expected range of fluctuations in

Table B-41. Values of minimum and maximum landings and the ratio of maximum to minimum for Hudson River, New York, Middle Atlantic, and Chesapeake Bay

Period	Hudson River			New York[a]			Middle Atlantic			Chesapeake Bay		
	Min (10^3 lb)	Max (10^3 lb)	Max/min	Min (10^3 lb)	Max (10^3 lb)	Max/min	Min (10^3 lb)	Max (10^3 lb)	Max/min	Min (10^3 lb)	Max (10^3 lb)	Max/min
1933–1942	11	35	3.2	19	266	14.0[b]	40	446	11.2[b]	642	3,286	5.1[b]
1938–1947	21	79	3.8	139	504	3.6	311	963	3.1	1,839	4,545	2.5
1943–1952	30	79	2.6	244	626	2.6	413	1,141	2.8	3,413	5,834	1.7
1948–1957	19	93	4.9	356	626	1.8	473	1,141	2.4	2,788	5,834	2.1
1953–1962	19	133	7.0	395	910	2.3	473	1,259	2.7	2,788	7,262	2.6
1958–1967	29	133	4.6	398	1,630	4.1	479	2,023	4.2	4,422	7,262	1.6
1963–1972	25	77	3.1	673	1,630	2.4	1,429	2,059	1.4	3,860	7,759	2.0
Average			4.2			2.8			2.8			2.1
Standard error			0.6			0.4			0.4			0.1

[a]Including Hudson River landings.
[b]Not included in average.

Sources:
T. S. Y. Koo, "The Striped Bass Fishery in the Atlantic States," *Chesapeake Sci.* 11(2): 73–93 (1970).
U.S. Department of Commerce, National Marine Fisheries Service, Fisheries Statistics Bulletins.

population size over 10-year periods would not cause the probability of surviving fishing to reach either PMAX or PMIN.

LEGAL

The best estimate for the parameter LEGAL, the minimum legal length of striped bass for the fisheries, is 438 mm (Table B-40), which corresponds to the present legal fork length of 16 in. for keeping striped bass in New York, Connecticut, Rhode Island, and Massachusetts waters. The minimum and maximum values for LEGAL in Table B-40 correspond approximately to fork lengths of 12 in. and 20 in. LEGAL was varied to examine the possible interactions between reduced survival in the zero-age class and altering the legal size for striped bass.

(c) Probability of Survival for Age Class 0

(i) PNSO

Of the 46 parameters in this model (excluding PPO, which is discussed in the next section), PNSO, the probability of survival from causes of natural mortality for age class 0, is known the least well. Thus, rather than "guess" at PNSO, the staff estimates the other 45 parameters, sets PPO = 1.0, and requires that at steady state the fishable biomass be the average of TOTP1 and RATIO * TOTP1 (i.e., the midpoint of the expected range of fluctuations over 10-year periods). This procedure uniquely determines PNSO, which is calculated as indicated in Section IV.B of Van Winkle et al.[21] (1974).

(ii) PPO

The major purpose of this simulation model is to investigate for different combinations of the preceding 46 parameters the effects of varying PPO, where (1.0 - PPO) specifies the fractional reduction in the probability of survival of young-of-the-year striped bass due to power plant impacts. PPO values ranging from 0.25 (corresponding to a 75% reduction in the number of young-of-the-year surviving their first year) to 1.25 (corresponding to a 25% increase in the number of young-of-the-year surviving their first year) are used. The rationale for using PPO values greater than 1.0 is to examine to a first approximation the possible consequences of stocking the Hudson with enough hatchery-reared striped bass to more than compensate for losses caused by operation of power plants. The majority of the results, however, deal with simulations using PPO values between 0.50 and 1.00.

(d) Summary

The 47 input parameters in the staff's Hudson River striped bass life-cycle model are listed and defined in Table B-42, along with the values for the minimum, best estimate, and maximum.

(6) Types of Model Runs

There are two types of model runs: (1) RO runs, which involve running the model for the entire period (e.g., 40 years) with the same parameter values, including the value for PPO; and (2) RC runs, which involve running the model for part of the period (e.g., 5 years) with one set of parameter values and then changing one or more parameters for the remainder of the period — generally the only parameter changed is PPO.

Table B-43 lists the parameter combinations used for the 21 sets of RO and RC runs. Set 1 represents the staff's best estimate of each of the parameters. The other 20 sets are the basis for the staff's sensitivity analysis and may be grouped under six headings: Sets 2 and 3 deal with age at sexual maturity; Sets 4 and 5 deal with probabilities of natural survival; Sets 6 and 7 deal with rate of growth; Sets 8 to 11 deal with the independent variable in the fishing control function; Sets 12 to 19 deal with the dependent variable in the fishing control function; and Sets 20 and 21 deal with the minimum legal length of striped bass for the fishery. The sensitivity analysis, particularly Sets 12 to 19, focuses most closely on changes in the fishing parameters, because the model has been developed around the assumption that fishing mortality is in part density-dependent and is the primary mechanism currently controlling the Hudson River spawned striped bass.

The steady-state solution for the model was obtained for each of the 21 parameter combinations with PPO set equal to 1.0. Then RO and RC runs for each parameter combination were done using a range of PPO values, but with the other 46 parameters, including PNSO, held constant.

(7) Results and Discussion

(a) Steady-State Solutions with PPO = 1.0

Comparison of the output from the steady-state runs with PPO = 1.0 is of value in pointing out the different effects of the 21 parameter combinations under non-stress conditions. Such a comparison has been made using three criteria: (1) vital statistics, (2) steady-state age distributions, and (3) yield, probability of surviving fishing, and other output variables.

Table B-42. Minimum, best estimate, and maximum values and definitions for each of the 47 input parameters in the staff's Hudson River striped bass life cycle model

Parameter	Unit	Minimum	Best estimate	Maximum	Definition
FF			0.5		Probability that a given fertilized egg will develop into a female.
$FMAT_1$			0.0		The probability that a female is sexually mature upon entering the age class is indicated by the subscript on FMAT.
$FMAT_2$			0.0		
$FMAT_3$			0.0		
$FMAT_4$			0.0		
$FMAT_5$			0.0	0.5	
$FMAT_6$		0.0	0.67	1.0	
$FMAT_7$		0.5	1.0		
$FMAT_8$			1.0		
$FMAT_9$			1.0		
$FMAT_{10}$			1.0		
$FMAT_{11}$			1.0		
$FMAT_{12}$			1.0		
$FMAT_{13}$			1.0		
$FMAT_{14}$			1.0		
$FMAT_{15}$			1.0		
B1	Number of eggs		1.38×10^6		Coefficient of the zero-order term in the linear relationship between EGGS and WT (weight) of fish.
B2	Eggs/lb		73,030		Coefficient of the first-order term in the linear relationship between EGGS and WT.
WTMEAN	lb		17.62		Mean weight parameter used in the regression relationship between EGGS and WT.
B3	Log_{10} grams		−5.340		Coefficient of the zero-order term in the linear relationship between $LOG_{10}(WT_i)$ and $LOG_{10}(LENGTH_i)$.
B4	Log_{10} grams/Log_{10}mm		3.130		Coefficient of the first-order term in the linear relationship between $LOG_{10}(WT_i)$ and $LOG_{10}(LENGTH_i)$.
ACON	mm		0.0		Coefficient of the zero-order term in the quadratic relation between LENGTH and AGE.
B	mm/year	106.1	115.1	124.1	Coefficient of the first-order term in the quadratic relation between LENGTH and AGE.
C	mm/year^2	−3.890	−3.090	−2.290	Coefficient of the second-order term in the quadratic relationship between LENGTH and AGE.
PNS_0		See Section B.4.C(5)(c)(i)			The probability of survival from death by natural causes for the age class indicated by the subscript on PNS.
PNS_1		0.2	0.4	0.6	
PNS_2		0.4	0.6	0.8	
PNS_3		0.6	0.8	0.9	
PNS_4		0.6	0.8	0.9	
PNS_5		0.6	0.8	0.9	
PNS_6		0.6	0.8	0.9	
PNS_7		0.6	0.8	0.9	
PNS_8		0.6	0.8	0.9	
PNS_9		0.6	0.8	0.9	
PNS_{10}		0.6	0.8	0.9	
PNS_{11}		0.6	0.8	0.9	
PNS_{12}		0.6	0.8	0.9	
PNS_{13}		0.6	0.8	0.9	
PNS_{14}		0.6	0.8	0.9	
PNS_{15}		0.6	0.8	0.9	
TOTPI	lb	10^5	10^6	10^7	The minimum annual biomass expected to be available to the fishery over, for example, a 10-year period.

Table B-42 (continued)

Parameter	Unit	Minimum	Best estimate	Maximum	Definition
RATIO		2.0	3.0	5.0	The average ratio of the maximum to the minimum annual biomass actually available to the fishery within, for example, 10-year periods; used in calculating TOTP2 from TOTP1.
PMAX		0.75	0.85	0.95	Maximum probability of survival from fishing; corresponds to the minimum instantaneous fishing mortality rate, FMIN.
PMIN		0.50	0.60	0.70	Minimum probability of survival from fishing; corresponds to the maximum instantaneous fishing mortality rate, FMAX.
D		0.4	0.6	0.8	The middle fraction (or percentage) of the interval PMIN to PMAX corresponding to the interval TOTP1 to TOTP2; used in calculating PFCON and BMIN.
LEGAL	mm	338	438	538	Minimum legal length of striped bass for the fisheries.
PPO		0.25		1.25	Probability of surviving (or not experiencing) entrainment and impingement at power plants.

Table B-43. Parameter combinations used for the 21 sets of RO and RC runs[a]

Set	FMT5	FMT6	FMT7	PNS1	PNS2	PNS_i (i = 3, 15)	B (mm/year)	C (mm/year^2)	TOTP1 (lb)	RATIO	PMAX	PMIN	D	LEGAL (mm)
1	0.0	0.67	1.0	0.4	0.6	0.8	115.1	−3.090	1E6	3.0	0.85	0.6	0.6	438
2	0.0	0.0	0.5											
3	0.5	1.0	1.0											
4				0.2	0.4	0.6								
5				0.6	0.8	0.9								
6							106.1	−3.890						
7							124.1	−2.290						
8									1E5					
9									1E7					
10										2.0				
11										5.0				
12											0.75	0.5	0.4	
13											0.75	0.5	0.8	
14											0.75	0.7	0.4	
15											0.75	0.7	0.8	
16											0.95	0.5	0.4	
17											0.95	0.5	0.8	
18											0.95	0.7	0.4	
19											0.95	0.7	0.8	
20														338
21														538

[a]Set 1 = Best estimate values for all parameters. For sets 2–21, the values of one or more of the parameters listed across the top of the table were changed to the minimum or maximum values indicated in the body of the table. All other parameters remained at the best estimate values.

(i) Vital Statistics

The vital statistics are summarized in Table B-44. For most of the sets the vital statistics are all the same (i.e., Sets 1, 4, 5, and 8 to 19). For Sets 2 and 3 the only difference is in the input values for the probability of being sexually mature (column headed FMAT). For Sets 6 and 7 the lengths and all variables calculated from the length are different from Set 1. Of particular interest is that for Set 6 the fish first enter the fishery as 5-year-olds, while for Set 7 they enter as 3-year-olds just before turning 4 years old (column headed CATCH). Also, there are substantial differences in the average fecundity values (column headed FSUBI). For Sets 20 and 21 the only change is in the legal length when striped bass are first recruited to the fishery (column headed CATCH). In this sense Set 20 is approximately comparable to Set 7, and Set 21 is approximately comparable to Set 6 (i.e., earlier and later recruitment to the fishery, respectively, relative to Set 1).

(ii) Steady-State Age Distributions

The initial age distributions for each of the 21 parameter combinations are given in Table B-45. Having the females attain sexual maturity later (Set 2) or earlier (Set 3) results in a substantial decrease (Set 2) or increase (Set 3) in the number of eggs relative to Set 1; differences among the other age classes, however, are minor. Decreasing (Set 4) or increasing (Set 5) the probabilities of natural survival for 1-year-old and older fish not only decreases (Set 4) or increases (Set 5) the number of eggs relative to Set 1, but it also substantially alters the relative number of fish in the other age classes. For instance, although there are nearly twice as many eggs in Set 5 as in Set 4, there are more than a factor of 10 fewer 1-year-olds in Set 5, indicating a relatively small PNSO value for Set 5, which in fact is the case as indicated in Table B-46 (column 3). On the other hand, because of the relatively high natural survival of 1-year-old and older fish for Set 5, the number of fish in the older age groups is more than a factor of 10 greater for Set 5 than for Set 4.

Decreasing the growth rate (Set 6) or increasing the growth rate (Set 7) results in an approximate proportional increase (Set 6) or decrease (Set 7) in the number of fish in each of the age classes. This result is due to the constraint that the steady-state value for TOTP, the fishable biomass, is fixed at the average of TOTP1 and RATIO*TOTP1 aand that this constraint may be satisfied by more small fish or fewer large fish.

Table B-44. Vital statistics for the females in each age class for the 21 sets of parameter combinations *

Sets 1, 4-5, 8-19

AGE	LENGTH	WEIGHT	FMAT	FSUBI	CATCH	AVWT
0	0.0	0.0	0.0	0.0	0.0	3.12E-03
1	1.12E 02	2.62E-02	0.0	0.0	0.0	8.91E-02
2	2.18E 02	2.10E-01	0.0	0.0	0.0	4.03E-01
3	3.17E 02	6.82E-01	0.0	0.0	0.0	1.06E 00
4	4.11E 02	1.53E 00	0.0	0.0	0.698	2.30E 00
5	4.98E 02	2.79E 00	0.0	0.0	1.000	3.59E 00
6	5.79E 02	4.48E 00	0.670	1.41E 05	1.000	5.47E 00
7	6.54E 02	6.56E 00	1.000	2.86E 05	1.000	7.72E 00
8	7.23E 02	8.96E 00	1.000	3.74E 05	1.000	1.03E 01
9	7.86E 02	1.16E 01	1.000	4.71E 05	1.000	1.30E 01
10	8.42E 02	1.44E 01	1.000	5.74E 05	1.000	1.59E 01
11	8.92E 02	1.73E 01	1.000	6.79E 05	1.000	1.87E 01
12	9.36E 02	2.01E 01	1.000	7.82E 05	1.000	2.15E 01
13	9.74E 02	2.28E 01	1.000	8.79E 05	1.000	2.40E 01
14	1.01E 03	2.52E 01	1.000	9.66E 05	1.000	2.63E 01
15	1.03E 03	2.72E 01	1.000	1.04E 06	1.000	2.81E 01

*AGE: age class in years.

LENGTH: average total length (mm) at annulus formation.

WEIGHT: average weight (lbs) at annulus formation.

FMAT: probability of being sexually mature upon entering the indicated age class.

FSUBI (= F_i): average (over both sexually mature and immature females) number of mature "female" eggs in the ovaries upon entering the indicated age class.

CATCH: the effective fraction of the fish in the indicated age class at the beginning of the year that are legally available to the fishery (approximated as the fraction of the year for which the average length is greater than or equal to the minimum legal length, LEGAL).

AVWT: average weight (lbs) at AGE + 1/2 year.

Set 2

AGE	LENGTH	WEIGHT	FMAT	FSUBI	CATCH	AVWT
0	0.0	0.0	0.0	0.0	0.0	3.12E-03
1	1.12E 02	2.62E-02	0.0	0.0	0.0	8.91E-02
2	2.18E 02	2.10E-01	0.0	0.0	0.0	4.03E-01
3	3.17E 02	6.82E-01	0.0	0.0	0.0	1.06E 00
4	4.11E 02	1.53E 00	0.0	0.0	0.698	2.30E 00
5	4.98E 02	2.79E 00	0.0	0.0	1.000	3.59E 00
6	5.79E 02	4.48E 00	0.0	0.0	1.000	5.47E 00
7	6.54E 02	6.56E 00	0.500	1.43E 05	1.000	7.72E 00
8	7.23E 02	8.96E 00	1.000	3.74E 05	1.000	1.03E 01
9	7.86E 02	1.16E 01	1.000	4.71E 05	1.000	1.30E 01
10	8.42E 02	1.44E 01	1.000	5.74E 05	1.000	1.59E 01
11	8.92E 02	1.73E 01	1.000	6.79E 05	1.000	1.87E 01
12	9.36E 02	2.01E 01	1.000	7.82E 05	1.000	2.15E 01
13	9.74E 02	2.28E 01	1.000	8.79E 05	1.000	2.40E 01
14	1.01E 03	2.52E 01	1.000	9.66E 05	1.000	2.63E 01
15	1.03E 03	2.72E 01	1.000	1.04E 06	1.000	2.81E 01

Set 3

AGE	LENGTH	WEIGHT	FMAT	FSUBI	CATCH	AVWT
0	0.0	0.0	0.0	0.0	0.0	3.12E-03
1	1.12E 02	2.62E-02	0.0	0.0	0.0	8.91E-02
2	2.18E 02	2.10E-01	0.0	0.0	0.0	4.03E-01
3	3.17E 02	6.82E-01	0.0	0.0	0.0	1.06E 00
4	4.11E 02	1.53E 00	0.0	0.0	0.698	2.30E 00
5	4.98E 02	2.79E 00	0.500	7.43E 04	1.000	3.59E 00
6	5.79E 02	4.48E 00	1.000	2.10E 05	1.000	5.47E 00
7	6.54E 02	6.56E 00	1.000	2.86E 05	1.000	7.72E 00
8	7.23E 02	8.96E 00	1.000	3.74E 05	1.000	1.03E 01
9	7.86E 02	1.16E 01	1.000	4.71E 05	1.000	1.30E 01
10	8.42E 02	1.44E 01	1.000	5.74E 05	1.000	1.59E 01
11	8.92E 02	1.73E 01	1.000	6.79E 05	1.000	1.87E 01
12	9.36E 02	2.01E 01	1.000	7.82E 05	1.000	2.15E 01
13	9.74E 02	2.28E 01	1.000	8.79E 05	1.000	2.40E 01
14	1.01E 03	2.52E 01	1.000	9.66E 05	1.000	2.63E 01
15	1.03E 03	2.72E 01	1.000	1.04E 06	1.000	2.81E 01

Set 6

AGE	LENGTH	WEIGHT	FMAT	FSUBI	CATCH	AVWT
0	0.0	0.0	0.0	0.0	0.0	2.38E-03
1	1.02E 02	1.96E-02	0.0	0.0	0.0	6.58E-02
2	1.97E 02	1.52E-01	0.0	0.0	0.0	2.88E-01
3	2.83E 02	4.77E-01	0.0	0.0	0.0	7.25E-01
4	3.62E 02	1.03E 00	0.0	0.0	0.0	1.39E 00
5	4.33E 02	1.80E 00	0.0	0.0	0.929	2.30E 00
6	4.97E 02	2.77E 00	0.670	9.89E 04	1.000	3.30E 00
7	5.52E 02	3.85E 00	1.000	1.87E 05	1.000	4.42E 00
8	6.00E 02	5.00E 00	1.000	2.29E 05	1.000	5.56E 00
9	6.40E 02	6.11E 00	1.000	2.70E 05	1.000	6.64E 00
10	6.72E 02	7.13E 00	1.000	3.07E 05	1.000	7.58E 00
11	6.96E 02	7.97E 00	1.000	3.38E 05	1.000	8.31E 00
12	7.13E 02	8.58E 00	1.000	3.60E 05	1.000	8.79E 00
13	7.22E 02	8.92E 00	1.000	3.72E 05	1.000	8.98E 00
14	7.23E 02	8.95E 00	1.000	3.74E 05	1.000	8.87E 00
15	7.16E 02	8.70E 00	1.000	3.64E 05	1.000	8.47E 00

Set 7

AGE	LENGTH	WEIGHT	FMAT	FSUBI	CATCH	AVWT
0	0.0	0.0	0.0	0.0	0.0	4.00E-03
1	1.22E 02	3.40E-02	0.0	0.0	0.0	1.17E-01
2	2.39E 02	2.81E-01	0.0	0.0	0.0	5.47E-01
3	3.52E 02	9.39E-01	0.0	0.0	0.205	2.02E 00
4	4.60E 02	2.17E 00	0.0	0.0	1.000	3.04E 00
5	5.63E 02	4.10E 00	0.0	0.0	1.000	5.35E 00
6	6.62E 02	6.81E 00	0.670	1.98E 05	1.000	8.46E 00
7	7.56E 02	1.03E 01	1.000	4.24E 05	1.000	1.24E 01
8	8.46E 02	1.47E 01	1.000	5.82E 05	1.000	1.71E 01
9	9.31E 02	1.98E 01	1.000	7.70E 05	1.000	2.27E 01
10	1.01E 03	2.57E 01	1.000	9.84E 05	1.000	2.89E 01
11	1.09E 03	3.22E 01	1.000	1.22E 06	1.000	3.57E 01
12	1.16E 03	3.93E 01	1.000	1.48E 06	1.000	4.30E 01
13	1.23E 03	4.68E 01	1.000	1.76E 06	1.000	5.07E 01
14	1.29E 03	5.47E 01	1.000	2.04E 06	1.000	5.87E 01
15	1.35E 03	6.27E 01	1.000	2.34E 06	1.000	6.68E 01

Table B-44 (continued)

Set 20

AGE	LENGTH	WEIGHT	FMAT	FSUBI	CATCH	AVWT
0	0.0	0.0	0.0	0.0	0.0	3.12E-03
1	1.12E 02	2.62E-02	0.0	0.0	0.0	8.91E-02
2	2.18E 02	2.10E-01	0.0	0.0	0.0	4.03E-01
3	3.17E 02	6.82E-01	0.0	0.0	0.786	1.15E 00
4	4.11E 02	1.53E 00	0.0	0.0	1.000	2.11E 00
5	4.98E 02	2.79E 00	0.0	0.0	1.000	3.59E 00
6	5.79E 02	4.48E 00	0.670	1.41E 05	1.000	5.47E 00
7	6.54E 02	6.56E 00	1.000	2.86E 05	1.000	7.72E 00
8	7.23E 02	8.96E 00	1.000	3.74E 05	1.000	1.03E 01
9	7.86E 02	1.16E 01	1.000	4.71E 05	1.000	1.30E 01
10	8.42E 02	1.44E 01	1.000	5.74E 05	1.000	1.59E 01
11	8.92E 02	1.73E 01	1.000	6.79E 05	1.000	1.87E 01
12	9.36E 02	2.01E 01	1.000	7.82E 05	1.000	2.15E 01
13	9.74E 02	2.28E 01	1.000	8.79E 05	1.000	2.40E 01
14	1.01E 03	2.52E 01	1.000	9.66E 05	1.000	2.63E 01
15	1.03E 03	2.72E 01	1.000	1.04E 06	1.000	2.81E 01

Set 21

AGE	LENGTH	WEIGHT	FMAT	FSUBI	CATCH	AVWT
0	0.0	0.0	0.0	0.0	0.0	3.12E-03
1	1.12E 02	2.62E-02	0.0	0.0	0.0	8.91E-02
2	2.18E 02	2.10E-01	0.0	0.0	0.0	4.03E-01
3	3.17E 02	6.82E-01	0.0	0.0	0.0	1.06E 00
4	4.11E 02	1.53E 00	0.0	0.0	0.0	2.11E 00
5	4.98E 02	2.79E 00	0.0	0.0	0.519	4.00E 00
6	5.79E 02	4.48E 00	0.670	1.41E 05	1.000	5.47E 00
7	6.54E 02	6.56E 00	1.000	2.86E 05	1.000	7.72E 00
8	7.23E 02	8.96E 00	1.000	3.74E 05	1.000	1.03E 01
9	7.86E 02	1.16E 01	1.000	4.71E 05	1.000	1.30E 01
10	8.42E 02	1.44E 01	1.000	5.74E 05	1.000	1.59E 01
11	8.92E 02	1.73E 01	1.000	6.79E 05	1.000	1.87E 01
12	9.36E 02	2.01E 01	1.000	7.82E 05	1.000	2.15E 01
13	9.74E 02	2.28E 01	1.000	8.79E 05	1.000	2.40E 01
14	1.01E 03	2.52E 01	1.000	9.66E 05	1.000	2.63E 01
15	1.03E 03	2.72E 01	1.000	1.04E 06	1.000	2.81E 01

Table B-45. Initial age distribution vectors (number of fish in the indicated age class at the beginning of the year) for each of the 21 parameter combinations [a]

Age Class	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Set 7
0	5.21389E 10	3.49930E 10	6.73960E 10	3.41222E 10	6.00367E 10	6.53272E 10	4.80997E 10
1	1.10843E 06	1.10277E 06	1.10405E 06	8.64803E 06	3.24306E 05	1.78513E 06	7.64793E 05
2	4.43348E 05	4.41112E 05	4.41558E 05	1.72955E 06	1.94611E 05	7.14064E 05	3.05877E 05
3	2.65995E 05	2.64677E 05	2.64893E 05	6.91791E 05	1.55711E 05	4.28448E 05	1.83504E 05
4	2.12785E 05	2.11753E 05	2.11878E 05	4.15057E 05	1.40162E 05	3.42765E 05	1.38067E 05
5	1.35709E 05	1.35118E 05	1.35165E 05	1.98545E 05	1.00588E 05	2.74217E 05	7.84090E 04
6	7.70148E 04	7.67350E 04	7.67444E 04	8.45133E 04	6.42340E 04	1.60112E 05	4.45285E 04
7	4.37057E 04	4.35778E 04	4.35754E 04	3.59747E 04	4.10193E 04	9.08432E 04	2.52867E 04
8	2.48026E 04	2.47469E 04	2.47427E 04	1.53132E 04	2.61947E 04	5.15424E 04	1.43592E 04
9	1.40752E 04	1.40526E 04	1.40496E 04	6.51816E 03	1.67275E 04	2.92442E 04	8.15398E 03
10	7.98767E 03	7.97995E 03	7.97777E 03	2.77449E 03	1.06813E 04	1.65926E 04	4.63062E 03
11	4.53312E 03	4.53173E 03	4.53003E 03	1.18098E 03	6.82010E 03	9.41427E 03	2.63004E 03
12	2.57272E 03	2.57363E 03	2.57233E 03	5.02707E 02	4.35439E 03	5.34132E 03	1.49397E 03
13	1.46015E 03	1.46164E 03	1.46074E 03	2.13999E 02	2.78013E 03	3.03043E 03	8.48654E 02
14	8.28691E 02	8.30130E 02	8.29570E 02	9.10994E 01	1.77514E 03	1.71932E 03	4.82007E 02
15	1.08745E 03	1.09091E 03	1.09053E 03	6.75217E 01	3.13515E 03	2.25477E 03	6.33476E 02

Age Class	Set 8	Set 9	Set 10	Set 11	Set 12	Set 13	Set 14
0	5.20235E 09	5.20449E 11	3.89995E 10	7.82182E 10	4.33313E 10	4.03120E 10	5.33430E 10
1	1.10310E 05	1.10334E 07	8.27188E 05	1.66116E 06	1.52749E 06	1.69358E 06	1.04927E 06
2	4.41219E 04	4.41350E 06	3.30744E 05	6.64490E 05	6.10932E 05	6.77418E 05	4.19714E 05
3	2.64717E 04	2.64818E 06	1.98371E 05	3.98710E 05	3.66521E 05	4.06440E 05	2.51831E 05
4	2.11761E 04	2.11861E 06	1.58648E 05	3.18979E 05	2.93184E 05	3.25145E 05	2.01468E 05
5	1.35109E 04	1.35176E 06	1.01231E 05	2.03466E 05	1.72010E 05	1.84913E 05	1.30035E 05
6	7.67236E 03	7.67610E 05	5.75008E 04	1.15488E 05	8.50276E 04	8.66334E 04	7.52203E 04
7	4.35688E 03	4.35895E 05	3.26565E 04	6.55512E 04	4.20307E 04	4.05885E 04	4.35121E 04
8	2.47415E 03	2.47529E 05	1.85422E 04	3.72074E 04	2.07766E 04	1.90156E 04	2.51701E 04
9	1.40502E 03	1.40562E 05	1.05272E 04	2.11192E 04	1.02704E 04	8.90864E 03	1.45599E 04
10	7.97887E 02	7.98196E 04	5.97782E 03	1.19874E 04	5.07706E 03	4.17360E 03	8.42236E 03
11	4.53110E 02	4.53255E 04	3.39631E 03	6.60395E 03	2.50984E 03	1.95531E 03	4.87201E 03
12	2.57317E 02	2.57375E 04	1.93116E 03	3.86178E 03	1.24076E 03	9.16104E 02	2.81827E 03
13	1.46128E 02	1.46145E 04	1.09852E 03	2.19183E 03	6.13382E 02	4.29242E 02	1.63026E 03
14	8.29854E 01	8.29860E 03	6.24513E 02	1.24404E 03	3.03231E 02	2.01119E 02	9.43043E 02
15	1.09075E 02	1.09042E 04	8.21218E 02	1.63299E 03	2.96482E 02	1.77285E 02	1.29410E 03

Table B-45. (continued)

Age Class	Set 15	Set 16	Set 17	Set 18	Set 19	Set 20	Set 21
0	5.26414E 10	5.30446E 10	5.09005E 10	6.15681E 10	6.00938E 10	4.45583E 10	6.70599E 10
1	1.08073E 06	1.05393E 06	1.16246E 06	6.77211E 05	7.42228E 05	1.37917E 06	9.49117E 05
2	4.32291E 05	4.21458E 05	4.64983E 05	2.70900E 05	2.96888E 05	5.51690E 05	3.79626E 05
3	2.59375E 05	2.52807E 05	2.78989E 05	1.62550E 05	1.78131E 05	3.31025E 05	2.27763E 05
4	2.07500E 05	2.02196E 05	2.23191E 05	1.30049E 05	1.42503E 05	2.04323E 05	1.82200E 05
5	1.33053E 05	1.30312E 05	1.40754E 05	9.11040E 04	9.83146E 04	1.15957E 05	1.45752E 05
6	7.61631E 04	7.52141E 04	7.84371E 04	5.98932E 04	6.31395E 04	6.58074E 04	9.90048E 04
7	4.35977E 04	4.34099E 04	4.37106E 04	3.93748E 04	4.05493E 04	3.73481E 04	5.61967E 04
8	2.49564E 04	2.50518E 04	2.43587E 04	2.58855E 04	2.60415E 04	2.11971E 04	3.18981E 04
9	1.42857E 04	1.44571E 04	1.35743E 04	1.70174E 04	1.67243E 04	1.20306E 04	1.81058E 04
10	8.17748E 03	8.34380E 03	7.56448E 03	1.11874E 04	1.07407E 04	6.82788E 03	1.02772E 04
11	4.68099E 03	4.81675E 03	4.21536E 03	7.35455E 03	6.89800E 03	3.87483E 03	5.83363E 03
12	2.67952E 03	2.78152E 03	2.34898E 03	4.83484E 03	4.43014E 03	2.19880E 03	3.31143E 03
13	1.53382E 03	1.60649E 03	1.30897E 03	3.17840E 03	2.84518E 03	1.24770E 03	1.87977E 03
14	8.78000E 02	9.27641E 02	7.29468E 02	2.08948E 03	1.82725E 03	7.08062E 02	1.06707E 03
15	1.17544E 03	1.26675E 03	9.18230E 02	4.00922E 03	3.28008E 03	9.29316E 02	1.40102E 03

[a]Number in age class 0 is the total number of mature "female" eggs in the ovaries of all sexually mature females combined.

Table B-46. Summary of steady-state solutions with PPO = 1.0

Parameter	Set	PNSO[a]	TOTP[b]	YIELD[c]	n_0[d]	n_1[e]	RCRTN[f]	RSN[g]	PSF[h]
	1	2.1E–5	2.0E6	6.0E5	5.2E10	1.1E6	2.0E5	1.5E5	0.71
FMAT	2	3.2E–5	2.0E6	5.9E5	3.5E10	1.1E6	2.0E5	7.9E4	0.71
	1	2.1E–5	2.0E6	6.0E5	5.2E10	1.1E6	2.0E5	1.5E5	0.71
	3	1.6E–5	2.0E6	6.0E5	6.7E10	1.1E6	2.0E5	2.5E5	0.71
PNS_j	4	2.5E–4	2.0E6	5.2E5	3.4E10	8.7E6	3.6E5	1.2E5	0.71
	1	2.1E–5	2.0E6	6.0E5	5.2E10	1.1E6	2.0E5	1.5E5	0.71
	5	5.4E–6	2.0E6	6.3E5	6.0E10	3.2E5	1.4E5	1.6E5	0.71
B,C	6	2.6E–5	2.0E6	5.9E5	6.5E10	1.8E6	2.7E5	3.2E5	0.71
	1	2.1E–5	2.0E6	6.0E5	5.2E10	1.1E6	2.0E5	1.5E5	0.71
	7	1.6E–5	2.0E6	6.2E5	4.8E10	7.7E5	1.5E5	8.8E4	0.71
TOTP1	8	2.1E–5	2.0E5	5.9E4	5.2E9	1.1E5	2.0E4	1.5E4	0.71
	1	2.1E–5	2.0E6	6.0E5	5.2E10	1.1E6	2.0E5	1.5E5	0.71
	9	2.1E–5	2.0E7	5.9E6	5.2E11	1.1E7	2.0E6	1.5E6	0.71
RATIO	10	2.1E–5	1.5E6	4.5E5	3.9E10	8.3E5	1.5E5	1.1E5	0.71
	1	2.1E–5	2.0E6	6.0E5	5.2E10	1.1E6	2.0E5	1.5E5	0.71
	11	2.1E–5	3.0E6	8.9E5	7.8E10	1.7E6	3.0E5	2.3E5	0.71
D, PMIN,	12	3.5E–5	2.0E6	7.8E5	4.3E10	1.5E6	2.8E5	1.4E5	0.62
	13	4.2E–5	2.0E6	8.5E5	4.0E10	1.7E6	3.0E5	1.3E5	0.58
PMAX	14	2.0E–5	2.0E6	5.7E5	5.3E10	1.0E6	1.9E5	1.5E5	0.72
	15	2.0E–5	2.0E6	5.8E5	5.3E10	1.1E6	2.0E5	1.5E5	0.72
	1	2.1E–5	2.0E6	6.0E5	5.2E10	1.1E6	2.0E5	1.5E5	0.71
	16	2.0E–5	2.0E6	5.8E5	5.3E10	1.1E6	1.9E5	1.5E5	0.72
	17	2.3E–5	2.0E6	6.2E5	5.1E10	1.2E6	2.1E5	1.5E5	0.70
	18	1.1E–5	2.0E6	3.6E5	6.2E10	6.8E5	1.2E5	1.5E5	0.82
	19	1.2E–5	2.0E6	4.0E5	6.0E10	7.4E5	1.3E5	1.6E5	0.80
LEGAL	20	3.1E–5	2.0E6	6.3E5	4.4E10	1.4E6	3.2E5	1.3E5	0.71
	1	2.1E–5	2.0E6	6.0E5	5.2E10	1.1E6	2.0E5	1.5E5	0.71
	21	1.4E–5	2.0E6	5.6E5	6.7E10	9.5E5	1.3E5	2.0E5	0.71

[a]PNSO = probability of survival from causes of natural mortality for 0-year old striped bass.
[b]TOTP = total female biomass (pounds) legally available to the fishery.
[c]YIELD = yield (pounds/year) of female striped bass to the fisheries.
[d]n_0 = number of eggs.
[e]n_1 = number of 1-year olds.
[f]RCRTN = number of female striped bass recruited to the fishery each year.
[g]RSN = number of spawners.
[h]PSF = probability of surviving fishing.

The age distributions for Sets 8 and 9 indicate that changes in TOTP1 result in exactly comparable changes in the number of fish in each of the age classes. In other words, changing TOTP1 without changing RATIO or the survival-fecundity relationships in the population results in exactly the same translation (i.e., by a factor of 10) of the steady-state value of TOTP and of the number of fish in each age class. Changing RATIO (Sets 10 and 11) has a similar effect to changing TOTP1, although changing RATIO alters the ratio of the steady-state value of TOTP to TOTP1 so that decreases (Set 10) and increases (Set 11) in the number of fish in each age class are not proportional to the change in RATIO.

The parameter changes in Sets 12 to 19 result in changing the steady-state PSF value (Table B-46, column 8), which in turn changes the steady-state PNSO value (Table B-47, column 3) in order to satisfy the constraint that the steady-state TOTP equal the average of TOTP1 and RATIO*TOTP1. Thus, the highest PSF (lowest fishing mortality) and lowest PNSO are paired (Set 18), as are the lowest PSF (highest fishing mortality) and the highest PNSO (Set 13). The age distributions reflect this counter-balancing of PNSO and PSF. For example, Set 13 has fewer eggs but more 1-year-olds than Set 18 because for Set 13 the probability of survival of eggs is higher (4.2E-5 vs 1.1E-5).* However, Set 13 has 4.1E5* 3-year-olds and only 1.8E2 15-year-olds as compared to 1.6E5 3-year-olds and 4.0E3 15-year-olds for Set 18. The higher survival of adult striped bass for Set 18 is due to the higher value of PSF (0.82 vs 0.58).

Sets 20 and 21 illustrate an effect on the age distribution similar to Sets 13 and 18 but without altering PSF (note column 8 of Table B-46). Changes in LEGAL do not alter the fishing control function per se but rather alter the number of age classes legally available to the fishery such that the probability of surviving fishing from age at recruitment through age class 15 is altered. As with other parameter changes, changes that alter the survival-fecundity balance of the population are balanced by changes in PNSO (note column 3 of Table B-46).

(iii) <u>Yield and Other Output Variables</u>

The values of eight of the output variables are given in Table B-46 for each of the 21 parameter combinations. Reference has already been made to PSF and PNSO values and the number of eggs and 1-year-olds in this table in discussing the differences among the age distributions in the previous subsection. TOTP, again, is

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*4.2E-5 means 4.2×10^{-5}; 4.1E5 means 4.1×10^{5}.

Table B-47. Summary of RO runs – relative yield at the end of 40 years

Parameter	Set	Fractional change in survival of young-of-the-year (PPO – 1.0)						
		−0.75	−0.50	−0.25	−0.10	0.0	0.10	0.25
	1	0.04	0.25	0.59	0.83	1.00	1.18	1.47
FMAT	2	0.07	0.32	0.65	0.86	1.00	1.14	1.36
	1	0.04	0.25	0.59	0.83	1.00	1.18	1.47
	3	0.03	0.20	0.54	0.80	1.00	1.22	1.59
PNS_i	4	0.01	0.13	0.49	0.78	1.00	1.24	1.65
	1	0.04	0.25	0.59	0.83	1.00	1.18	1.47
	5	0.09	0.33	0.65	0.86	1.00	1.15	1.39
B,C	6	0.02	0.16	0.50	0.78	1.00	1.24	1.67
	1	0.04	0.25	0.59	0.83	1.00	1.18	1.47
	7	0.06	0.31	0.64	0.85	1.00	1.15	1.39
TOTP1	8	0.04	0.25	0.59	0.83	1.00	1.18	1.47
	1	0.04	0.25	0.59	0.83	1.00	1.18	1.47
	9	0.04	0.25	0.59	0.83	1.00	1.18	1.47
RATIO	10	0.05	0.34	0.66	0.86	1.00	1.14	1.37
	1	0.04	0.25	0.59	0.83	1.00	1.18	1.47
	11	0.03	0.20	0.54	0.80	1.00	1.21	1.56
D, PMIN,	12	0.02	0.17	0.51	0.79	1.00	1.22	1.60
PMAX	13	0.05	0.38	0.68	0.87	1.00	1.14	1.39
	14	0.01	0.07	0.34	0.67	1.00	1.43	2.34
	15	0.01	0.09	0.40	0.71	1.00	1.39	2.28
	1	0.04	0.25	0.59	0.83	1.00	1.18	1.47
	16	0.04	0.26	0.61	0.84	1.00	1.16	1.39
	17	0.11	0.45	0.74	0.90	1.00	1.10	1.24
	18	0.02	0.16	0.49	0.78	1.00	1.24	1.63
	19	0.04	0.27	0.62	0.85	1.00	1.16	1.41
LEGAL	20	0.06	0.33	0.66	0.86	1.00	1.14	1.36
	1	0.04	0.25	0.59	0.83	1.00	1.18	1.47
	21	0.02	0.18	0.51	0.78	1.00	1.24	1.68

the steady-state biomass available to the fishery and is defined as the average of TOTP1 and RATIO*TOTP1. Thus, the only parameter change that alters TOTP is a change in RATIO (Sets 10 and 11). Shifts in TOTP, of course, result in shifts in the same direction of yield to the fishery (YIELD), number of recruits (RCRTN), and number of spawners (RSN). Sets 12 to 19 illustrate that there is a close relationship between the probability of surviving fishing (column 8) and yield (column 3). For example, Set 13 has the lowest probability of surviving fishing (0.58) and the highest annual yield (8.5E5 = 8.5 x 10^5 pounds per year), whereas Set 18 has the highest probability of surviving fishing (0.82) and the lowest annual yield (3.6E5 = 3.6 x 10^5 pounds per year).

For Sets 12 to 19 the number of female striped bass recruited to the fishery each year (column 6) shows a pattern similar to the YIELD values. However, the number of spawners in Sets 12 to 19 (column 7) shows very little variation. This lack of change in number of spawners is somewhat misleading since the importance of spawners is in their egg production, which is more a function of total weight of spawners than of their number. The n_o values (Table B-46, column 4) illustrate that the 1.5E5 spawners in Set 18 are not equivalent to the 1.5E5 spawners in Set 17, because the spawners in Set 18 produce approximately 1.1E10 more eggs. This difference, in turn, suggests that there are more older and larger fish in Set 18 than in Set 17, a suggestion that is verified by examining the two age distributions in Table B-45.

As commented on earlier, a comparison of the output from the steady-state runs with PPO = 1.0 is of value in pointing out the different effects of the 21 parameter combinations under non-stress conditions. Equally important is that such a comparison familiarizes the reader with the names and definitions of the parameters, and it illustrates that the qualitative and semiquantitative response of the model to parameter changes is predictable and reasonable.

(b) RO Runs

The parameter space for the staff's striped bass, life-cycle model has 47 dimensions, one for each of the 47 parameters. For the purpose of discussion, this parameter space may be collapsed to three dimensions (Fig. B-46), one dimension for fecundity [encompassing all the parameters discussed in Section B.4.c(5)(a)] and a second dimension for survival (encompassing all the parameters dealing with the probability of survival from fishing and from sources of natural mortality). The third dimension is the percentage change in the probability of survival of 0-year-old striped bass due to operation of power plants [100(PPO - 1.0)]; 0% along this axis means no net change or impact, a negative value means a

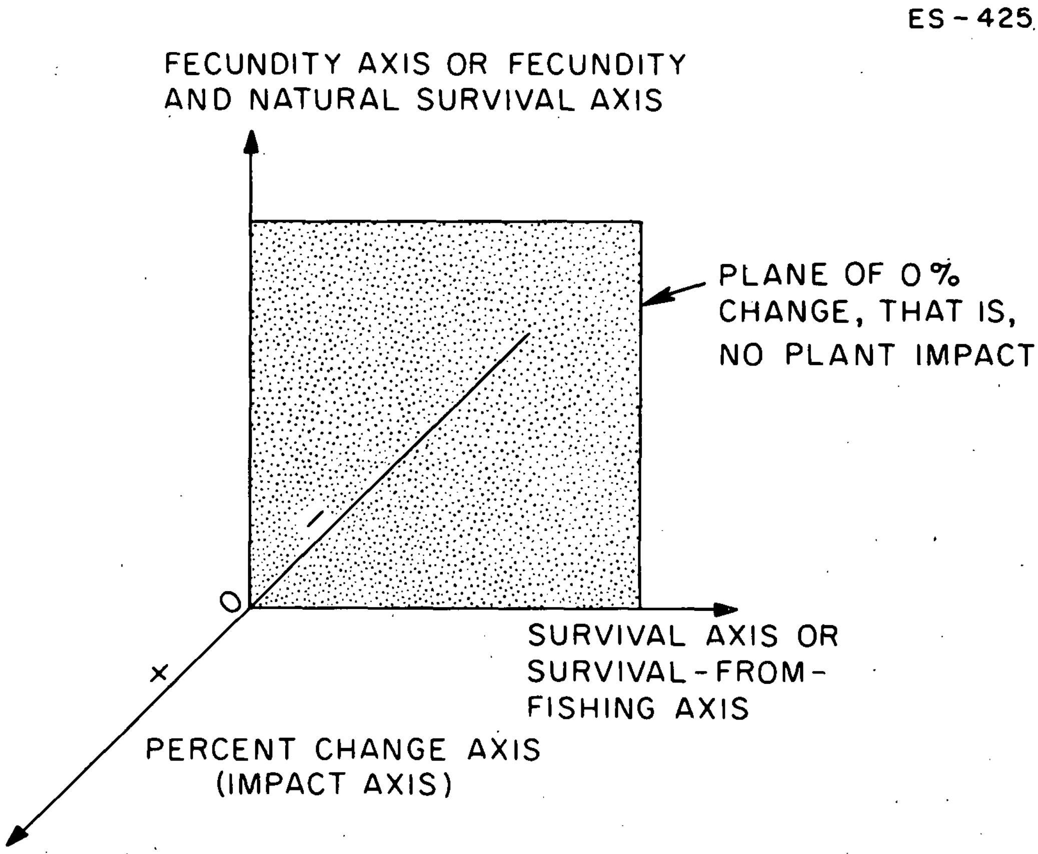

Fig. B-46. A simplified representation of the parameter space of the staff's striped bass, life-cycle model.

percentage reduction, and a positive value means a percentage increase. In Section B.4.c(7)(a) the behavior of the model was considered at 21 points in this three-dimensional parameter space, all in the plane of 100(PPO - 1.0) = 0% reduction, i.e., PPO = 1.0. In this section the behavior of the model in response to changes in PPO alone is considered for each of these 21 parameter combinations.

Figures B-47 and B-48 illustrate the standard output using the staff's best estimates for all parameters (Set 1). Relative yield vs time in years is plotted in Fig. B-47, while relative number of 1-year-olds vs years is plotted in Fig. B-48. The Y-axis scale in both cases is relative to 0% change in the probability of survival of 0-year-old striped bass. At year 0, (PPO - 1.0) was assigned one of the seven values indicated in the figure captions.

Certain general features of the curves merit comment:

(1) There is no change in relative yield until after the third year.

(2) There is a change in relative number of 1-year-olds after the first year.

(3) The rate of change of either relative yield or relative number of 1-year-olds steadily decreases, and if the % change is not too great, approaches a new steady state. The less the % change the more quickly the new steady state is approached.

A new steady state is reached due to the density-dependent fishing function (Figs. B-41 to B-43). That this function behaves in a compensatory manner is illustrated in Fig. B-49. If there were no compensation, the plotted points would all fall on the horizontal line through 0.0 on the Y-axis. The greater the deviation between the plotted curves and this horizontal line, the greater the compensation. The sequence of curves in going from 5 years to 40 years clearly indicates that, in response to a constant decrease in the probability of survival of 0-year-old striped bass, there is a compensatory increase in the probability of survival of adults from fishing. Conversely, in response to an increase in the probability of survival of 0-year-old fish, due possibly to extensive stocking of fingerling striped bass as proposed by the applicant, there is a compensatory decrease in the probability of surviving fishing due to the increased fishing effort, resulting from an increase in the size of the striped bass population.

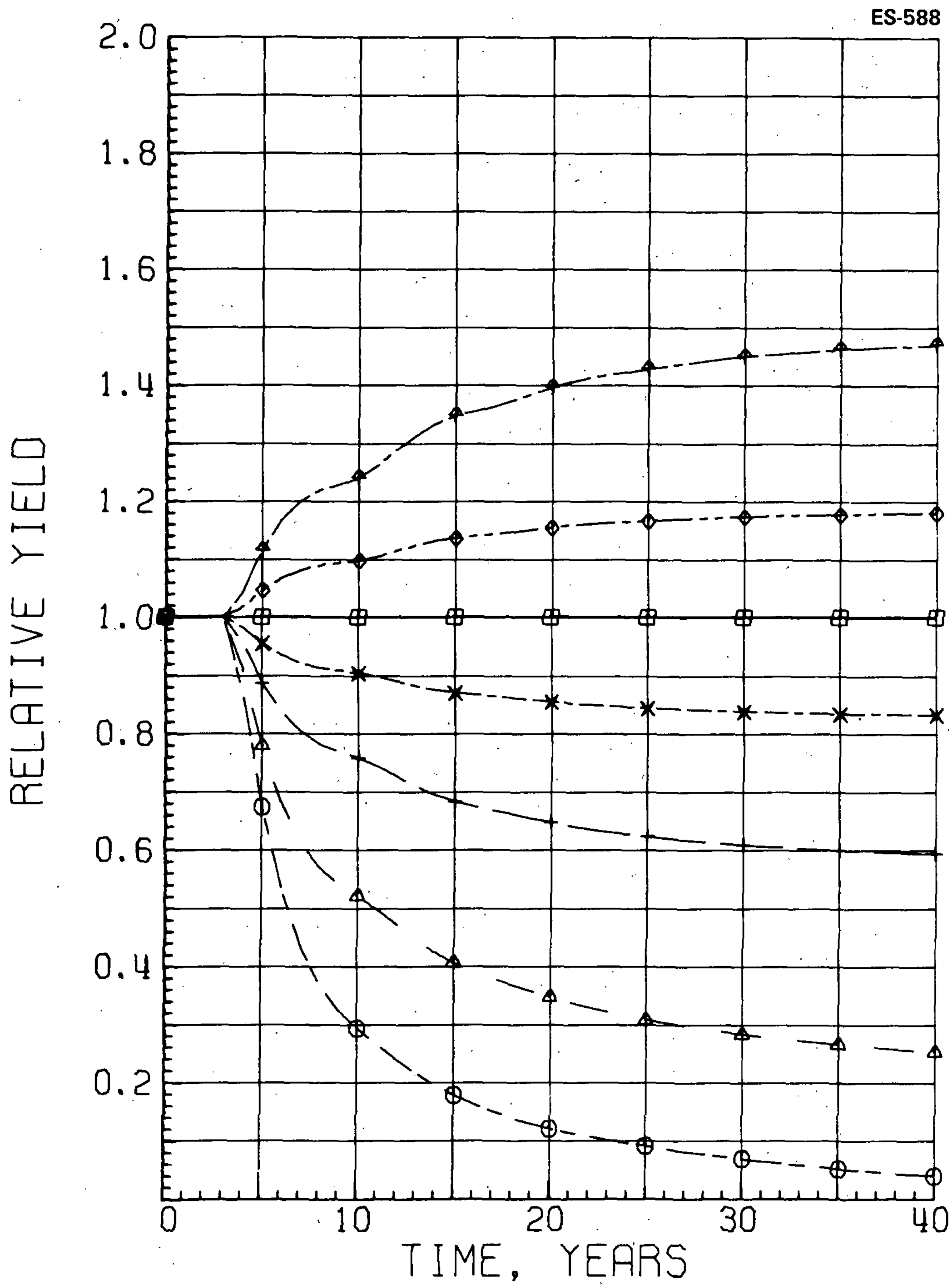

Fig. B-47. Curves of relative yield vs time for seven values of (PPO − 1.0): □ = 0.0, ○ = −0.75, △ = −0.50, + = −0.25 × = −0.10, ◊ = 0.10, △ = 0.25.

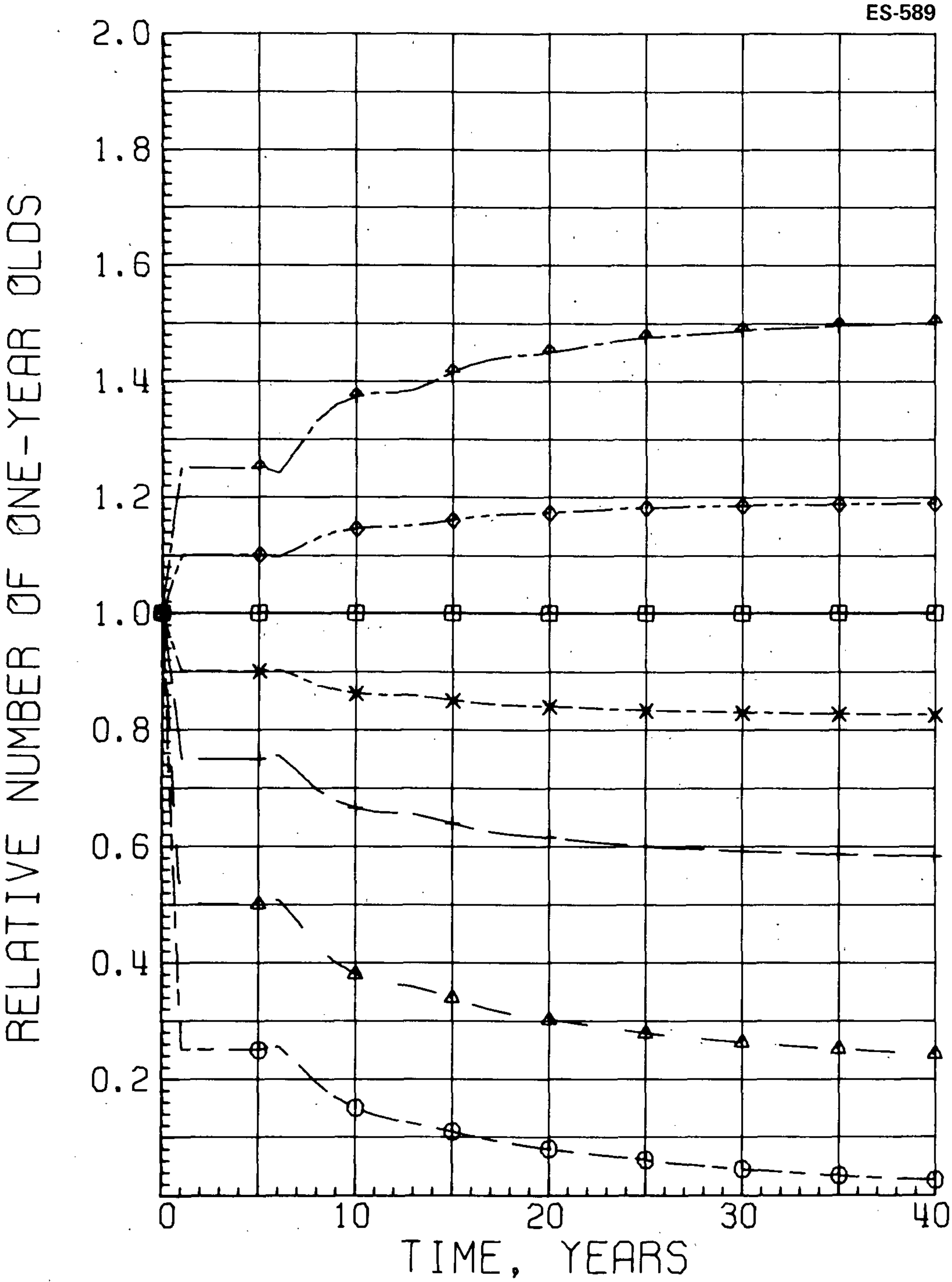

Fig. B-48. Curves of relative number of one-year-olds for seven values of (PPO − 1.0): □ = 0.0, ○ = −0.75, △ = −0.50, + = −0.25, × = −0.10, ◊ = 0.10, ⍋ = 0.25.

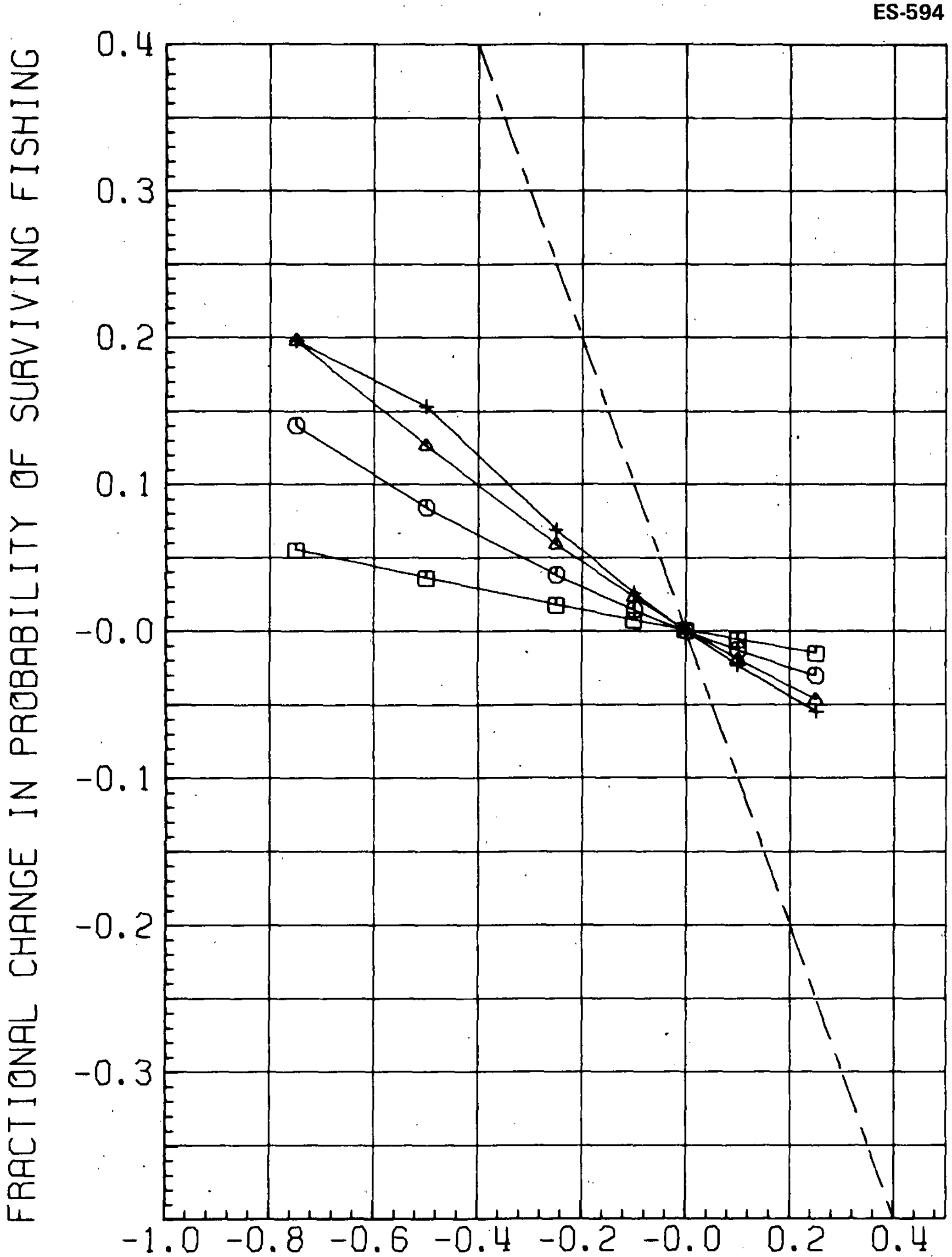

Fig. B-49. Curves of fractional change in probability of surviving fishing vs fractional change in survival probability for age class 0 (PPO — 1.0) after 5 (□), 10 (○), 20 (△), and 40 (+) years. The deviation from the horizontal line through 0.0 on the Y-axis is a measure of the degree of compensation by the fishery.

A final point illustrated by Fig. B-49 is that the fractional reduction in survival probability for age class 0 can be great enough that, if it is continued for long enough, the compensatory limits of the density-dependent fishing function are exceeded and the striped bass population in the model is doomed to extinction. In Fig. B-49 this situation is indicated by the superposition of the 20-year and 40-year points for (PPO - 1.0) = 0.75, because for Parameter Set 1 a value of 0.20 for the fractional change in probability of surviving fishing means that the probability of surviving fishing has increased to PMAX, the maximum probability of surviving fishing and the upper bound of the density-dependent fishing function.

Tables B-47 and B-48 give values for relative yield and relative number of 1-year-olds after 40 years for each of the 21 parameter combinations for each of six values of fractional change (multiplication by 100 gives percentage change) in survival of young-of-the year, in addition to the reference case of 0% change. The 21 parameter combinations can be grouped in order of decreasing sensitivity to (PPO - 1.0) values: Sets 12 to 19 (most sensitive), Sets 20 to 21, Sets 6 to 7, Sets 4 to 5, Sets 2 to 3, Sets 10 to 11, and Sets 8 to 9 (least sensitive). Actually, compared to the range of values for relative yield and relative number 1-year-olds for Sets 12 to 19 at a given level of (PPO - 1.0), the differences among all other sets are not very great. In addition, the results for Sets 8 to 9 indicate that changes in relative yield and relative number of 1-year-olds is entirely independent of TOTP1.

Thus, this analysis suggests that further analysis need not focus on the sensitivity of percentage reduction values to fraction mature (FMAT), probabilities of survival from sources of natural mortality (PNS), growth rate of individuals (B,C), magnitude of the fluctuations in the size of the striped bass population (RATIO), or the legal length limit for keeping striped bass (LEGAL).

Returning to the 3-dimensional representation of the parameter space for the model, these results suggest redefining the first two dimensions as follows: one dimension (X-axis) for survival from fishing (encompassing the parameters PMAX, PMIN, and D) and the second dimension (Y-axis) encompassing all the other parameters (Fig. B-46). The results of the RO runs with a range of (PPO - 1.0) values indicate that forecasts of impact are considerably more dependent on where the staff assumes the population is along the X-axis than along the Y-axis. Stated another way, using the forecasts of relative yield and relative number of 1-year-olds as criteria, it appears that the data available are more adequate and the degree of uncertainty is less for all parameters other than PMAX, PMIN, and D.

Table B-48. Summary of RO runs – relative number of 1-year olds at the end of 40 years

Parameter	Set	Fractional change in survival of young-of-the-year (PPO – 1.0)						
		–0.75	–0.50	–0.25	–0.10	0.0	0.10	0.25
	1	0.03	0.24	0.58	0.82	1.00	1.19	1.50
FMAT	2	0.07	0.32	0.65	0.86	1.00	1.14	1.36
	1	0.03	0.24	0.58	0.82	1.00	1.19	1.50
	3	0.02	0.19	0.53	0.80	1.00	1.23	1.64
PNS_i	4	0.01	0.17	0.54	0.81	1.00	1.21	1.57
	1	0.03	0.24	0.58	0.82	1.00	1.19	1.50
	5	0.05	0.28	0.60	0.83	1.00	1.18	1.47
B,C	6	0.01	0.17	0.52	0.79	1.00	1.24	1.66
	1	0.03	0.24	0.58	0.82	1.00	1.19	1.50
	7	0.04	0.29	0.62	0.84	1.00	1.17	1.44
TOTP1	8	0.03	0.24	0.58	0.82	1.00	1.19	1.50
	1	0.03	0.24	0.58	0.82	1.00	1.19	1.50
	9	0.03	0.24	0.58	0.82	1.00	1.19	1.50
RATIO	10	0.03	0.34	0.66	0.86	1.00	1.15	1.39
	1	0.03	0.24	0.58	0.82	1.00	1.19	1.50
	11	0.02	0.18	0.52	0.80	1.00	1.22	1.60
D, PMIN,	12	0.01	0.14	0.49	0.78	1.00	1.24	1.65
PMAX	13	0.04	0.35	0.66	0.86	1.00	1.16	1.43
	14	0.00	0.05	0.29	0.64	1.00	1.50	2.60
	15	0.00	0.06	0.37	0.69	1.00	1.45	2.54
	1	0.03	0.24	0.58	0.82	1.00	1.19	1.50
	16	0.03	0.25	0.60	0.84	1.00	1.16	1.42
	17	0.15	0.44	0.73	0.89	1.00	1.11	1.27
	18	0.02	0.16	0.50	0.78	1.00	1.23	1.62
	19	0.06	0.33	0.65	0.86	1.00	1.15	1.40
LEGAL	20	0.05	0.30	0.63	0.85	1.00	1.16	1.41
	1	0.03	0.24	0.58	0.82	1.00	1.19	1.50
	21	0.01	0.17	0.50	0.78	1.00	1.25	1.72

(c) RC Runs

Table B-49 gives twenty-four cases, each having a set of PPO values and durations, classified as follows:

1. Three alternatives for Indian Point Units Nos. 2 and 3, viz., cooling towers at both units (Alternative B), a cooling tower at Unit No. 2 and once-through cooling at Unit No. 3 (Alternative A), and once-through cooling at both Units Nos. 2 and 3 (base design). The time sequence of changes within each alternative determines the duration (number of years) associated with each PPO value.

2. Four combinations of values for the convective transport defect factor [CTDF; see Section B.4.b(5)(6)] and the intake f factor [f_I; see Section V.D.2.b(2)(e)]. Each combination of (CTDF, f_I) in the staff's young-of-the-year model determines a percent reduction value for a specified alternative at Indian Point and conditions at the other power plants. From each percent reduction value, PPO is calculated as

$$\frac{100 - \text{percent reduction}}{100} .$$

3. Without and with Cornwall (Storm King Pumped-Storage Plant).

For example, for the base design, (CTDF, f_I) = (0.4, 0.5), and without Cornwall, there is a 25% reduction in the probability of survival of 0-year old striped bass for each of the first two years (1974-1975) when just Unit No. 2 is operating with once-through cooling, followed by a 31% reduction for each of the next 33 years (1976-2008) when both Units Nos. 2 and 3 are operating with once-through cooling, followed by a return to a 25% reduction for the next two years (2009-2010) when Unit No. 2 is decommissioned but Unit No. 3 is still operating, then followed by a 0% reduction for each of the next 43 years (2011-2053) after Units Nos. 1 and 3 and all units at Bowline, Lovett, Roseton, and Danskammer are decommissioned.

The RC runs are for 80 years when Cornwall is not included and for 100 years when Cornwall is included. The objective was to continue the simulations for enough years to permit essentially complete recovery to the original level following cessation of the impact on the young-of-the-year striped bass.

The pre-1974 baseline condition is assumed to be the clean river. All other power plants on the river, except Cornwall which is

Table B-49. Input parameters for the life-cycle model based on results from the young-of-the-year model[a]

Configuration at Indian Point[b]				Number of years	Value (CTDF[c], f_I[c])							
					CTDF = 0.4, f_I = 0.5		CTDF = 0.4, f_I = 1.0		CTDF = 0.8, f_I = 0.5		CTDF = 0.8, f_I = 1.0	
Alternative	IP-2	IP-3	Period		% reduction	PPO[d]	% reduction	PPO	% reduction	PPO	% reduction	PPO
							Without Cornwall					
B	OT[e]		1974–75	2	25	0.75	43	0.57	32	0.68	52	0.48
	OT	OT	1976–78	3	31	0.69	49	0.51	39	0.61	58	0.42
	CT[f]	OT	1979–81	3	26	0.74	44	0.56	33	0.67	53	0.47
	CT	CT	1982–2008	27	19	0.81	35	0.65	25	0.75	44	0.56
		CT	2009–10	2	18*	0.82*	34*	0.66*	24*	0.76*	43*	0.57*
			2011–53	43	0	1.00	0	1.00	0	1.00	0	1.00
A	OT		1974–75	2	25	0.75	43	0.57	32	0.68	52	0.48
	OT	OT	1976–78	3	31	0.69	49	0.51	39	0.61	58	0.42
	CT	OT	1979–2008	30	26	0.74	44	0.56	33	0.67	53	0.47
		OT	2009–10	2	25	0.75	43	0.57	32	0.68	52	0.48
			2011–53	43	0	1.00	0	1.00	0	1.00	0	1.00
Base design	OT		1974–75	2	25	0.75	43	0.57	32	0.68	52	0.48
	OT	OT	1976–2008	33	31	0.69	49	0.51	39	0.61	58	0.42
		OT	2009–10	2	25	0.75	43	0.57	32	0.68	52	0.48
			2011–53	43	0	1.00	0	1.00	0	1.00	0	1.00
							With Cornwall (1982–2031)					
B	OT		1974–75	2	25	0.75	43	0.57	32	0.68	52	0.48
	OT	OT	1976–78	3	31	0.69	49	0.51	39	0.61	58	0.42
	CT	OT	1979–81	3	26	0.74	44	0.56	33	0.67	53	0.47
	CT	CT	1982–2008	27	31	0.69	51	0.49	42	0.58	63	0.37
		CT	2009–10	2	30*	0.70*	50*	0.50*	41*	0.59*	62*	0.38*
			2011–31	21	17	0.83	28	0.72	24	0.76	35	0.65
			2032–73	42	0	1.00	0	1.00	0	1.00	0	1.00
A	OT		1974–75	2	25	0.75	43	0.57	32	0.68	52	0.48
	OT	OT	1976–78	3	31	0.69	49	0.51	39	0.61	58	0.42
	CT	OT	1979–81	3	26	0.74	44	0.56	33	0.67	53	0.47
	CT	OT	1982–2008	27	36	0.64	57	0.43	48	0.52	69	0.31
		OT	2009–10	2	35*	0.65*	56*	0.44*	47*	0.53*	68*	0.32*
			2011–31	21	17	0.83	28	0.72	24	0.76	35	0.65
			2032–73	42	0	1.00	0	1.00	0	1.00	0	1.00
Base design	OT		1974–75	2	25	0.75	43	0.57	32	0.68	52	0.48
	OT	OT	1976–81	6	31	0.69	49	0.51	39	0.61	58	0.42
	OT	OT	1982–2008	27	41	0.59	62	0.38	53	0.47	73	0.27
		OT	2009–10	2	35*	0.65*	56*	0.44*	47*	0.53*	68*	0.32*
			2011–31	21	17	0.83	28	0.72	24	0.76	35	0.65
			2032–73	42	0	1.00	0	1.00	0	1.00	0	1.00

[a] Percent reduction values with an asterisk were estimated by assuming that the shutdown of Unit No. 2 with a cooling tower after the year 2008 would decrease the percent reduction 1%.

[b] All units at Bowline, Lovett, Danskammer, and Roseton are assumed to start operation in 1974 and to cease operation in 2010.

[c] TDF = transport defect factor. CTDF = convective transport defect factor.

[d] $PPO = \frac{100 - \%\ \text{reduction}}{100}$

[e] OT denotes once-through cooling.

[f] CT denotes cooling tower.

treated separately, are assumed to start operation in 1974, along with Indian Point Unit No. 2, and to terminate operation in 2010, along with Indian Point Unit No. 3. Additional runs of the life-cycle model with a more realistic pre-1974 baseline and alternative assumptions concerning termination dates for operation of the other plants with once-through cooling (in particular, Bowline and Roseton) are being done.

Before presenting results, a caveat is in order to the effect that the staff wishes to deemphasize and discourage efforts to play meaningless games with "soft" numbers by treating them as "hard" numbers. The emphasis in discussing the results of the life-cycle model is on trends, inequalities, and qualitative and semi-quantitative properties of the forecasts. The staff offers no apology for not presenting a more quantitative assessment, which would have a lower level of uncertainty, of the potential impact of Indian Point on the Hudson River striped bass population. The staff's efforts reflect the state of the science and the state of the art of forecasting the effects of environmental impacts on a large fish population, inhabiting an open system, that is the subject of an intense sport and commercial fishery. The staff hastens to add that these comments are equally valid for the applicant's modeling efforts.

Results of three RC runs using Parameter Set 1 (Table B-43; staff's best estimate for all parameters) are illustrated in Figs. B-50 and B-51 for relative yield versus years and relative number of 1-year olds versus years. The three curves in each of these figures correspond to the three alternatives at Indian Point using the PPO values in the column headed CTDF = 0.8 and f_I = 1.0, without Cornwall, in Table B-49.

General properties of these curves are as follows:

1. As with the RO runs, there is no change in relative yield until after the third year, while there is a change in relative number of 1-year olds after the first year.

2. Similarly, following any subsequent change in the value of PPO, there is a three-year lag before a change in relative yield but only a one-year lag before a change in relative number of 1-year olds.

3. All of the simulations indicate essentially 100% recovery by year 80.

4. The curves for relative number of 1-year olds fluctuate somewhat more in comparison with those for relative yield, although they indicate the same pattern of decrease and recovery and the same maximum decrease.

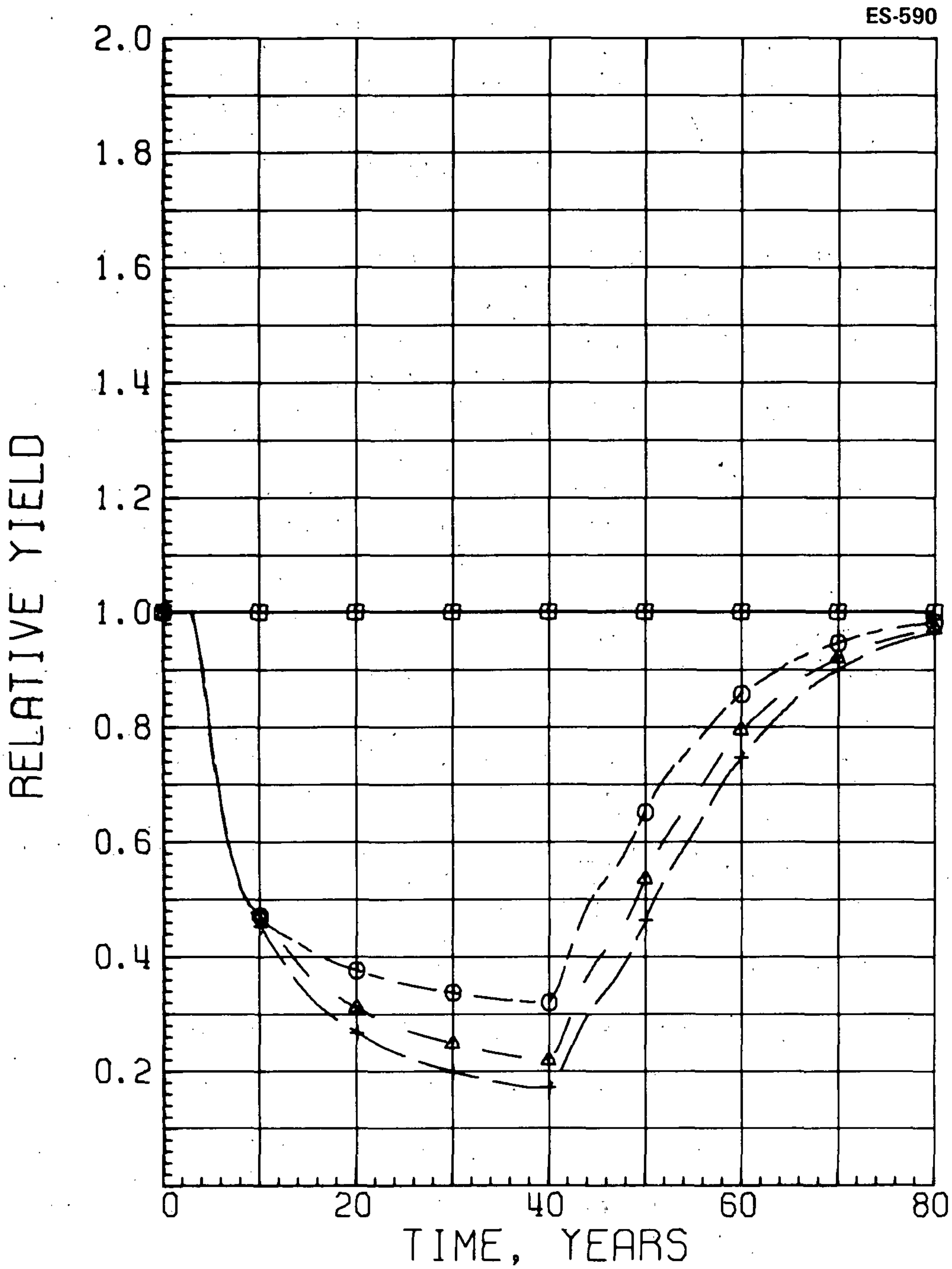

Fig. B-50. Relative yield vs time curves for various configurations at Indian Point without Cornwall [i.e., base design (+) — once-through cooling at both Units Nos. 2 and 3; alternative A (Δ) — a cooling tower at Unit No. 2 and once-through cooling at Unit No. 3; and alternative B (○) — cooling towers at both units].

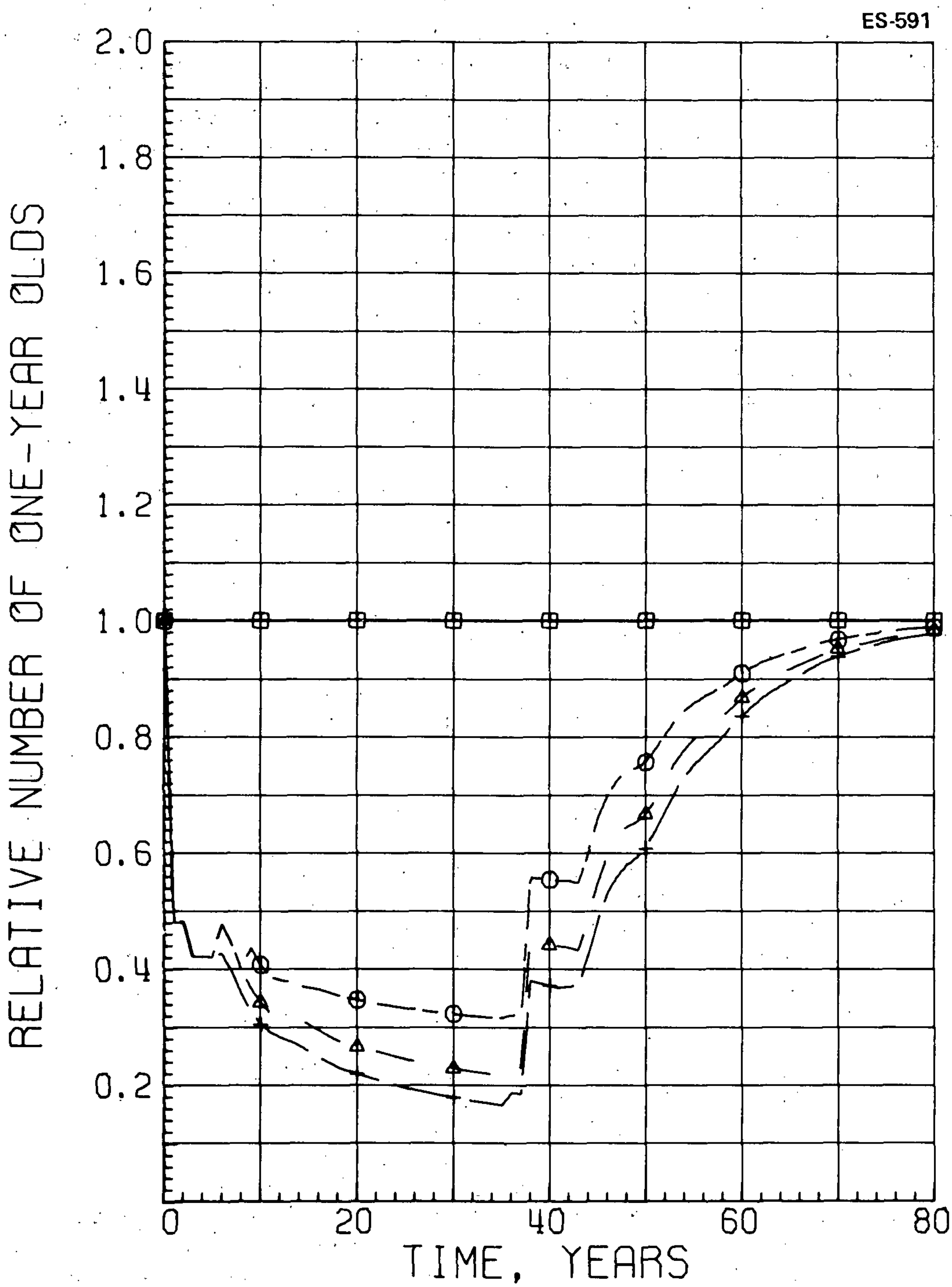

Fig. B-51. Curves for relative number of one-year-olds vs time for the base design (+), Alternative A (Δ), and Alternative B (O) without Cornwall and with a value of 0.8 for the convective transport defect factor and a value of 1.0 for the intake f factor.

Similar runs were done for the three alternatives and the other 7 sequences of PPO values (Table B-49) using life-cycle Parameter Set 1. The results are summarized and discussed in Chapters V and XI. In addition, the staff repeated the three runs illustrated in Figs. B-50 and B-51 using the other 20 sets of life-cycle model parameters (Table B-43. As in Chapters V and XI the staff has used two criteria to analyze the information in curves of the type given in Figs. B-50 and B-51; these criteria may be understood more clearly by referring to the hypothetical curves in Fig. B-51a. First, the increase in cumulative yield over the duration of the model run (80 or 100 years) for an alternative is expressed as a percent of the cumulative yield for the base design. In other words, the shaded area in Fig. B-51a is expressed as a percent of the area under the curve from year 0 through year 100 for the base design. Second, for the base design and each alternative the number of years for which the relative yield is less than 0.75 and less than 0.50 is calculated. For example, referring to the hypothetical curves in Fig. B-51a, for the base design the relative yield is less than 0.75 for 43 years and less than 0.50 for 29 years, while for the alternative the relative yield is less than 0.75 for 13 years and less than 0.50 for 0 years.

The changes in cumulative yield tend to be of greater socioeconomic interest, and when they are given yearly, they can serve as the basis for estimating the monetary benefit to the striped bass sport and commercial fisheries of installing cooling towers at Indian Point Units Nos. 2 and 3, as has been done in Section XI.J.2.c(1). However, of greater ecological interest and of greater environmental concern to the staff is the number of years the relative yield (and thus the population) is depressed below a given level. As indicated above, all of these simulations indicate essentially 100% recovery by year 80 (or 100 when Cornwall is included). However, the greater the reduction in the population and the longer this reduction is continued, the less likely it is that the model simulations are even qualitatively accurate. [See Section V.D.2.d(3)(c)(iv) for a further discussion of the risk of irreversible impacts.

The staff emphasizes that its striped bass life-cycle model is a single-species population model, which appears to simulate the behavior of the population in a reasonable manner. However, in reality the Hudson River spawned striped bass population is one component of a complicated fish community inhabiting an even more complicated estuarine and marine ecosystem. Thus, the dynamics of the striped bass population undoubtedly depend to an extent on interactions between striped bass and other biotic and abiotic components of the ecosystem. In addition, since striped bass are the subject of an intense sport and commercial fishery, and since fishing mortality may be of importance in regulating the population,

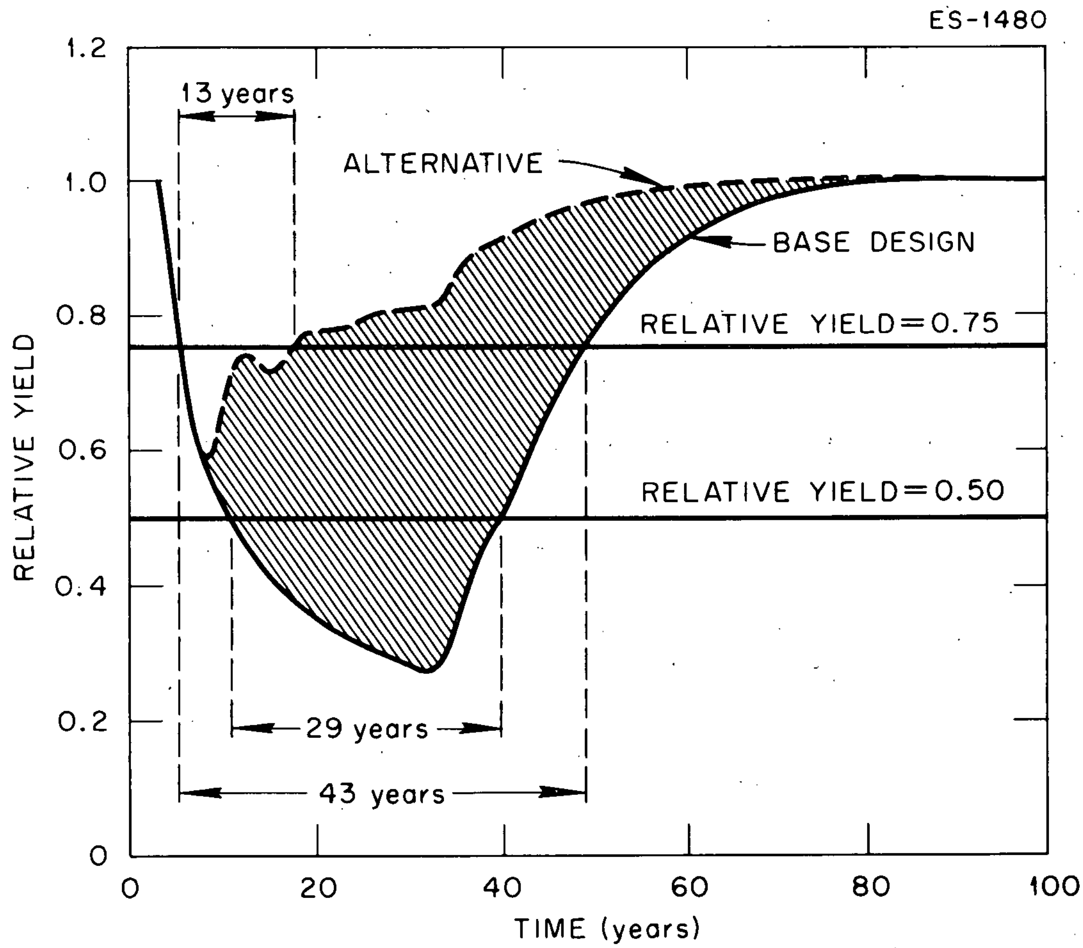

Fig. B-51a. Two hypothetical curves of relative yield versus years to illustrate the two criteria used by the staff to further analyze results from the life-cycle model.

the dynamics of the Hudson River striped bass population also may depend on social and economic factors affecting fishing effort. Neither the staff's nor the applicant's life-cycle model include interactions between the striped bass and other biotic and abiotic components of the ecosystem or the social and economic factors that may influence fishing effort. The justification for the more limited approach adopted is that data on these interactions and social and economic factors are lacking, and even if they were available, an understanding of the cause-effect relationships necessary to include such phenomena in a model is not adequate. The hope is that by focusing on the population per se, where there are relatively adequate data on fecundities and survivals, the staff's life-cycle model will be sufficiently realistic to a first approximation to serve as part of the basis for making a rational management decision concerning the unacceptability of once-through cooling at Indian Point Unit No. 3 (Base Design or Alternative A) and the timing of installation of closed-cycle cooling at Unit No. 3.

A comparison (Table B-50) of Sets 1, 2, and 3 indicates that the predicted impact is more severe when female striped bass become sexually mature at an earlier age (e.g., as 5-year olds as in Set 3) than at a later age (e.g., as 7-year olds as in Set 2). More explicitly, the number of years for which the relative yield is less than 0.75 or 0.50 is greater when females first become sexually mature as 5-year olds than as 7-year olds. Thus, as expected, the benefit of installing cooling towers at Units Nos. 2 and 3 is greater when females mature as 5-year olds versus as 7-year olds (Table B-50).

A comparison of Sets 1, 4, and 5 indicates that the predicted impact is more severe when the probabilities of surviving sources of natural mortality are low (Set 4) than high (Set 5), as indicated by the greater number of years for which the relative yield is less than 0.75 or 0.50 (Table B-50). Thus, the benefits of installing cooling towers at Units Nos. 2 and 3 are greater when probabilities of surviving sources of natural mortality are low (Set 4) rather than high (Set 5) (Table B-50).

These two examples illustrate the general pattern that applies to the remaining sets. With respect to both severity of ecological impact, as measured by the number of years relative yield is less than 0.75 or 0.50, and benefits of installing cooling towers at Indian Point Units Nos. 2 and 3, as measured by the increase in cumulative yield at year 80 (or 100 when Cornwall is included) as a percent of the cumulative yield for the base design (Table B-50), there is a trend from high to low with the values for Set 1 in the

Table B-50. Number of years relative yield is less than 0.75 (columns A) or 0.50 (columns B) and the increase in cumulative yield at year 80 as a percent of the cumulative yield the base design (columns C)[a]

Parameter	Set	A			B			C		
		Alternative			Alternative			Alternative		
		B	A	Base design	B	A	Base design	B	A	Base design
	1	49	52	55	36	41	42	18	7	0
FMAT	2	44	47	48	33	35	38	14	6	0
	1	49	52	55	36	41	42	18	7	0
	3	53	58	61	40	44	47	22	8	0
PNS	4	57	63	67	44	50	55	35	14	0
	1	49	52	55	36	41	42	18	7	0
	5	46	49	51	31	34	37	14	5	0
B,C	6	59	64	68	44	50	54	28	11	0
	1	49	52	55	36	41	42	18	7	0
	7	44	47	49	33	35	38	14	6	0
TOTP1	8	49	52	55	36	41	42	18	7	0
	1	49	52	55	36	41	42	18	7	0
	9	49	52	55	36	41	42	18	7	0
RATIO	10	42	45	45	34	35	36	12	5	0
	1	49	52	55	36	41	42	18	7	0
	11	58	63	67	42	48	51	26	10	0
D,	12	63	70	74	45	52	56	32	12	0
PMIN,	13	40	43	44	33	34	35	11	4	0
PMAX	14	75	75	75	71	71	71	33	11	0
	15	75	75	75	71	71	71	44	14	0
	1	49	52	55	36	41	42	18	7	0
	16	47	52	54	36	40	42	19	7	0
	17	37	38	39	8	33	34	10	4	0
	18	68	75	75	48	56	60	33	12	0
	19	44	46	48	35	38	40	15	6	0
LEGAL	20	44	46	48	33	35	37	14	5	0
	1	49	52	55	36	41	42	18	7	0
	21	60	66	69	44	50	54	27	10	0

[a]Alternative B is cooling towers at Indian Point Units Nos. 2 and 3; Alternative A is a cooling tower at Unit No. 2 and once-through cooling at Unit No. 3; the base design is once-through cooling at Units Nos. 2 and 3. PPO values used are based on young-of-the-year model runs using 0.8 for the convective transport defect factor and 1.0 for the intake f factor, without Cornwall.

middle. Thus, the potential ecological impact is more severe and the expected benefits for the striped bass population and fisheries when closed-cycle cooling systems are installed at Units Nos. 2 and 3 are greater if:

1. female striped bass become sexually mature at an earlier age (Set 3);

2. probabilities of surviving sources of natural mortality are low (Set 4);

3. individual growth rates are low (Set 6);

4. the ratio of the maximum to the minimum size of the striped bass population over ten-year periods is large (Set 11);

5. the density-independent fishing mortality (1.0 - PMAX) is high (Sets 12-15);

6. the maximum total fishing mortality (1.0 - PMIN) is low (Sets 14-15 and 18-19);

7. the slope of the fishing control function is less steep, as indicated by a smaller value of the parameter D (Sets 12, 14, 16, and 18);

8. the range (= PMAX - PMIN) of the density-dependent part of the fishing control function is small (Sets 14 and 15 versus Sets 16 and 17);

9. the minimum legal length limit is high (Set 21).

As in analyzing the RO runs, the results are more sensitive to changes in the fishing control parameters (PMAX, PMIN, and D) than to changes in any other parameters. Thus, in terms of ability to forecast the impact of plant operation, the present uncertainties in the values of these three parameters are the primary impediments to narrowing the range of uncertainty in the forecasts themselves.

The staff has used the life-cycle model to assess the difference in the potential benefit and impact of installing a closed-cycle cooling system at Indian Point Unit No. 3 in 1980, 1982, or 1984. Table B-51 summarizes the percent reduction values and durations assumed for these three model runs. The percent reduction values correspond to those in Table B-50 for (CTDF, f_I) = (0.8, 1.0), without Cornwall. The life-cycle model was run using Parameter Set 1 (Table B-43). As indicated both by the last columns in

Table B-51. Difference in the potential benefit and impact to the striped bass population and fishery of installing a cooling tower at Indian Point Unit No. 3 in 1980, 1982, or 1984

Year[a]	IP-2[b]	IP-3[b]	Period	Number of years	Percent reduction	PPO[c]	Results[d]		
							A	B	C
1980	OT	–	1974–75	2	52	0.48	49	36	1
	OT	OT	1976–78	3	58	0.42			
	CT	OT	1979	1	53	0.47			
	CT	CT	1980–2008	29	44	0.56			
	–	CT	2009–10	2	43	0.57			
	–	–	2011–53	43	0	1.00			
1982	OT	–	1974–75	2	52	0.48	49	36	1
	OT	OT	1976–78	3	58	0.42			
	CT	OT	1979–81	3	53	0.47			
	CT	CT	1982–2008	27	44	0.56			
	–	CT	2009–10	2	43	0.57			
	–	–	2011–53	43	0	1.00			
1984	OT	–	1974–75	2	52	0.48	49	36	0
	OT	OT	1976–78	3	58	0.42			
	CT	OT	1979–83	5	53	0.47			
	CT	CT	1984–2008	25	44	0.56			
	–	CT	2009–10	2	43	0.57			
	–	–	2011–53	43	0	1.00			

[a]Year in which operation of Indian Point Unit No. 3 with a cooling tower starts.

[b]OT = once-through cooling; CT = cooling tower. A dash indicates unit not in operation.

[c]The values used correspond to those in Table B-49 for (CTDF, f_I) = (0.8, 1.0) without Cornwall.

[d]Number of years relative yield is less than 0.75 (column A) or 0.50 (column B) and the increase in cumulative yield at year 80 as a percent of the cumulative yield for the 1984 date (C column).

Table B-51 and by the overlapping curves in Figs. B-52 and B-53, there are no appreciable long-term differences in benefits or impacts for the striped bass population or fishery.

Since the applicant is committed to a cooling tower for Indian Point Unit No. 3 at some date, the sooner it is installed the better from the point of view of reducing the impact on the striped bass population. However, the results of the staff's striped bass life-cycle model suggest that for the levels of impact considered there is not a critical balance point for the Hudson River spawned striped bass population such that, for example, once-through cooling for four years, while undesirable, would be acceptable but that once-through cooling for six or eight years would be unquestionably unacceptable.

(8) Applicant's Striped Bass Life-Cycle Model

The applicant also has developed and used a striped bass life-cycle model. Some of the features of the applicant's model dealing with the young-of-the-year striped bass population are discussed in the preceding section on the staff's new young-of-the-year model. The present discussion of the applicant's life-cycle model deals with the older age classes of striped bass. Given the number of one-year old fish, the number of fish in successive year classes is obtained in the applicant's model as follows:[56]

"$N_i = N_{i-1} \exp(-K_{i-1}\Delta t_{i-1})$,†

in which:

N_i = the number of fish in the ith age group at beginning of the ith year,

N_{i-1} = the number of fish in the (i - 1)th age group at beginning of the (i - 1)th year,

K_{i-1} = first order mortality rate to which the (i - 1)th age group is subject,

Δt_{i-1} = 365 days or one year,

$i = 2, 3, 4, 5, \ldots, 13.$

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†$\exp(-K_{i-1}\Delta t_{i-1}) \equiv e^{-K_{i-1}\Delta t_{i-1}}$.

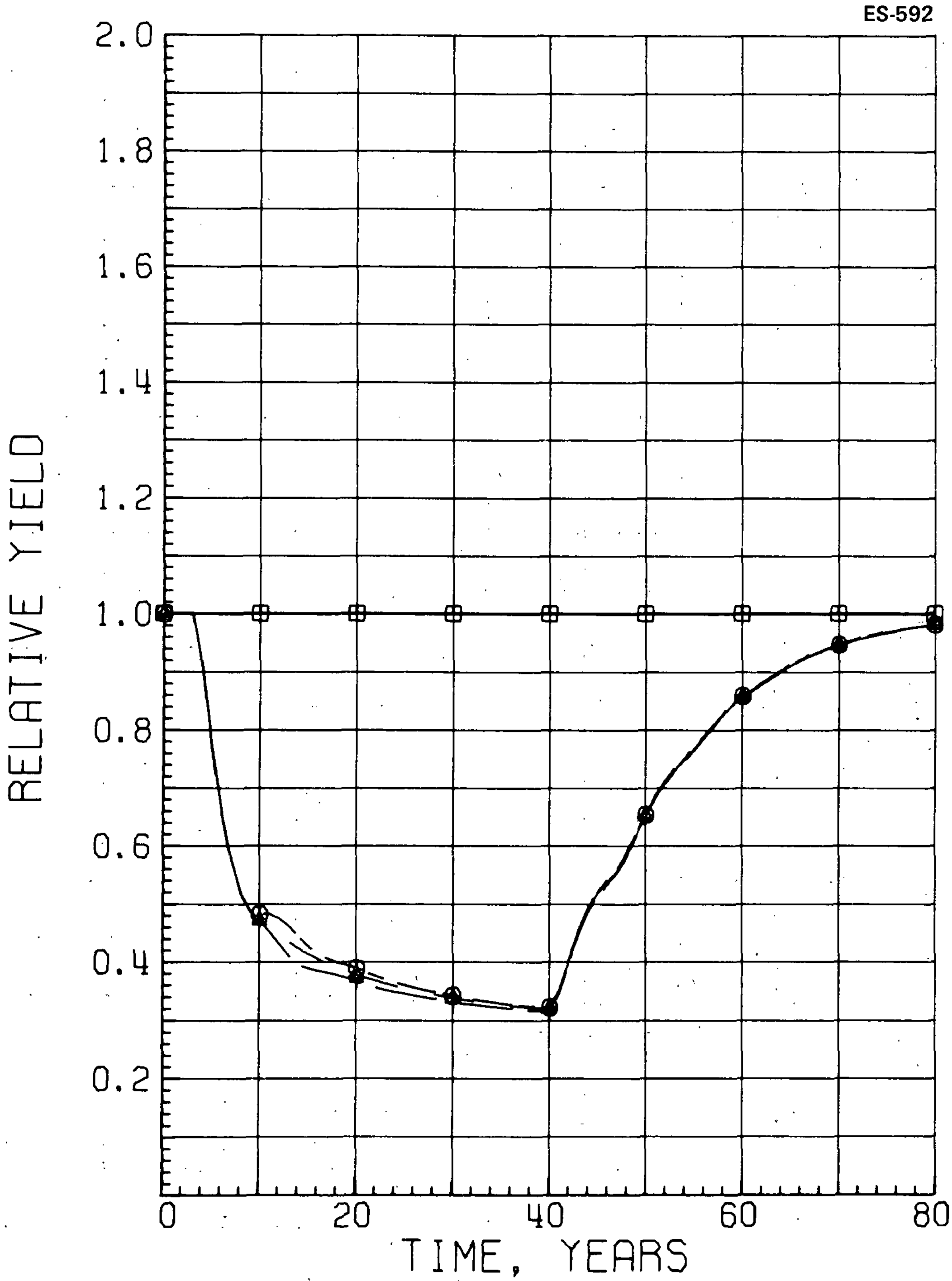

Fig. B-52. Curves for relative yield vs time for Alternative B with cooling towers installed in 1980 (○), in 1982 (△), or in 1984 (+) without Cornwall and with a value of 0.8 for the convective transport defect factor and a value of 1.0 for the intake f factor.

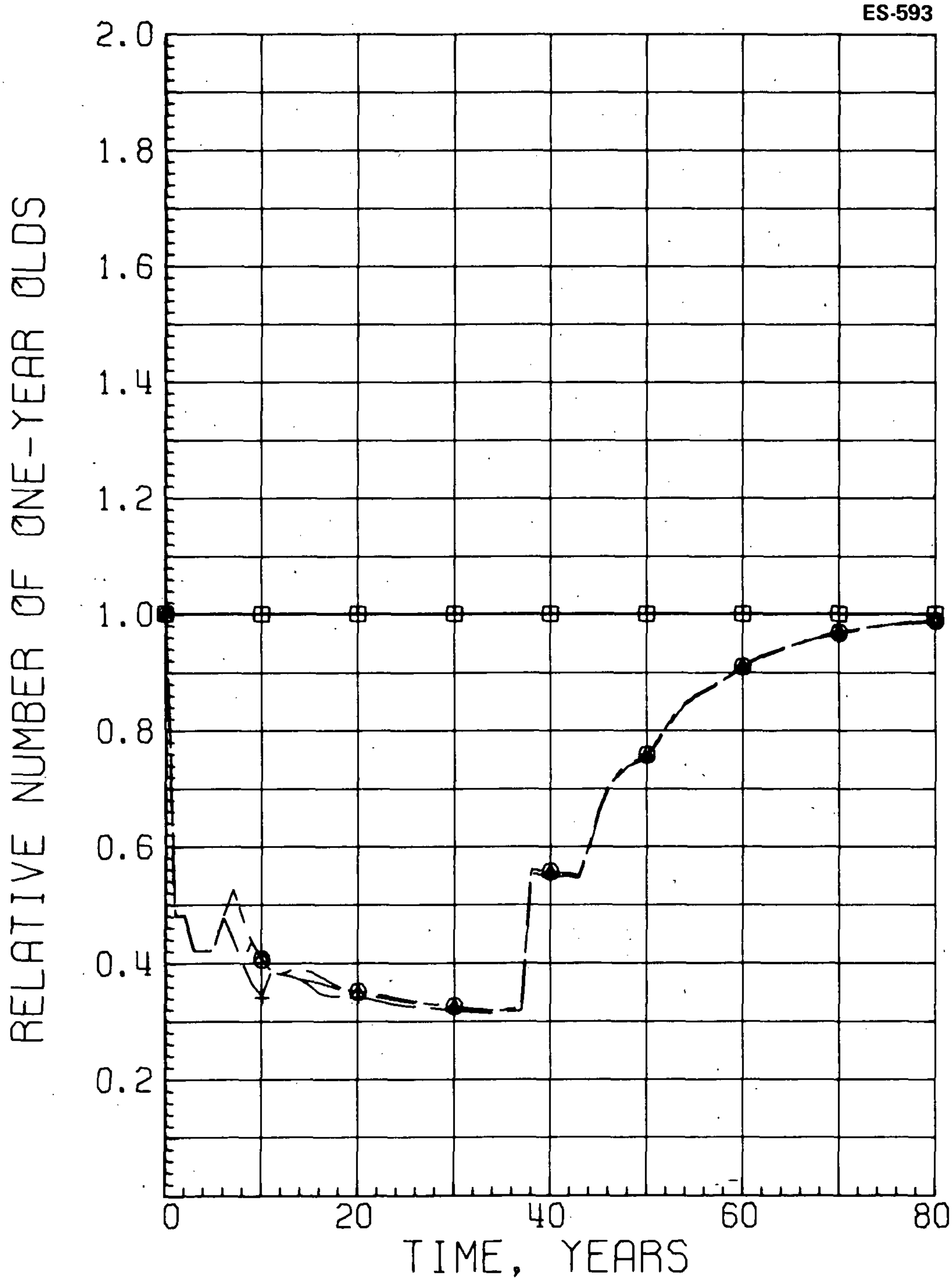

Fig. B-53. Curves for relative number of one-year-olds vs time for Alternative B with cooling towers installed in 1980 (O), in 1982 (Δ), or in 1984 (+) without Cornwall and with a value of 0.8 for the convective transport defect factor and a value of 1.0 for the intake f factor.

"The term, exp $(-K_{i-1}\Delta t_{i-1})$ represents the fractional survival from one year to the next, or the fraction of the (i - 1)th population that makes it through the (i - 1)th year. Therefore, the number of fish in any given age group is:

$$N_i = N_1 \exp\left(\sum_{j=1}^{i-1} - K_j \Delta t_j\right),$$

in which j = 1 ... i - 1, the number of age groups, from one-year olds to (i - 1) year olds, involved in the computation of the number of ith year olds, N_i and i = 2, ... , 13.

"The total adult fish population on May 9 of any given year is then written:

$$\sum_{i-1}^{13} N_i = N_1 \left(i + \sum_{i=2}^{13} e^{-\sum_{J=1}^{i-1} K_J \Delta t_J} \right).$$

Since N_1 is given by another equation in terms of total spawn and survival through the juvenile stage, the total population can be reduced to a product of spawn and survival through all subsequent life stages.

"Now we can come full circle by realizing that total egg count is given by accounting for the total number of spawning females and their associated fecundities. This is written:

$$\int_0^{T_E} P'(t)\, dt = \sum_{i=1}^{13} N_i f_{s_i} f_{m_i} F_i ,$$

in which:

N_i = ith year class,

f_{s_i} = fraction of females within N_i,

f_{m_i} = maturation or fraction of sexually mature females within N_i,

F_i = average fecundity of N_i or eggs/mature female.

"Given survival information (a knowledge of K and Δt) for each life stage, fecundity data (f_{s_i}, f_{m_i}, F_i) for each adult age group and spawn data ($P'(t)$, T_E) for a given year, the set of equations can be solved for N_1, any N_i, egg production, and total population for a succession of years afterwards.

"[The applicant[56]] has focused on the condition of equilibrium, since it will permit simplification of the mathematics, and also since it seems to be a good frame of reference from which departures, due to plant impact, can be evaluated.

"Two equations are required to define the equilibrium adult striped bass population (at start of spawning, May 9):

1. the equilibrium equation
2. the total adult bass population equation

These equations are given below with emphasis on the meaning of the individual terms:

Total adult bass population:

$$\sum_{i=1}^{13} N_i = [\text{total eggs produced}] \cdot [\text{egg survival}] \cdot [\text{larval survival}]$$

$$\cdot\ [\text{Juvenile I survival}] \cdot [\text{Juvenile II survival}]$$

$$\cdot\ [\text{Juvenile III survival}] \sum_{i=1}^{13} \exp - \sum_{j=1}^{i-1} K_j \Delta t_j \ ,$$

in which:

$$\text{Total eggs produced} = P'(t)\, T_E \;;$$

$$\text{Egg survival} = e^{-K_E \Delta t_E} \;;$$

$$\text{Larval survival} = e^{-K_L \Delta t_L} \;;$$

$$\text{Juvenile I survival} = e^{-K_{J_I} \Delta t_{J_I}} \;;$$

$$\text{Juvenile II survival} = \frac{1}{K_{JII} T_E} \left[e^{-K_{J_{II}}(C-T_E)} - e^{-K_{J_{II}} C} \right] ;$$

$$C = t_{II,III} - t_s - \left[\Delta t_E + \Delta T_L + \Delta T_{J_I} \right] ;$$

$$\text{Juvenile III survival} = e^{-K_{J_{III}} \Delta t_{J_{III}}} \;;$$

Equilibrium: 1 = [egg survival] • [larval survival]
• [Juvenile I survival]

• [Juvenile II survival] • [Juvenile III survival]

$$\cdot \sum_{i=1}^{13} f_{s_i} f_{m_i} F_i \left(e^{-\sum_{j=1}^{i-1} K_J \Delta t_J} \right),$$

where:

i = year class,

f_{s_i} = sex ratio of i (number of females/number of fish),

f_{m_i} = maturity index (number of mature females/number of females),

F_i = fecundity (number of eggs spawned/mature female);

$$\sum_{j=1}^{i-1} K_j \Delta t_j = 0 \ .$$

"The equilibrium condition requires that a balance be reached between survivals at individual stages such that the product of all items in the above equation equal unity.

"[The applicant[57] points out that] the Plant does not affect adults directly via impingement or entrainment. To offset a lower zero-year class recruitment, compensation may occur, over several years, in the adult classes. The reduced number of adults may be balanced by greater survival among the remaining adults, an earlier onset of maturity, increased fecundity in certain year classes, and possibly a change in the sex ratio to yield a higher ratio of females to males, giving a more fecund population per adult class.

"To date, adult compensation generally has not been applied in our use of the transport model. However, we have incorporated in the model an ability for compensation in the adult stages, for possible future use. The mechanism chosen to compensate for adult reductions is a variation of the previous compensation mechanism. Without compensation, adult mortality is modeled as a first-order reaction such that the fraction of year class i that survives is:

$$\exp^{-K_i \Delta t} = \exp^{-K_i 365}$$

in which K_i equals the first-order removal rate for that age group.

"Since behavior of the adults within the year is not of concern in the cycling model, any expression for survival could have been used which would reduce to the estimated age group survival.

"Adult compensation is quantified in the model by modifying the first-order K once at the beginning of the year, based on the initial number (N_{AB_i}) of adult fish in year class i, that is:

$$K_{A_i} = K_{E_{A_i}} + \left(K_{E_{A_i}} - K_{o_{A_i}}\right)\left(\frac{N_{AB_i} - N_{SA_i}}{N_{SA_i}}\right)^3 ,$$

in which:

N_{AB_i} = number of adults in year class i at start of year.

N_{SA_i} = the characteristic saturation or carrying capacity constant for that age group. This is equal to the population of that year class at the beginning of the year when the Plant is not operating.

$K_{o_{A_i}}$, $K_{E_{A_i}}$ = the unit mortality rates at $N_{AB_i} = 0$ and N_{SA_i} respectively.

K_{A_i} = the overall adult mortality rate during the ith year.

"Since, over the full year, K is equal to the K_i (above) for adult age group i, this amounts to varying the overall yearly survival ($e^{-K_A 365}$) with the recruits to the year class (N_{AB_i}). This differs from early stage compensation in that the instantaneous daily survival rate is continually modified as a function of the current stage concentration.

"The adult compensation mechanism was applied to the first three-year groups only. The remaining nine age group (4-12) survivals were assumed to remain constant.

"Adult (age groups 1-13) parameters were chosen to yield a year-to-year equilibrium such that the egg complement from year to year (without a Plant) would be constant.

"The adult survival rates for age groups 1-3 are assumed as input to the transport model. Given these values, the equilibrium condition is satisfied by utilizing a Newton-Raphson technique to compute the survivals for adults 4-12. With these survivals and the number of recruits to age group 1 and no Plant effect, an adult distribution based on age group 1 population can be computed.

"The survivals for age groups 4-12 must depend largely upon external disturbances, chiefly commercial and sport fishing; the fish are considered to have already undergone a long-term process of adaptation to fishing disturbances.

"Based on the equilibrium equation, these survivals are computed to be 61.4% per year when the age groups 1-3 survival is 16% per year. It should be noted that the survival of age groups 4-12 depends entirely on the assumed survivals of age groups 1-3. Assuming higher survivals in age groups 1-3 would necessitate lower survivals in age groups 4-12 and vice-versa, if the equilibrium behavior is to be preserved."

Using the version of the life-cycle model which includes river hydrodynamics, transport, and compensation in early life stages, the applicant predicts (ER, IP-3, App. AA) a decrease in striped bass population from the operation of Units Nos. 1 and 2 of 5.0% after ten years. For Indian Point Units Nos. 1 and 2 plus Bowline and Roseton, the predicted decrease is approximately 13.0%.

The applicant claims that these results show clearly that operation of Units Nos. 1 and 2 should not be expected to cause a substantial or irreversible adverse impact on the river's striped bass population, particularly during the first ten years of operation. These reductions are expected to stabilize at the above values after approximately ten years.

A study using this model and 1967 data was also performed to predict the impact of Indian Point Units Nos. 2 and 3. This study predicted reductions of 6% after ten years from the operation of Indian Point Units Nos. 2 and 3 and 16% after ten years from the operation of Indian Point Units Nos. 2, 3, Bowline, and Roseton. The applicant claims that these results indicate that operation of Units Nos. 2 and 3 should not be expected to cause a substantial or irreversible adverse impact on the river's striped bass population, particularly during the first ten years of operation, and that these reductions are expected to stabilize at the above values after approximately ten years (ER, IP-3, App. AA).

The staff notes that results have not yet been presented for Indian Point Units Nos. 1, 2, and 3 alone or in combination with not only Bowline and Roseton but also Lovett and Danskammer.

The staff further notes that (1) the applicant has not specified what percentage reduction in the striped bass population after ten years it would consider substantial and why, and (2) that the values used for the female maturity parameters (f_{m_i}) are not consistent with findings by Clark[58] and Texas Instruments[39] for Hudson River striped bass.

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Appendix C

RADIATION EFFECTS ON AQUATIC BIOTA

Dose calculations were based on the assumption that the organisms live continuously in effluent water containing radionuclides in concentrations equal to those at the point of discharge from the Indian Point Station (i.e., before dilution with Hudson River water occurs). This pathway of exposure was used to maximize estimated doses for conservative purposes. Organisms living in the river will receive a lower dose as radionuclide concentrations become diluted with the Hudson River water.

Each total dose was computed as the sum of the internal and immersion doses. The internal dose to aquatic organisms results from intake of radionuclides through ingestion (food chain) and direct absorption from the water. Immersion dose results from immersion of the organism in the contaminated water.

The annual internal dose from each radionuclide to biota that derives all its food from water in the Indian Point discharge canal is:

$$D_i^b = 1.87 \times 10^7 \, C_i^b W_i E_i \quad \text{(millirads/year)} \qquad (1)$$

where 1.87×10^7 is a constant to convert microcuries per gram of biota to dose, C_i^b is the bioaccumulation factor for radionuclide "i" and biotic group "b", W_i is the concentration (μCi/ml) of radionuclide "i" in the water in the Indian Point discharge canal, and E_i is the effective absorbed energy of radionuclide "i".

Bioaccumulation factors (C_i^b), defined as the ratio of radionuclide concentration in the organism to that in water, are presented in Table C-1 for three biotic groups: aquatic plants, invertebrates, and fin fish. Each species usually has a different accumulation factor, which can be influenced by environmental factors. The highest accumulation factors found in the literature[1-3] are given in Table C-1. Not all organisms in each group would have such a high accumulation factor and, consequently, would not receive such a high internal dose.

The radionuclide concentrations (W_i) in effluent water are based on several assumptions of Station operation which tend to maximize

Table C-1. Radionuclide bioaccumulation factors for aquatic plants, invertebrates, and fin fish used in estimating the internal radiation doses

The letter E followed by a number denotes multiplication by a power of 10; e.g., 1.00E+00 means 1.00×10^0

Radionuclide	Bioaccumulation factor		
	Plants	Invertebrates	Fin fish
H-3	1.00E+00	1.00E+00	1.00E+00
Cr-51	1.00E+02	5.00E+01	2.00E+02
Mn-54	3.50E+04	1.40E+05	2.50E+01
Fe-55	5.00E+03	3.20E+03	3.00E+02
Fe-59	5.00E+03	3.20E+03	3.00E+02
Co-58	2.50E+03	1.50E+03	5.00E+02
Co-60	2.50E+03	1.50E+03	5.00E+02
Rb-86	1.00E+03	2.00E+03	2.00E+03
Sr-89	3.00E+03	4.00E+03	1.50E+02
Sr-90	3.00E+03	4.00E+03	1.50E+02
Sr-91	3.00E+03	4.00E+03	1.50E+02
Y-90	1.00E+04	1.00E+03	1.00E+02
Y-91	1.00E+04	1.00E+03	1.00E+02
Y-93	1.00E+04	1.00E+03	1.00E+02
Zr-95	1.50E+03	1.50E+02	1.00E+01
Zr-97	1.50E+03	1.50E+02	1.00E+01
Nb-95	1.00E+03	1.00E+02	1.00E+01
Mo-99	1.00E+02	1.00E+02	1.00E+02
Ru-103	2.00E+03	2.00E+03	1.00E+02
Ru-106	2.00E+03	2.00E+03	1.00E+02
Rh-105	2.00E+03	2.00E+03	1.00E+02
Te-125m	1.00E+03	6.10E+03	4.00E+02
Te-127m	1.00E+03	6.10E+03	4.00E+02
Te-127	1.00E+03	6.10E+03	4.00E+02
Te-129m	1.00E+03	6.10E+03	4.00E+02
Te-131m	1.00E+03	6.10E+03	4.00E+02
Te-132	1.00E+03	6.10E+03	4.00E+02
I-130	2.00E+02	1.00E+03	5.00E+01
I-131	2.00E+02	1.00E+03	5.00E+01
I-133	2.00E+02	1.00E+03	5.00E+01
I-135	2.00E+02	1.00E+03	5.00E+01
Cs-134	2.50E+04	1.10E+04	1.00E+03
Cs-136	2.50E+04	1.10E+04	1.00E+03
Cs-137	2.50E+04	1.10E+04	1.00E+03
Ba-140	5.00E+02	2.00E+02	1.00E+01
La-140	1.00E+04	1.00E+03	1.00E+02
Ce-141	1.00E+04	1.00E+03	1.00E+02
Ce-143	1.00E+04	1.00E+03	1.00E+02
Ce-144	1.00E+04	1.00E+03	1.00E+02
Pr-143	1.00E+04	1.00E+03	1.00E+02
Nd-147	1.00E+04	1.00E+03	1.00E+02
Pm-147	1.00E+04	1.00E+03	1.00E+02
Np-239	1.00E+03	2.86E+02	1.00E+04

radionuclide concentrations in effluent water, based on comparisons with actual operating histories of other plants. For normal operation, radionuclide concentrations in effluent water will probably not reach the concentrations used for these dose calculations, but the staff has taken a conservative approach in calculating the doses.

The computed internal doses are further maximized since the maximum effective absorbed energies (E_i) in man were used in the calculation.[4] For most aquatic organisms the internal dose will be considerably overestimated because these organisms will not absorb the full amount of energy emitted from a radionuclide deposited internally.

The estimated internal radiation doses to aquatic plants, invertebrates, and fin fish are given in Table C-2 for the initial radioactive waste treatment system and in Table C-3 for the modified system. See Section V.E for a description of the two radwaste systems.

Immersion doses in water were computed with the EXREM computer code[5,6] and are tabulated in Table C-4 for the initial radioactive waste system and in Table C-5 for the modified system. This calculation assumes continuous immersion of the organism in water containing radionuclides in the concentrations as listed.

Both the internal and immersion dose calculations assume steady-state conditions (i.e., the radionuclide concentrations in water and in the organisms are constant).

In conclusion, the estimated total doses (see Tables C-2 through C-5) to the aquatic organisms living in the undiluted effluent are higher than those that the organisms would receive from background radiation but considerably less than the levels which would produce observable effects. As a result of these considerations, no discernible radiation effect is expected in the aquatic community of the Hudson River as a result of Indian Point activities.

Table C-2. Estimated internal radiation dose to aquatic plants, invertebrates, and fin fish in the Indian Point discharge canal for the initial radioactive waste treatment process[a]

The letter E followed by a number denotes multiplication by a power of 10; e.g., 1.1E–05 means 1.1 × 10^{-5}

Radionuclide	Concentration (μCi/ml)[a]	Dose (millirads/year)		
		Plants	Invertebrates	Fin fish
H-3	1.1E–05	2.1E+00	2.1E+00	2.1E+00
Cr-51	1.9E–10	8.9E–03	4.4E–03	1.8E–02
Mn-54	4.3E–12	1.4E+00	5.7E+00	1.0E–03
Fe-55	1.8E–10	1.1E–01	7.0E–02	6.6E–03
Fe-59	1.0E–10	7.6E+00	4.8E+00	4.5E–01
Co-58	1.7E–09	4.8E+01	2.9E+01	9.7E+00
Co-60	2.1E–10	1.5E+01	8.8E+00	2.9E+00
Rb-86	4.8E–11	6.3E–01	1.3E+00	1.3E+00
Sr-89	8.5E–11	2.6E+00	3.5E+00	1.3E–01
Sr-90	2.3E–12	1.4E–01	1.9E–01	7.1E–03
Sr-91	2.7E–11	3.2E+00	4.2E+00	1.6E–01
Y-90	1.2E–12	2.0E–01	2.0E–02	2.0E–03
Y-91	3.3E–10	3.6E+01	3.6E+00	3.6E–01
Y-93	2.5E–12	7.9E–01	7.9E–02	7.9E–03
Zr-95	1.0E–11	3.1E–01	3.1E–02	2.1E–03
Zr-97	1.3E–13	7.7E–03	7.7E–04	5.1E–05
Nb-95	1.0E–11	9.5E–02	9.5E–03	9.5E–04
Mo-99	4.1E–09	4.1E+00	4.1E+00	4.1E+00
Ru-103	1.0E–11	1.6E–01	1.6E–01	8.2E–03
Ru-106	2.2E–12	1.2E–01	1.2E–01	5.8E–03
Rh-105	2.7E–12	1.8E–02	1.8E–02	9.1E–04
Te-125m	5.5E–12	1.5E–02	9.4E–02	6.2E–03
Te-127m	6.0E–11	3.6E–01	2.2E+00	1.4E–01
Te-127	8.0E–11	3.6E–01	2.2E+00	1.4E–01
Te-129m	3.2E–11	6.6E–01	4.0E+00	2.6E–01
Te-131m	2.2E–10	6.6E+00	4.0E+01	2.6E+00
Te-132	4.0E–09	1.4E+02	8.7E+02	5.7E+01
I-130	8.5E–10	4.1E+00	2.1E+01	1.0E+00
I-131	5.8E–08	9.5E+01	4.8E+02	2.4E+01
I-133	3.2E–08	1.0E+02	5.0E+02	2.5E+01
I-135	7.0E–09	3.4E+01	1.7E+02	8.5E+00
Cs-134	1.6E–08	8.2E+03	3.6E+03	3.3E+02
Cs-136	7.1E–09	2.2E+03	9.5E+02	8.6E+01
Cs-137	1.3E–08	3.6E+03	1.6E+03	1.4E+02
Ba-140	9.0E–11	1.9E+00	7.7E–01	3.9E–02
La-140	6.5E–11	2.3E+01	2.3E+00	2.3E–01
Ce-141	1.6E–11	6.3E–01	6.3E–02	6.3E–03
Ce-143	2.4E–13	4.4E–02	4.4E–03	4.4E–04
Ce-144	5.5E–12	1.3E+00	1.3E–01	1.3E–02
Pr-143	1.0E–11	6.0E–01	6.0E–02	6.0E–03
Nd-147	4.8E–12	3.6E–01	3.6E–02	3.6E–03
Pm-147	6.0E–14	7.7E–04	7.7E–05	7.7E–06
Np-239	7.5E–11	4.1E–01	1.2E–01	4.1E+00
Total dose		1.5E+04	8.3E+03	7.0E+02

[a]Radionuclide concentrations are based on the estimated annual releases from all three units.

Table C-3. Estimated internal radiation dose to aquatic plants, invertebrates, and fin fish in the Indian Point discharge canal for the modified radioactive waste treatment process[a]

The letter E followed by a number denotes multiplication by a power of 10; e.g., 1.1E–05 means 1.1×10^{-5}

Radionuclide	Concentration (μCi/ml)[a]	Dose (millirads/year)		
		Plants	Invertebrates	Fin fish
H-3	1.1E–05	2.1E+00	2.1E+00	2.1E+00
Cr-51	1.8E–11	8.4E–04	4.2E–04	1.7E–03
Mn-54	6.5E–12	2.2E+00	8.7E+00	1.5E–03
Fe-55	2.0E–11	1.2E–02	7.8E–03	7.3E–04
Fe-59	6.0E–12	4.5E–01	2.9E–01	2.7E–02
Co-58	1.8E–10	5.1E+00	3.1E+00	1.0E+00
Co-60	2.0E–11	1.4E+00	8.4E–01	2.8E–01
Rb-86	5.0E–11	6.5E–01	1.3E+00	1.3E+00
Sr-89	6.0E–12	1.9E–01	2.5E–01	9.3E–03
Sr-90	2.3E–13	1.4E–02	1.9E–02	7.1E–04
Sr-91	2.1E–12	2.5E–01	3.3E–01	1.2E–02
Y-90	1.6E–12	2.7E–01	2.7E–02	2.7E–03
Y-91	5.0E–10	5.5E+01	5.5E+00	5.5E–01
Y-93	3.6E–12	1.1E+00	1.1E–01	1.1E–02
Zr-95	1.0E–12	3.1E–02	3.1E–03	2.1E–04
Zr-97	2.0E–13	1.2E–02	1.2E–03	7.9E–05
Nb-95	1.0E–12	9.5E–03	9.5E–04	9.5E–05
Mo-99	6.0E–09	6.0E+00	6.0E+00	6.0E+00
Ru-103	7.5E–13	1.2E–02	1.2E–02	6.2E–04
Ru-106	2.3E–13	1.2E–02	1.2E–02	6.0E–04
Rh-105	2.3E–13	1.5E–03	1.5E–03	7.7E–05
Te-125m	6.0E–13	1.7E–03	1.0E–02	6.7E–04
Te-127m	4.8E–12	2.9E–02	1.8E–01	1.1E–02
Te-127	6.5E–12	2.9E–02	1.8E–01	1.2E–02
Te-129m	4.8E–11	9.9E–01	6.0E+00	3.9E–01
Te-131m	1.8E–11	5.4E–01	3.3E+00	2.2E–01
Te-132	3.2E–10	1.1E+01	6.9E+01	4.5E+00
I-130	2.3E–11	1.1E–01	5.6E–01	2.8E–02
I-131	1.4E–08	2.3E+01	1.2E+02	5.8E+00
I-133	7.0E–09	2.2E+01	1.1E+02	5.5E+00
I-135	1.4E–09	6.8E+00	3.4E+01	1.7E+00
Cs-134	1.8E–08	9.3E+03	4.1E+03	3.7E+02
Cs-136	7.0E–09	2.1E+03	9.4E+02	8.5E+01
Cs-137	1.4E–08	3.9E+03	1.7E+03	1.5E+02
Ba-140	7.0E–12	1.5E–01	6.0E–02	3.0E–03
La-140	4.7E–12	1.7E+00	1.7E–01	1.7E–02
Ce-141	1.1E–12	4.3E–02	4.3E–03	4.3E–04
Ce-143	3.6E–13	6.5E–02	6.5E–03	6.5E–04
Ce-144	6.5E–13	1.6E–01	1.6E–02	1.6E–03
Pr-143	9.0E–13	5.4E–02	5.4E–03	5.4E–04
Nd-147	3.6E–13	2.7E–02	2.7E–03	2.7E–04
Pm-147	9.0E–14	1.2E–03	1.2E–04	1.2E–05
Np-239	6.0E–12	3.3E–02	9.3E–03	3.3E–01
Total dose		1.5E+04	7.1E+03	6.4E+02

[a]Radionuclide concentrations are based on the estimated annual releases from all three units.

Table C-4. Estimated water-immersion dose to all biota in the Indian Point discharge canal for the initial radioactive waste treatment process

The letter E followed by a number denotes multiplication by a power of 10; e.g., 1.1E–05 means 1.1 × 10^{-5}

Radionuclide	Concentration (μCi/ml)[a]	Dose (millirads/year)	
		Beta + gamma	Gamma
H-3	1.1E–05	6.6E–01	*b*
Cr-51	1.9E–10	1.1E–04	1.1E–04
Mn-54	4.3E–12	6.7E–05	6.7E–05
Fe-55	1.8E–10	3.3E–05	3.3E–05
Fe-59	1.0E–10	2.4E–03	2.3E–03
Co-58	1.7E–09	3.1E–02	3.1E–02
Co-60	2.1E–10	1.0E–02	9.8E–03
Rb-86	4.8E–11	1.1E–04	8.6E–05
Sr-89	8.5E–11	4.4E–04	*b*
Sr-90	2.3E–12	2.3E–05	*b*
Sr-91	2.7E–11	9.0E–04	5.9E–04
Y-90	1.2E–12	1.0E–05	*b*
Y-91	3.3E–10	1.8E–03	2.2E–05
Y-93	2.5E–12	2.7E–05	4.6E–06
Zr-95	1.0E–11	2.9E–04	2.8E–04
Zr-97	1.3E–13	5.0E–06	3.4E–06
Nb-95	1.0E–11	1.5E–04	1.4E–04
Mo-99	4.1E–09	3.5E–02	2.1E–02
Ru-103	1.0E–11	1.0E–04	9.4E–05
Ru-106	2.2E–12	4.2E–05	1.2E–05
Rh-105	2.7E–12	6.1E–06	1.6E–06
Te-125m	5.5E–12	5.7E–06	5.7E–06
Te-127m	6.0E–11	2.3E–04	1.0E–04
Te-127	8.0E–11	1.8E–04	5.6E–06
Te-129m	3.2E–11	2.1E–04	1.1E–04
Te-131m	2.2E–10	1.1E–02	1.0E–02
Te-132	4.0E–09	2.0E–01	1.8E–01
I-130	8.5E–10	3.9E–02	3.3E–02
I-131	5.8E–08	5.4E–01	4.3E–01
I-133	3.2E–08	5.0E–01	3.6E–01
I-135	7.0E–09	4.4E–01	4.3E–01
Cs-134	1.6E–08	5.0E–01	4.7E–01
Cs-136	7.1E–09	3.2E–01	3.0E–01
Cs-137	1.3E–08	1.7E–01	1.5E–01
Ba-140	9.0E–11	5.2E–03	4.5E–03
La-140	6.5E–11	3.3E–03	3.0E–03
Ce-141	1.6E–11	4.7E–05	2.4E–05
Ce-143	2.4E–13	4.4E–06	2.8E–06
Ce-144	5.5E–12	7.1E–05	5.4E–06
Pr-143	1.0E–11	3.1E–05	*b*
Nd-147	4.8E–12	3.0E–05	1.6E–05
Pm-147	6.0E–14	3.9E–08	*b*
Np-239	7.5E–11	2.7E–04	1.7E–04
Total dose		3.5E+00	2.5E+00

[a]Radionuclide concentrations are based on the estimated annual releases from all three units.

[b]This radionuclide does not emit gamma rays.

Table C-5. Estimated water-immersion dose to all biota in the Indian Point discharge canal for the modified radioactive waste treatment process[a]

The letter E followed by a number denotes multiplication by a power of 10; e.g., 1.1E–05 means 1.1×10^{-5}

Radionuclide	Concentration (μCi/ml)[a]	Dose (millirads/year)	
		Beta + gamma	Gamma
H-3	1.1E–05	6.6E–01	b
Cr-51	1.8E–11	1.0E–05	1.0E–05
Mn-54	6.5E–12	1.0E–04	1.0E–04
Fe-55	2.0E–11	3.7E–06	3.7E–06
Fe-59	6.0E–12	1.4E–04	1.4E–04
Co-58	1.8E–10	3.3E–03	3.3E–03
Co-60	2.0E–11	9.6E–04	9.4E–04
Rb-86	5.0E–11	1.2E–04	8.9E–05
Sr-89	6.0E–12	3.1E–05	b
Sr-90	2.3E–13	2.3E–06	b
Sr-91	2.1E–12	7.0E–05	4.6E–05
Y-90	1.6E–12	1.4E–05	b
Y-91	5.0E–10	2.8E–03	3.4E–05
Y-93	3.6E–12	3.9E–05	6.7E–06
Zr-95	1.0E–12	2.9E–05	2.8E–05
Zr-97	2.0E–13	7.7E–06	5.3E–06
Nb-95	1.0E–12	1.5E–05	1.4E–05
Mo-99	6.0E–09	5.1E–02	3.1E–02
Ru-103	7.5E–13	7.7E–06	7.1E–06
Ru-106	2.3E–13	4.4E–06	1.2E–06
Rh-105	2.3E–13	5.2E–07	1.3E–07
Te-125m	6.0E–13	6.3E–07	6.3E–07
Te-127m	4.8E–12	1.8E–05	8.3E–06
Te-127	6.5E–12	1.5E–05	4.6E–07
Te-129m	4.8E–11	3.1E–04	1.7E–04
Te-131m	1.8E–11	9.0E–04	8.2E–04
Te-132	3.2E–10	1.6E–02	1.5E–02
I-130	2.3E–11	1.0E–03	8.8E–04
I-131	1.4E–08	1.3E–01	1.0E–01
I-133	7.0E–09	1.1E–01	7.8E–02
I-135	1.4E–09	8.8E–02	8.5E–02
Cs-134	1.8E–08	5.6E–01	5.3E–01
Cs-136	7.0E–09	3.2E–01	2.9E–01
Cs-137	1.4E–08	1.8E–01	1.6E–01
Ba-140	7.0E–12	4.0E–04	3.5E–04
La-140	4.7E–12	2.4E–04	2.1E–04
Ce-141	1.1E–12	3.2E–06	1.7E–06
Ce-143	3.6E–13	6.7E–06	4.2E–06
Ce-144	6.5E–13	8.3E–06	6.4E–07
Pr-143	9.0E–13	2.8E–06	b
Nd-147	3.6E–13	2.2E–06	1.2E–06
Pm-147	9.0E–14	5.9E–08	b
Np-239	6.0E–12	2.1E–05	1.4E–05
Total dose		2.2E+00	1.3E+00

[a]Radionuclide concentrations are based on the estimated annual releases from all three units.

[b]This radionuclide does not emit gamma rays.

REFERENCES FOR APPENDIX C

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Appendix D

CONDITIONS, ASSUMPTIONS, AND PARAMETERS USED IN CALCULATING RADIOACTIVE RELEASES

Table D-1. Principal conditions and parameters used in calculating releases of radioactive effluents for Indian Point Nuclear Generating Plant Unit No. 3

Reactor power	3,216 MWt
Plant factor	0.8
Failed fuel[a]	0.25%
Primary coolant system	
Total mass	520,000 lb
Flow rate to boron recovery	14,000 gpd
Leak to secondary coolant	20 gpd
Leak to containment building	40 gpd
Leak to auxiliary building	20 gpd
System volume	12,000 ft^3
System degassing	2/year
Secondary coolant system	
Number of steam generators	4
Steam in each generator	4,800 lb
Liquid in each generator	82,000 lb
Total coolant mass	3,700,000 lb
Steam generator blowdown rate	10 gpm
Condensate flow rate	13,000,000 lb/hr
Steam leak to turbine building	5 gpm
Condenser circulating water flow rate	870,000 gpm
Containment	
Volume	2,600,000 ft^3
Purges	4/year
Kidney charcoal adsorber flow rate	16,000 cfm
Iodine partition coefficients (gas/liquid)	
Primary coolant	
Leakage to containment	0.1
Leakage to auxiliary building	0.0001
Secondary coolant	
Steam generator	0.1
Condenser air ejector	0.0005
Iodine decontamination factor	
Reactor containment building ventilation – charcoal adsorber	10

[a]This value is constant and corresponds to 0.25% of the operating-power fission-product source term.

Table D-2. Principal assumptions and parameters for liquid waste treatment systems for Indian Point Unit No. 3

System	Radioactive waste feed: Rate (gpd)	Radioactive waste feed: Concentration (% PCA[a])	Capacity: Holdup tanks (gal)	Capacity: Process[b] (gpd)	Delay time (days)	Decontamination factors: I	Decontamination factors: Cs,Rb	Decontamination factors: Cation	Decontamination factors: Anion	Processed effluent released (%)
Primary coolant system[c]										
Chemical and volume control system	110,000	100				10	1	10	10	0
Boron recovery	15,000	10	229,000	43,000	3	10^4	2×10^3	10^5	10^5	10
Dirty waste	470	100	29,000	2,900	3	10^3	10^4	10^4	10^4	100
Steam generator blowdown	14,000	10	300,000[d]	35,000[d]		10^2	2	10^2	10^2	100
Turbine building drain	7,200	0.1		None						100

[a]Primary coolant activity.

[b]Rated capacity; practical operating capacity reduced by filter backwashing, demineralizer regeneration, evaporator bottoms discharge, and recycling of off-specification products.

[c]Holdup decontamination factors in reactor coolant system: 100 for Mo and Tc; 10 for Y.

[d]Modified Unit No. 1 system providing service for Units Nos. 1, 2, and 3.

APPENDIX E

METEOROLOGY FOR RADIOLOGICAL DISPERSION CALCULATIONS

The meteorological data as furnished by the applicant in the Final Facility Description and Safety Analysis Report, Supplement 16, (Table 2.6-1, sheets 1-7) were used. These data were modified as follows:

1. The wind speed was changed to meters per second. (The wind speed headings in Tables E-1 through E-7 are the mid-points of ranges of wind speeds as follows: 1-3, 4-7, 8-12, 13-18, 19-24, and greater than 24 mph.)

2. The direction was changed to indicate the direction toward which the wind blows.

3. The calms were omitted.

4. The frequencies were normalized to total 1.000.

The resulting data are given in Tables E-1 through E-7. Values of χ/Q calculated from these data are given in Table E-8.

Table E-1. Frequency of wind speed and direction: A stability condition

Wind toward	Frequency for wind speed (m/sec) of –						Total
	0.89	2.46	4.47	6.93	9.61	10.73	
N		0.00281	0.00281	0.00108			0.00670
NNE	0.00011	0.00205	0.00162	0.00011			0.00389
NE		0.00162	0.00097	0.00022			0.00281
ENE	0.00022	0.00086	0.00086				0.00194
E	0.00022	0.00151	0.00173	0.00011	0.00011		0.00368
ESE	0.00011	0.00022	0.00162	0.00248	0.00097		0.00540
SE		0.00097	0.00238	0.00281	0.00205	0.00011	0.00832
SSE		0.00194	0.00292	0.00227	0.00065		0.00778
S	0.00011	0.00335	0.00421	0.00086	0.00011		0.00864
SSW		0.00119	0.00076	0.00022			0.00217
SW		0.00032	0.00032				0.00064
WSW		0.00054		0.00011	0.00011		0.00076
W				0.00011			0.00011
WNW							
NW		0.00022	0.00022	0.00108	0.00022		0.00174
NNW	0.00011	0.00119	0.00605	0.00399	0.00022		0.01156
Total	0.00088	0.01879	0.02647	0.01545	0.00444	0.00011	0.06614

Table E-2. Frequency of wind speed and direction: B stability condition

Wind toward	Frequency for wind speed (m/sec) of –						Total
	0.89	2.46	4.47	6.93	9.61	10.73	
N	0.00022	0.00184	0.00151	0.00022			0.00379
NNE	0.00011	0.00108	0.00065				0.00184
NE	0.00022	0.00032	0.00054	0.00022			0.00130
ENE	0.00022		0.00032				0.00054
E	0.00011	0.00032	0.00054	0.00054			0.00151
ESE	0.00011	0.00032	0.00032	0.00022	0.00022		0.00119
SE	0.00011	0.00022	0.00032	0.00086	0.00022	0.00011	0.00184
SSE		0.00065	0.00151	0.00054	0.00032	0.00011	0.00313
S	0.00022	0.00108	0.00151	0.00054	0.00011		0.00346
SSW	0.00011	0.00065	0.00065	0.00032			0.00173
SW		0.00054	0.00011				0.00065
WSW							
W		0.00032	0.00011	0.00011			0.00054
WNW			0.00011				0.00011
NW		0.00022	0.00022	0.00011			0.00055
NNW		0.00086	0.00184	0.00151			0.00421
Total	0.00143	0.00842	0.01026	0.00519	0.00087	0.00022	0.02639

Table E-3. Frequency of wind speed and direction: C stability condition

Wind toward	Frequency for wind speed (m/sec) of –						Total
	0.89	2.46	4.47	6.93	9.61	10.73	
N		0.00140	0.00108	0.00011			0.00259
NNE		0.00086	0.00032				0.00118
NE	0.00011	0.00022	0.00011				0.00044
ENE	0.00011	0.00022	0.00032				0.00065
E	0.00022		0.00108	0.00022	0.00011		0.00163
ESE	0.00011		0.00054	0.00054	0.00022	0.00022	0.00163
SE	0.00032	0.00022	0.00054	0.00076	0.00065	0.00032	0.00281
SSE	0.00011	0.00065	0.00076	0.00076	0.00022		0.00250
S	0.00051	0.00086	0.00108	0.00054			0.00302
SSW	0.00011	0.00054	0.00086	0.00022			0.00173
SW	0.00022	0.00032	0.00011				0.00065
WSW	0.00011				0.00011		0.00022
W							
WNW		0.00022		0.00011			0.00033
NW			0.00022	0.00011			0.00033
NNW		0.00151	0.00140	0.00076	0.00011		0.00378
Total	0.00196	0.00702	0.00842	0.00413	0.00142	0.00054	0.02349

Table E-4. Frequency of wind speed and direction: D stability condition

Wind toward	Frequency for wind speed (m/sec) of –						Total
	0.89	2.46	4.47	6.93	9.61	10.73	
N	0.00399	0.01468	0.00777	0.00227			0.02871
NNE	0.00259	0.00594	0.00421	0.00140			0.01414
NE	0.00281	0.00270	0.00097	0.00108	0.00011		0.00767
ENE	0.00194	0.00205	0.00097	0.00162			0.00658
E	0.00119	0.00227	0.00399	0.00324	0.00097	0.00022	0.01188
ESE	0.00194	0.00151	0.00572	0.01284	0.00767	0.00205	0.03173
SE	0.00162	0.00184	0.00605	0.01112	0.00939	0.00356	0.03358
SSE	0.00238	0.00583	0.00831	0.00939	0.00259	0.00032	0.02882
S	0.00238	0.01641	0.01717	0.00734	0.00054	0.00011	0.04395
SSW	0.00356	0.01760	0.01188	0.00313	0.00076	0.00011	0.03704
SW	0.00292	0.00777	0.00205	0.00086	0.00022		0.01382
WSW	0.00248	0.00194	0.00054	0.00022			0.00518
W	0.00281	0.00194	0.00097	0.00011			0.00583
WNW	0.00238	0.00227	0.00151	0.00054			0.00670
NW	0.00292	0.00594	0.00659	0.00097			0.01642
NNW	0.00270	0.01404	0.01490	0.00583	0.00011		0.03758
Total	0.04061	0.10473	0.09360	0.06196	0.02236	0.00637	0.32963

Table E-5. Frequency of wind speed and direction: E stability condition

Wind toward	Frequency for wind speed (m/sec) of –						Total
	0.89	2.46	4.47	6.93	9.61	10.73	
N	0.00443	0.01749	0.01101	0.00151	0.00032	0.00032	0.03508
NNE	0.00529	0.01090	0.00831	0.00086			0.02536
NE	0.00453	0.00842	0.00410	0.00076	0.00011	0.00011	0.01803
ENE	0.00324	0.00410	0.00313	0.00140	0.00076	0.00022	0.01285
E	0.00248	0.00270	0.00594	0.00205	0.00162	0.00054	0.01533
ESE	0.00238	0.00184	0.00777	0.00853	0.00637	0.00173	0.02862
SE	0.00140	0.00324	0.01058	0.01296	0.00464	0.00108	0.03390
SSE	0.00259	0.00767	0.00961	0.00756	0.00108		0.02851
S	0.00702	0.01544	0.01609	0.00497	0.00097		0.04449
SSW	0.00680	0.03099	0.01976	0.00378	0.00108	0.00011	0.06252
SW	0.00637	0.01328	0.00464	0.00065	0.00054		0.02548
WSW	0.00335	0.00345	0.00086				0.00766
W	0.00270	0.00443	0.00194	0.00011	0.00011		0.00929
WNW	0.00313	0.00443	0.00227	0.00011			0.00994
NW	0.00464	0.00669	0.00292	0.00032	0.00065		0.01522
NNW	0.00410	0.01231	0.00961	0.00248	0.00076	0.00022	0.02948
Total	0.06445	0.14738	0.11854	0.04805	0.01901	0.00433	0.40176

Table E-6. Frequency of wind speed and direction: F stability condition

Wind toward	Frequency for wind speed (m/sec) of –						Total
	0.89	2.46	4.47	6.93	9.61	10.73	
N	0.00238	0.00464	0.00076				0.00778
NNE	0.00335	0.00626	0.00065				0.01026
NE	0.00356	0.00443	0.00076				0.00875
ENE	0.00205	0.00140	0.00032				0.00377
E	0.00227	0.00097	0.00076		0.00011		0.00411
ESE	0.00173	0.00054	0.00086	0.00011			0.00324
SE	0.00184	0.00065	0.00076	0.00022			0.00347
SSE	0.00259	0.00162	0.00065	0.00011			0.00497
S	0.00486	0.00356	0.00076				0.00918
SSW	0.00572	0.01544	0.00551	0.00054			0.02721
SW	0.00540	0.01015	0.00086				0.01641
WSW	0.00335	0.00151					0.00486
W	0.00119	0.00065					0.00184
WNW	0.00097	0.00086					0.00183
NW	0.00173	0.00173	0.00011				0.00357
NNW	0.00313	0.00443	0.00054	0.00011			0.00821
Total	0.04612	0.05884	0.01330	0.00109	0.00011		0.11946

Table E-7. Frequency of wind speed and direction: G stability condition

Wind toward	Frequency for wind speed (m/sec) of –						Total
	0.89	2.46	4.47	6.93	9.61	10.73	
N	0.00097	0.00086					0.00183
NNE	0.00140	0.00173	0.00011				0.00324
NE	0.00173	0.00054					0.00227
ENE	0.00097	0.00022	0.00011				0.00130
E	0.00086	0.00032					0.00118
ESE	0.00108	0.00022					0.00130
SE	0.00119	0.00022					0.00141
SSE	0.00108	0.00032		0.00011			0.00151
S	0.00108	0.00054	0.00011				0.00173
SSW	0.00162	0.00453	0.00011				0.00626
SW	0.00194	0.00367					0.00561
WSW	0.00086	0.00011					0.00097
W	0.00108	0.00022					0.00130
WNW	0.00054	0.00022					0.00076
NW	0.00151	0.00011					0.00162
NNW	0.00076	0.00054					0.00130
Total	0.01867	0.01437	0.00044	0.00011			0.03359

Table E-8. Values of χ/Q for Indian Point Unit No. 3

Distance (meters)	χ/Q (sec/m^3) for indicated direction from stack							
	E	ENE	NE	NNE	N	NNW	NW	WNW
150.	5.682E-05	5.745E-05	9.766E-05	1.150E-04	1.176E-04	1.109E-04	7.617E-05	4.220E-05
200.	3.251E-05	3.288E-05	5.580E-05	6.580E-05	6.766E-05	6.378E-05	4.370E-05	2.427E-05
300.	1.477E-05	1.494E-05	2.532E-05	2.990E-05	3.093E-05	2.916E-05	1.995E-05	1.111E-05
400.	8.438E-06	8.542E-06	1.446E-05	1.709E-05	1.776E-05	1.674E-05	1.144E-05	6.384E-06
500.	5.469E-06	5.538E-06	9.366E-06	1.108E-05	1.155E-05	1.089E-05	7.434E-06	4.154E-06
600.	3.922E-06	3.975E-06	6.719E-06	7.954E-06	8.307E-06	7.828E-06	5.343E-06	2.992E-06
700.	2.962E-06	3.004E-06	5.076E-06	6.011E-06	6.287E-06	5.922E-06	4.042E-06	2.267E-06
800.	2.323E-06	2.357E-06	3.981E-06	4.717E-06	4.940E-06	4.651E-06	3.175E-06	1.783E-06
900.	1.876E-06	1.904E-06	3.214E-06	3.810E-06	3.995E-06	3.762E-06	2.566E-06	1.442E-06
1000.	1.550E-06	1.573E-06	2.655E-06	3.148E-06	3.305E-06	3.112E-06	2.121E-06	1.193E-06
1100.	1.314E-06	1.334E-06	2.249E-06	2.668E-06	2.805E-06	2.641E-06	1.798E-06	1.013E-06
1200.	1.129E-06	1.147E-06	1.933E-06	2.294E-06	2.415E-06	2.274E-06	1.547E-06	8.722E-07
1300.	9.830E-07	9.980E-07	1.681E-06	1.997E-06	2.105E-06	1.982E-06	1.347E-06	7.601E-07
1400.	8.644E-07	8.777E-07	1.478E-06	1.756E-06	1.853E-06	1.745E-06	1.185E-06	6.692E-07
1600.	6.858E-07	6.964E-07	1.172E-06	1.393E-06	1.473E-06	1.387E-06	9.407E-07	5.320E-07
1800.	5.592E-07	5.679E-07	9.546E-07	1.136E-06	1.203E-06	1.133E-06	7.674E-07	4.346E-07
2000.	4.660E-07	4.732E-07	7.949E-07	9.462E-07	1.004E-06	9.459E-07	6.397E-07	3.627E-07
2500.	3.312E-07	3.364E-07	5.665E-07	6.730E-07	7.092E-07	6.678E-07	4.535E-07	2.563E-07
3000.	2.508E-07	2.548E-07	4.298E-07	5.098E-07	5.341E-07	5.028E-07	3.425E-07	1.931E-07
3500.	1.983E-07	2.014E-07	3.404E-07	4.032E-07	4.203E-07	3.957E-07	2.703E-07	1.520E-07
4000.	1.618E-07	1.644E-07	2.782E-07	3.291E-07	3.417E-07	3.216E-07	2.202E-07	1.236E-07
4500.	1.353E-07	1.374E-07	2.328E-07	2.752E-07	2.846E-07	2.679E-07	1.838E-07	1.030E-07
5000.	1.153E-07	1.171E-07	1.986E-07	2.345E-07	2.418E-07	2.275E-07	1.563E-07	8.745E-08
6000.	8.848E-08	8.987E-08	1.526E-07	1.800E-07	1.848E-07	1.739E-07	1.197E-07	6.684E-08
7000.	7.075E-08	7.186E-08	1.222E-07	1.440E-07	1.473E-07	1.386E-07	9.559E-08	5.326E-08
8000.	5.831E-08	5.921E-08	1.008E-07	1.186E-07	1.210E-07	1.138E-07	7.865E-08	4.375E-08
10000.	4.221E-08	4.286E-08	7.304E-08	8.590E-08	8.715E-08	8.198E-08	5.679E-08	3.150E-08
15000.	2.422E-08	2.458E-08	4.195E-08	4.927E-08	4.961E-08	4.663E-08	3.234E-08	1.791E-08
20000.	1.634E-08	1.657E-08	2.832E-08	3.323E-08	3.330E-08	3.128E-08	2.170E-08	1.201E-08
30000.	9.747E-09	9.876E-09	1.692E-08	1.981E-08	1.963E-08	1.844E-08	1.284E-08	7.074E-09
40000.	6.761E-09	6.845E-09	1.175E-08	1.373E-08	1.351E-08	1.269E-08	8.861E-09	4.864E-09
50000.	5.093E-09	5.154E-09	8.860E-09	1.034E-08	1.012E-08	9.498E-09	6.648E-09	3.639E-09
60000.	4.037E-09	4.084E-09	7.029E-09	8.194E-09	7.972E-09	7.483E-09	5.248E-09	2.867E-09
70000.	3.318E-09	3.355E-09	5.781E-09	6.732E-09	6.521E-09	6.119E-09	4.299E-09	2.344E-09
80000.	2.800E-09	2.830E-09	4.882E-09	5.680E-09	5.481E-09	5.142E-09	3.618E-09	1.969E-09
100000.	2.114E-09	2.135E-09	3.686E-09	4.284E-09	4.114E-09	3.861E-09	2.720E-09	1.476E-09

Table E-8. (continued)

Distance (meters)	χ/Q (sec/m^3) for indicated direction from stack							
	W	WSW	SW	SSW	S	SSE	SE	ESE
150.	4.814E-05	6.042E-05	1.564E-04	2.293E-04	1.474E-04	8.507E-05	6.986E-05	6.538E-05
200.	2.757E-05	3.458E-05	8.928E-05	1.314E-04	8.477E-05	4.885E-05	4.008E-05	3.753E-05
300.	1.257E-05	1.573E-05	4.052E-05	5.987E-05	3.874E-05	2.228E-05	1.826E-05	1.713E-05
400.	7.202E-06	9.000E-06	2.314E-05	3.428E-05	2.224E-05	1.277E-05	1.046E-05	9.823E-06
500.	4.676E-06	5.837E-06	1.499E-05	2.225E-05	1.446E-05	8.298E-06	6.794E-06	6.383E-06
600.	3.359E-06	4.193E-06	1.075E-05	1.599E-05	1.040E-05	5.958E-06	4.876E-06	4.585E-06
700.	2.540E-06	3.170E-06	8.124E-06	1.210E-05	7.874E-06	4.504E-06	3.684E-06	3.466E-06
800.	1.994E-06	2.488E-06	6.372E-06	9.505E-06	6.188E-06	3.536E-06	2.891E-06	2.721E-06
900.	1.610E-06	2.010E-06	5.143E-06	7.682E-06	5.005E-06	2.858E-06	2.336E-06	2.199E-06
1000.	1.330E-06	1.661E-06	4.247E-06	6.350E-06	4.142E-06	2.363E-06	1.931E-06	1.818E-06
1100.	1.127E-06	1.407E-06	3.596E-06	5.384E-06	3.516E-06	2.005E-06	1.638E-06	1.542E-06
1200.	9.693E-07	1.210E-06	3.089E-06	4.631E-06	3.028E-06	1.725E-06	1.409E-06	1.327E-06
1300.	8.435E-07	1.053E-06	2.686E-06	4.032E-06	2.639E-06	1.502E-06	1.227E-06	1.155E-06
1400.	7.417E-07	9.258E-07	2.361E-06	3.547E-06	2.324E-06	1.322E-06	1.079E-06	1.017E-06
1600.	5.883E-07	7.343E-07	1.870E-06	2.816E-06	1.848E-06	1.050E-06	8.570E-07	8.073E-07
1800.	4.796E-07	5.986E-07	1.523E-06	2.297E-06	1.510E-06	8.574E-07	6.993E-07	6.589E-07
2000.	3.995E-07	4.986E-07	1.267E-06	1.914E-06	1.260E-06	7.151E-07	5.831E-07	5.494E-07
2500.	2.837E-07	3.548E-07	9.043E-07	1.360E-06	8.901E-07	5.061E-07	4.130E-07	3.890E-07
3000.	2.146E-07	2.687E-07	6.866E-07	1.028E-06	6.704E-07	3.819E-07	3.119E-07	2.936E-07
3500.	1.696E-07	2.125E-07	5.440E-07	8.122E-07	5.276E-07	3.011E-07	2.460E-07	2.315E-07
4000.	1.383E-07	1.735E-07	4.448E-07	6.622E-07	4.289E-07	2.451E-07	2.004E-07	1.885E-07
4500.	1.155E-07	1.450E-07	3.725E-07	5.531E-07	3.573E-07	2.044E-07	1.672E-07	1.572E-07
5000.	5.840E-08	1.236E-07	3.178E-07	4.709E-07	3.035E-07	1.739E-07	1.423E-07	1.337E-07
6000.	7.546E-08	9.484E-08	2.443E-07	3.610E-07	2.320E-07	1.331E-07	1.090E-07	1.024E-07
7000.	6.029E-08	7.583E-08	1.956E-07	2.883E-07	1.848E-07	1.062E-07	8.698E-08	8.170E-08
8000.	4.965E-08	6.247E-08	1.614E-07	2.374E-07	1.519E-07	8.735E-08	7.157E-08	6.721E-08
10000.	3.590E-08	4.521E-08	1.170E-07	1.715E-07	1.094E-07	6.304E-08	5.169E-08	4.851E-08
15000.	2.048E-08	2.588E-08	6.719E-08	9.814E-08	6.233E-08	3.596E-08	2.951E-08	2.763E-08
20000.	1.375E-08	1.743E-08	4.534E-08	6.606E-08	4.186E-08	2.417E-08	1.985E-08	1.855E-08
30000.	8.165E-09	1.037E-08	2.711E-08	3.923E-08	2.470E-08	1.430E-08	1.177E-08	1.097E-08
40000.	5.644E-09	7.183E-09	1.883E-08	2.713E-08	1.700E-08	9.872E-09	8.135E-09	7.570E-09
50000.	4.241E-09	5.403E-09	1.420E-08	2.038E-08	1.273E-08	7.408E-09	6.112E-09	5.679E-09
60000.	3.353E-09	4.278E-09	1.127E-08	1.612E-08	1.004E-08	5.850E-09	4.831E-09	4.483E-09
70000.	2.750E-09	3.512E-09	9.272E-09	1.322E-08	8.213E-09	4.793E-09	3.962E-09	3.672E-09
80000.	2.317E-09	2.961E-09	7.830E-09	1.114E-08	6.904E-09	4.034E-09	3.337E-09	3.090E-09
100000.	1.744E-09	2.231E-09	5.912E-09	8.384E-09	5.183E-09	3.035E-09	2.514E-09	2.324E-09

Appendix F

LIFE HISTORY INFORMATION OF IMPORTANT FISH SPECIES IN THE HUDSON RIVER NEAR INDIAN POINT

From an ecological standpoint, the most important fish species occurring near Indian Point are the estuarine and marine forms that migrate through the area to spawn and those that require the estuarine environment for a nursery area. Fresh water and marine fishes that occur in the area from time to time through random wandering are less important to the area and will not be discussed in detail.

Shortnose Sturgeon (*Acipenser brevirostris*)

The smallest species of sturgeon, the shortnose sturgeon, is classified as an endangered species.[1] Apparently, it never grows to more than about 3 ft.

The early history is unknown. Few small specimens have been recorded; probably the smallest fish is one of 7.3 in. (about 185 mm), from North Carolina. The smallest specimens taken in the Hudson River were two females, both a little less than 18 in.; one weighed 15 oz and the other 19 oz. The sizes of five specimens from the Delaware River observed by Ryder ranged between 18 and 23 in. Age determinations based on otolith readings[2] have shown that *A. brevirostris* is a very slow growing species. Specimens of *brevirostris* from the Hudson River that measured 17 to 35 in. (about 430 to 890 mm) total length were 4 to 15 years old.

Males may mature when they are only about 20 in. total length, and most of them do so by the time they pass 21 in.; most of the females mature at about 24 in. The ripe eggs are dark brown and the fecundity is not known. Spawning takes place in rivers early in the spring. For Hudson River fish, the spawning season evidently includes late April.

Because of its small size, *A. Brevirostris* has attracted little attention except when taken in nets in fresh, brackish, or salt water. It is found most often in tidal rivers, but the capture of specimens in the Gulf of Maine shows that some certainly go out into the open sea and wander for some distance from the parent stream.

Studies of stomach contents from Hudson River specimens show that *A. brevirostris* feeds upon the bottom, eating small animals and plants intermingled with mud. Some of the organisms consumed are sludgeworms, chironomid larvae, and small crustaceans.[3] Judging from the stomach contents of fish taken from the area between Rhinebach and Nyack, they seem to feed mostly on the bottom at a depth of 12 to 30 ft[4] with a main diet of snails, clams, crustaceans, and other bottom organisms.

The breeding range of *A. brevirostris* is not clearly defined, but it certainly includes the Hudson River, where the spawning areas appear to be very restricted.[2] The Delaware River may still maintain a small local population, and the Saint John River in New Brunswick probably has a spawning population, judging by the near-spawning condition of a male and female taken at Gagetown. If, through increased pollution or habitat changes, the population is no longer able to persist in these northern rivers, the species may become dangerously reduced.[2]

Atlantic Sturgeon (*Acipenser oxyrhynchus*)

The Atlantic sturgeon is an anadromous fish found on the Atlantic coast from the Saint Lawrence River, Canada, to northern Florida. This species lives in both fresh and brackish waters of the Hudson. Adults enter the river in the spring to deposit their eggs in fresh or brackish water (possibly preferring brackish),[5] and they then spend the remainder of the summer in the river before returning to the sea in the fall.

Sturgeon are bottom feeders and are usually found on sand or mud. Their diet consists mainly of worms, insect larvae, crustaceans, molluscs, and small fish.[6]

Female Atlantic sturgeons produce from 1 to 2-1/2 million eggs for each year's spawning. The eggs are heavy and strongly adhesive, sticking to each other and to the river bed, where they are deposited in large masses.[2,6] The eggs, 2.5 mm in diameter, hatch in about 6 days. At hatching, the larvae are about 11 mm long, but they reach a length of about 4 in. (10 cm) in one month's time.[2,6] Sturgeon young live on their yolk sac until about 20 mm long, then begin to feed on planktonic crustaceans. At a length of about 9 in. (23 cm), they become bottom feeders, rooting in the sand or mud with their snouts for amphipod and isopod crustaceans.[6]

Their juvenile distribution is not well known, because unlike striped bass and other species, the young are not taken by seines along the river's edge. Young sturgeon may remain in rivers until they reach 30 to 36 in. (76 to 91 cm) in length.[5] In March of 1968, 500 Atlantic sturgeon were captured in Haverstraw Bay with the 40-ft otter trawl. Of these, a sample of 71 fish ranged from 10 to 34 in. (26 to 87 cm).[3]

The Atlantic sturgeon is an anadromous species, invariably spawning in fresh or brackish water but making its growth in salt water. The adults migrate from the sea to fresh water in advance of the spawning season. The spawning migration begins at the end of April or beginning of May in the Hudson River.

When laid, the eggs are light to dark brown. The outside membrane of ripe eggs readily imbibes water and becomes attached to weeds and stones and the eggs are probably scattered over a wide area. There is no evidence of prenatal care, such as preparation of a nest area.[2,5]

Sturgeon are bottom fish and are seldom seen except when taken in nets or when jumping, and surprisingly, this relatively sluggish species is capable of making powerful jumps.[2]

Very little appears to be known about the behavior of the sturgeon in salt water. These fish can adapt to a sudden change from salt to fresh water, or vice versa. Some tagged specimens were forced to abruptly change salinity habitats at least twice during the same season, apparently without harmful results, because they were recaptured alive.[2]

The large sturgeon feeds on molluscs and other bottom organisms. It roots in the sand or mud with its snout to uncover the worms and molluscs on which it feeds and sucks into its mouth with considerable amounts of mud.[2,6] The sturgeon also eats small fishes, particularly launce (*Ammodytes*).[2] The mature sturgeon, like the salmon, eats little or nothing while traveling up the river to spawn.

The digestive tracts of 26 young *A. oxyrhynchus* weighing 1 to 7 lb from the Hudson River contained bottom mud along with plant and animal matter, including sludgeworms (*Limnodrilus*), chironomid larvae, isopods, amphipods, and small bivalve molluscs (*Pisidium*).[2]

The food of *A. Oxyrhynchus* varies with the type of habitat, as in the Saint Lawrence River, Quebec. Polychaete worms (*Nereis virens*) were found (265 on the average; the maximum number in a single stomach was 1,221) in 27 half-grown sturgeon taken in salt water. In addition, the sturgeon fed on marine gastropods, shrimps (*Crago*), amphipods, and isopods, in that order. In fresh water, the bulk of the food consisted of aquatic insects, amphipods, and oligochaete worms; in 88% of 178 sturgeon examined, larvae of the burrowing mayfly (*Hexagenia*) were present.[2]

Bluefish (*Pomatomus saltatrix*)

The bluefish occurs on the Atlantic coast seasonally from the Florida Keys to southern New England.[3] Throughout this range, it is particularly abundant in southern Florida, in North Carolina and Virginia, and from New Jersey to southern Massachusetts.

In the north, bluefish spawn in July and August between the 15-fathom (27-m) isobath and the edge of the shelf from northern North Carolina to Long Island.

After spawning, young bluefish lead a pelagic life for one month or longer, depending on the distance they must travel to the coast from the spawning areas and upon water temperature and other unknown environmental variables. In the New York area, the young arrive in two waves. The first reaches the coast from late June to early July, when most juveniles range from 3 to 5 in. (7.5 to 12.5 cm) in length. These juveniles are probably recruits from the spring spawning south of Cape Hatteras, having been carried north by the Gulf Stream system. The second wave, which reaches Middle Atlantic coasts in mid-August when the young range from 1 to 4 in. (3 to 10 cm), are probably recruits from the northern spawnings in summer. Those of the first wave change from a diet largely of planktonic forms (crustaceans and fish eggs) to one of small fish when they are 2.4 to 3.5 in. (6 to 9 cm) long. This is about the time they become abundant along the coast and move into the Hudson estuary. They grow very fast during the course of their first summer, those of the first wave reaching around 10 in. or more before the end of the summer. They leave the estuaries in the early part of autumn and disappear into the sea for winter. According to Greeley,[7] bluefish were moderately common in the Hudson in August and September in 1937, with considerable numbers of young fish inhabiting the lower areas of the river. However, recent surveys have not indicated so great an abundance in the area.

Menhaden (*Brevoortia tyrannus*)

The menhaden is a very abundant and economically important oceanic member of the herring family.[3] Its range extends from Nova Scotia to Florida. Adults undertake extensive migrations, moving northward along the coast in spring and southward in fall. During the summer, they tend to be found in inshore areas, while in winter they move to deeper water. They spawn at sea over a wide geographical range throughout much of the year.[8] The larvae move inshore to enter the estuaries along the coast and usually congregate near the upstream limits of the tidal zone. These areas are rich in plankton organisms, such as diatoms and holophytic flagellates, which provide the food necessary for the survival of the young. As they increase in size, they tend to move farther downstream, and as fall approaches, they congregate near the mouth of the river before moving out to sea.[8]

In 1936, Greeley reported that young menhaden were common in the Hudson and were numerous at the mouth of the Mamroneck River in mid-July.[7] In recent surveys, the menhaden have not been abundant. However, this species may once again become abundant as pollution abatement measures reduce the pollution level of the lower Hudson.[3]

Menhaden feed on small organisms strained from the water by their numerous long, slender, close-set gill rakers, which form an effective strainer. While feeding, the fish generally swim near the surface and often "break water;" they whirl around, sound a short distance, come out of the whirl, and swim up and straight ahead at a considerable speed for a rather short distance. During this time, the mouth is wide open and the gill covers are lifted, thus making it possible for a fish to filter a great amount of water with minimum effort. The food that is ingested depends in large measure upon the organisms present where the fish is feeding. Even a considerable amount of mud and general debris is often swallowed. Included in the stomach contents examined by various investigators were numerous small crustaceans, especially copepods; small annelid worms; rotifers; and unicellular plants, particularly diatoms and peridinians. Plant organisms, as a rule, constitute the chief food.[9]

Most predatory animals associated with the sea feed on Atlantic menhaden — an easy prey because of their habit of schooling. Their fiercest enemy probably is the bluefish (*Pomatomus*), which kills many more than it eats. Among the other fish that feed extensively on menhaden are the cod, pollock, hakes, weakfish, swordfish, tuna, dolphin, amberjacks, and sharks. Whales and porpoises, as well as birds, also devour many of them.[9]

Large commercial fisheries for this species obtain two products from them — oil and fish meal. The fish meal is used for poultry and livestock feed. These fish, though exceedingly valuable, are not used very extensively as food by man, mainly because of their bony nature and oiliness. However, some find the flesh delicious, and many people living along the coast, especially the fishermen, eat them in season as a common article of diet. Considerable quantities are often "corned" (salted) for home use during winter, and they are said to be delicious when smoked. They were canned to a limited extent for export during the last war, and a small quantity is still canned for home consumption.[9]

American Shad (*Alosa sapidissima*)

The American shad is an anadromous fish of the herring family, Clupeidae. Its range includes offshore, coastal, and river waters from Newfoundland to the Saint John's River, Florida. Shad are most abundant from Connecticut to North Carolina. They spend their adult lives in the ocean, except in spring, when they ascend rivers along the coast to spawn. Hudson fish, like others that spawn in rivers north of the Chesapeake Bay, are said to return to the sea and migrate north to the Gulf of Maine waters.[5] In winter they are presumed to remain in the deeper offshore waters of the Middle Atlantic coast, moving inshore again as the spawning season approaches.[10]

Shad begin their spawning run into the Hudson in late March and early April, and the run continues until the end of June. Although much of the river below the Troy Dam is used for spawning, the major breeding area appears to be just below the town of Catskill.[11] The average number of eggs produced by a single fish varies between 25,000 and 30,000, with larger fish producing more eggs than small ones.[12] The eggs are deposited in the water and sink, to be carried along near the bottom by the current. They are reported[12] to hatch in 52 hr at an average temperature of 57.2°F, and in less than 36 hr at an average of 74°F. However, a longer incubation period has been reported.[12] Eggs held under artificial conditions hatched in 12 to 15 days at 53.6°F (12°C) and in 6 to 8 days at 62.6°F (17°C). The yolk is absorbed in 4 to 5 days at 62.5°F.[12]

Newly hatched larval shad average 0.40 in. in length and are transported by water currents.[12] They were most abundant near river mile 110 during the 1940–1942 surveys (New York State Conservation Department, 1943).

The young, as they grow, tend to disperse from the upstream spawning grounds down into the lower brackish parts of the river. The larvae appear to feed on plankton; the principal diet of juveniles consists of small crustaceans and insect larvae.[13] Those found in the lower estuarine parts of the river are reported to grow faster than those further upstream.[14] In the autumn, the young migrate to the sea to stay until they mature and join the annual spring migrations into the river for spawning.

By working with young specimens from the Shubenacadie River, a tributary to the Bay of Fundy, and its estuary, Leim found that the first food taken by larvae 11 mm long consisted of midge larvae (Chironomidae), while the somewhat larger larvae fed principally on mature and immature copepods.[15] In fact, these organisms constituted the chief food of the young up to the time of transformation, and the relative abundance of these forms in a particular locality determined which food predominated. These data show also that young adults taken in the same vicinity continued to subsist principally on these same organisms. Other foods ingested consisted of ostracods, insects, and fish.[12]

Little or no food has been found in the stomachs of shad caught while in fresh water en route to their spawning grounds, indicating that these fish, like salmon, do not ordinarily feed at that time. However, there are some records showing that adults occasionally do take food while in fresh water, at least late during the spawning season. They will often take a live minnow or an artificial fly when working upstream on their spawning run.[12]

From an examination of about 350 stomachs of both mature and immature fish caught in the salt water of Scotsman Bay (Bay of Fundy). Leim found that, while copepods constituted the chief food of the smaller ones, as in fresh water, these crustaceans were unimportant in fish 400 mm and more in length.[15] Mysids, which were sparingly eaten by small fish, were the chief food of adult fish. In general, about 90% of the specimens of all sizes from that area had eaten copepods and mysids, with ostracods, amphipods, isopods, decapod larvae, insects, molluscs, algae, fish eggs, and fish making up the remainder. After examining many stomachs of specimens taken in the Bay of Fundy, Willey also concluded that the chief foods consisted of copepods and mysids, with a few shrimp and larval stages of barnacles.[12] Stomach samples from Hudson River fish support his conclusions.[13]

The shad is still an important contributor to the Hudson River commercial fishery. The catch was 238,000 lb in 1965 and 245,000 lb in 1968. The peak catch during the past 50 years was 3,800,000 lb in 1944. Sport fishing for shad in the Hudson is currently unimportant.[3]

Although there is no sport fishing for shad in the Hudson, more than 100,000 sport fishermen fished for shad in other Atlantic coastal rivers, estuaries, and bays in 1965 and took an estimated 4,700,000 lb of them. From Maine to North Carolina, commercial fishermen took 6,372,000 lb of shad in 1965. The part of this catch that depends upon Hudson stock is not certain. However, tagging experiments in the river indicate that Hudson shad migrate as far north as Maine and as far south as North Carolina, and thus contribute to coastal fisheries far from New York.[11] Tagging shad from pound nets on the New Jersey and New York coasts in 1956 indicated that Hudson River stock made up 76% of the catches of these nets; therefore, these catches were dependent on the size of the Hudson River shad population.[16]

Bay Anchovy (*Anchoa mitchilli*)

The bay anchovy is a schooling species found in coastal salt and brackish waters, ranging from Mexico to Maine. This species has a long spawning season from late spring to September in the New York area and is a major component of the fish fauna at Indian Point.

A total length of 4 in. (100 mm) is seldom exceeded, with a usual length of about 3 in. (75 mm). The largest specimens have been taken in New York, where this species evidently grows larger than in the southern part of its range.[17]

The anchovy numerically is the most abundant fish caught by trawls within the study area near Indian Point. This species constituted 43% of the bottom trawl and 68% of the surface trawl catches. However, it made up less than 1% of the beach seine populations, occurring only in small numbers in 11 catches from August through October.[18]

The highest concentrations of the anchovy were observed during the months of August through October and were confined primarily to Haverstraw Bay.[18] There appears to be a general dispersal of the anchovy population from lower Haverstraw Bay in July throughout the entire Bay during August. The anchovy was caught in every surface and bottom trawl sample taken in September by Raytheon Co. investigators in 1969.[19] There is an abrupt decrease and general disappearance of the anchovy from the area during November and December. This species occurred at only three of the 14 bottom trawl stations sampled during December, and the three stations were located in the immediate vicinity of the Indian Point and Lovett Power Plants.[17]

The eggs are buoyant when spawned but gradually become demersal. They hatch in about 24 hr at room temperature.[17] The newly hatched fish, 1.8 to 2.0 mm long, are rather slender, are perfectly transparent, and have no pigment spots. The yolk sacs are absorbed within about two days, and the large mouths, which are terminal at this stage, then seem to be functional. Larvae of this species are found at Indian Point.

Young-of-the-year fish, immatures, and adults are abundant from late spring to early autumn in the lower Hudson River. The early young of the season may become sexually mature during their first summer, for specimens 45 to 60 mm long that remained quite transparent, taken late in July and during the first half of August, contained well developed roe.[18]

The food apparently consists mostly of *Mysis* and copepods, the latter being the sole food of the young. Other food includes small fish, gastropods, and isopods.[17]

Eels (*Anguilla rostrata*)

The American eel is a catadromous species found in abundance in the Hudson River. The species occurs from the Gulf of Saint Lawrence to as far south as Brazil. The eel spends most of its life in freshwater creeks and ponds, rivers, and estuaries but migrates to the Sargasso Sea southwest of Bermuda to spawn. Newly hatched larvae, with the help of ocean currents, migrate from the ocean spawning grounds to the coastal rivers. The females travel far upstream into freshwater environments, but the males remain in the estuarine environment near the mouth of the river. As a mature adult, several years later, the eel retraces its route back to the oceanic spawning grounds, where it breeds and then dies. As eels migrate upstream in the vicinity of Indian Point, they are relatively common both in the surface and bottom samples but less so at mid depth.[18]

A small commercial fishery for eels is carried on in the Hudson River. The catch was 5,300 lb in 1965 and only 2,500 lb in 1968. Sport fishing catches are undoubtedly much higher than this, but no estimates are available for the Hudson.[3]

This species has been found to be a major component of the fish fauna in certain New Jersey streams[20] and may play a similar role for the tributaries of the Hudson.

Tomcod (*Microgadus tomcod*)

This species was previously described in relation to the Hudson by Clark and Smith.[3] The tomcod is a marine species that commonly spawns in the Hudson. It is a member of the family Gadidae, which contains some commercially important species. Tomcod spawn in shallow estuarine waters and around stream mouths. The demersal eggs are about 1.5 mm in diameter, heavy, and adhesive. They hatch in 24 to 30 days, depending on the temperature of the water. Spawning occurs from January through April in brackish water, and larvae are common at Indian Point in early spring. The adults move into the estuary from October to December and return to the lower estuary or the Atlantic after spawning. The juvenile fish spend their first summer in the waters where they were spawned and grow to a length of 2-1/2 to 3 in. by the following autumn.

Tomcod feed on a variety of organisms including small crustaceans, especially shrimp and amphipods, worms, small molluscs, squids, and small fish. They are most commonly found on the bottom.

White Perch (*Morone americana*)

This species is found in fresh, brackish, and coastal salt water between South Carolina and Nova Scotia.[21] Spawning of demersal and adhesive eggs (7.5 mm in diameter) occurs in fresh and brackish water from April to June, depending on geographic location, and at water temperatures between 45 and 60°F.[22] The eggs hatch in about 3 days at 58°F. Young and adults remain in fresh or brackish waters. They frequent shoal areas, except in winter, when they congregate in the deeper parts of bays and rivers, to remain sluggish until spring. During spring, summer, and autumn, localized wandering occurs.[21] This species feeds on small crustaceans and small fish.[13,21]

The white perch is a major resident species at Indian Point. It is one of the most abundant species in the lower Hudson and is found throughout the year in all life stages at Indian Point.[18]

This species grows to about 15 in. and weighs from 2 to 3 lb. It is of limited commercial importance but is commonly fished for along the shore at many localities.[18]

American Smelt (*Osmerus mordax*)

American smelt from salt water average 7 to 9 in. long when fully grown and about 12 to 13 in. at the maximum. They ordinarily run between 1 and 4 oz, with very large individuals weighing up to 6 oz. The following discussion has been abstracted from a discussion by Bigelow and Schroeder.[23]

Females weighing no more than 2 oz may produce as many as 40,000 to 50,000 eggs; one 9.12 in. long female taken in Crystal Lake, Michigan, contained 43,125 eggs. The eggs, which range in diameter from 0.6 mm to about 1.2 mm in different waters, sink to the bottom, where they adhere to each other in clusters or cling to any object they settle on. In European waters, the eggs hatch in 8 to 27 days, depending on the temperature of the water. In Massachusetts, they have been reported to hatch in 13 days.

The larvae are about 5 to 6 mm long when they hatch and are perfectly transparent at first. Once hatched, they rise close to the surface and drift downstream. On the average, they grow to 17 or 18 mm during their first month, 27 to 34 mm during the second month, and about 40 mm after 3-1/2 months. By the time the larvae have grown to 8 mm, the yolk sac is mostly absorbed, at 15 mm all the fins are more or less developed, and by 45 mm the formation of scales has begun.

In their second spring, when 1 year old, the fry average about 3.4 in. long. From scale studies they appear to average as follows: at 2 years about 5.7 in. and about 0.6 oz; at 3 years, 6.7 in. and about 1.1 oz; at 4 years, 8.7 in. and about 2 oz. The largest specimen measured was about 9 in. Four or more year classes are often represented in the commercial catches.

The marine fish normally spawn in freshwater, and as a rule they do not travel far upstream; they may go only a few hundred yards above the head of the tide. Others spawn in the tidal zone or even in brackish water behind barrier beaches. They generally spawn on pebbly bottom where there is a current, often in water only a few inches deep. Most often the spawners are 2 years old or older. Spawning takes place in late winter or early spring, depending on the temperature of the water. According to data from hatchery operations, the chief production of eggs takes place in temperatures of 50 to 57°F in Massachusetts and of about 45 to 50°F in Grand River, Quebec, representative of the northern part of their range. The spawning period lasts 10 to 14 days and is completed ordinarily by mid-May. The spent fish move downstream to brackish or salt water immediately after spawning, so that all of them have left fresh water by the middle of May.

The smelt mature in brackish or salt water if they are not landlocked. During the marine phase of their life, they are confined to so narrow a coastal belt that none have ever been reported more than about 6 miles out from the land and seldom below 2 or 3 fathoms deep; the deepest record for them is 9 or 10 fathoms at the mouth of Port-au-Port Bay on the west coast of Newfoundland. Many of them spend their entire growth period in estuarine areas, including the tidal reaches of rivers.

Their habitat in the summer along any particular section of the coast appears to depend chiefly on the temperature of the water. From Massachusetts southward, most of them desert the harbors and similar situations during the warmest season, moving only far enough out and deep enough to find slightly cooler water. Along the coasts of Maine and the Maritime Provinces of Canada, however, where water temperatures are lower, they are found in the harbors, bays, and estuaries all summer.

With the onset of autumn, those that have moved out to sea reenter the harbors and estuaries, so that by mid-October or early November, practically the entire population is concentrated there. The smaller ones tend to reappear the earliest, but reports are contradictory in this respect. By December, some have even worked up into stream mouths to the head of the tide. But the fish that will breed that season, most of which are at least 2 years old, do not actually enter fresh water until late winter or early spring, when the water off the mouth of the stream has warmed to at least 39 to 42°F.

The movement of the maturing fish into fresh water commences late in February along the southern coast of New England and southward, sometime in March along northern Massachusetts, seldom until April along the eastern part of the Maine coast, and not until the latter half of May along the southern shores of the Gulf of Saint Lawrence.

This species, though confined to shallow water, is not a bottom fish but tends to hold position at some intermediate level. The small ones, and probably the large ones also, gather and travel in schools composed, for the most part, of fish of about the same size — the product of one year's hatch. In the smaller harbors, they tend to move in and out with the tide, especially if the tidal flow is strong.

This species is carnivorous and predaceous. In salt and brackish water, shrimps (decapod and mysid) probably are their chief support on the Massachusetts coast; similarly, the stomach contents of those in the Gulf of Saint Lawrence have consisted chiefly of copepods, amphipods, and mysids, with algal debris probably taken incidentally. In some localities, small fish rank next. They have been found packed full of young Atlantic herring on the coast of Maine, and a wide variety of fishes have been recorded as occurring in their stomachs at Woods Hole. They also take small shellfish, small squid, annelid worms, and small crabs. But they cease to feed during the spawning season, as many other fishes do.

American smelt have been a favorite subject for artificial propagation. Many million fry were hatched in past years at the Cold Spring Harbor Hatchery, New York, as well as the Palmer Hatchery, Massachusetts. The results have been widely heralded, for great catch increases were reported for streams where fry were released. The most notable example is that 32 million eggs were collected in 1885 from a New York stream where there had been no smelts for at least some years previous. A similar example, though less spectacular, was reported for Massachusetts.

The American smelt is a favorite among the market fish, and great numbers, especially from the Gulf of Saint Lawrence, are marketed. The average landings reported for the 4-year period 1951-1954 were 5,323,000 lb for the Canadian Atlantic coast and 150,700 lb for the United States coast, a total of 5,473,700 lb; this represents 55 million individuals if these ran, for example, 10 to the pound, all marketed for human consumption. Years ago they served as cod bait in the Gulf of Saint Lawrence, and large quantities were used as manure along the Gulf of Saint Lawrence shores of New Brunswick.

Alewife (*Alosa pseudoharengus*)

The alewife is an important forage species found along the coast from Nova Scotia to the Carolinas. During April and May, the fish travel upstream into many tributary creeks and ponds to spawn at temperatures of 50 to 60°F, sometimes in rapidly flowing water but usually in sluggish water, often only a few inches deep. After spawning, the adult fish return to the sea, remaining in the coastal waters in the general vicinity of their natal estuaries.[12]

The average female deposits about 100,000 adhesive eggs in the annual spawning. After the demersal eggs hatch, the young alewives at about 5 mm long are carried along with the current. They grow to about 15 mm in a month's time, when they are common at Indian Point. When they are about 1 to 1-1/2 in. long, they are found in the shallows of the Hudson upper estuary, as well as in the freshwater parts of the river, and they apparently feed on small crustaceans and insect larvae.[18] Raytheon data indicate that these fish prefer to remain near the bottom.[24]

Although some of the young may remain in the river for more than a single season, most move out to sea before or at the end of their first season. They remain in salt water until they reach sexual maturity (at about 3 or 4 years old), at which time they return to the rivers to spawn.[12]

Blueback Herring (*Alosa aestivalis*)

The blueback herring closely resembles the alewife, and the two are often confused. The blueback has a more southerly range, extending from Nova Scotia to northern Florida, and is more abundant south of New England. Bluebacks spawn later in the season than alewives, usually when water temperatures reach 70 to 75°F.[3] They do not seem to run far above tidewater in the Hudson, preferring deeper water, with most spawning probably occurring in the open river above Indian Point.[18] Bluebacks return to the sea soon after spawning to reside in the inshore coastal waters until winter, when they apparently move offshore.[12]

The eggs of the blueback are demersal and adhesive and hatch in about 50 hr at 72°F. The larvae are common at Indian Point.

Within a month, the young reach a length of 1 to 2 in. They spend the summer in fresh and brackish water nursery areas.[3] During a sampling program conducted in the summer of 1966, young blueback herring were found to be the second most abundant species along the shores of the Hudson.[25] In the late summer and fall, they move out of the river to the sea.

Young bluebacks in the Hudson feed mainly on small crustaceans and insect larvae;[13] as adults, they feed mainly on copepods and amphipods.[12] Raytheon data indicate that the blueback herring has a stronger preference for surface water than its relative, the alewife.[18]

Striped Bass (*Morone saxatilis*)

The striped bass is an anadromous species of the family Serranidae. This family includes freshwater, estuarine, and marine forms. Although the species was originally an Atlantic form, it has been successfully introduced on the Pacific coast and is a common food and game fish in that area. On the Atlantic coast, these fish are found from Florida to Nova Scotia but are most abundant in protected waters between North Carolina and Massachusetts. Large fish often reach 35 lb or more and are generally found along the open coast within 5 miles of shore.[3] Most stripers are found associated with bays, sounds, and tidal rivers. However, according to Clark,[26] they are also abundant along the Atlantic seaboard from the Delaware Bay to Cape Cod.

Clark[26] described the movements of striped bass in the area from the Chesapeake Bay to New England. Evidence from his studies, as well as previous studies, indicates that the species is not homogeneous but is, instead, composed of a number of separate groups that are more or less isolated from other groups. In southern waters, the fish remain in protected water throughout their life span, and as a consequence, the various populations have little interchange and are most intensely isolated from each other. In contrast, striped bass from the Chesapeake Bay north to New England commonly leave their nursery areas after 3 or more years and migrate in groups along the open coast. Summer movements are generally north, while winter movements are generally south. In the northern part of their range, the striped bass become dormant in the winter.

Striped bass tagged in the Hudson have been caught in fisheries as far away as Massachusetts. However, most of the Hudson striped bass contribute to the commercial and sport fisheries in Connecticut, New York, and New Jersey.[3] Stripers that originate within the Hudson appear to be subdivided into three major groups: those that remain within the Hudson River, those in the southwestern portion of Long Island Sound, and those that are typically located along the New York–New Jersey coast.[26] In New York, Connecticut, and New Jersey, where the striped bass fishery is most dependent on the supply from the Hudson, the 1965 commercial catch amounted to 1,500,000 lb, and the sport catch has been estimated as over 19,000,000 lb caught by some 200,000 anglers.[3]

The best available evidence indicates that bass from New Jersey to Connecticut spawn in the Hudson. Clark[26] concluded that the "Hudson River is by far the most important spawning stream" in the New York area.

Details of the spawning and distribution of the species in the Hudson were described by Clark and Smith,[3] McCann and Carlson,[27] Jensen,[22] Schaefer,[28] Raney,[29] and Rathjen and Miller.[30] Their conclusions are summarized in the following description. The species spawns from Kingston to Bear Mountain, with the greatest concentrations of eggs in the vicinity of West Point, although the exact location varies from year to year. The variability is the result of the fact that the greatest area of spawning is a few miles upstream from the salt water front, which varies in location from year to year. The nonadhesive demersal eggs are semibuoyant and require sufficient vertical water flow to remain suspended. Eggs are encountered most often in fresh or only slightly brackish water (salinity below 1 ppt). They average 0.134 in. in diameter and hatch in 2 or 3 days at 60 to 64°F.[31] After hatching, the larvae, which are about 0.13 in. long, continue to drift downstream. At this stage in development, the larvae are still unable to move effectively against the currents and will settle to the bottom in quiet water despite swimming efforts to approach the surface. These larvae are reported to be concentrated above the Haverstraw Bay area, with the greatest abundance between Peekskill and Newburgh. Once the larvae reach a length of 0.5 in., they appear capable of sustained swimming. The larvae make extensive vertical diurnal migrations and are found in surface water at night and nearer the bottom during the day.[22,24] After they reach a length of about 1 in., they are found in greatest abundance in Haverstraw Bay.

As related to the Indian Point site, the striped bass generally spawn upstream from the area. Both eggs and larvae drift downstream past Indian Point. However, the majority of the spawn that drift through the Indian Point area is composed of larvae rather than eggs. A large proportion of the yearly spawn passes Indian Point as eggs, larvae, or early juvenile stages. The young fish apparently stop along shoal areas and remain there.

This species, like white perch, shows a definite preference for the bottom waters in shoal areas. Only small numbers were collected in the bottom trawls at the channel stations north of Stony Point, whereas large numbers were caught on shoals in Haverstraw Bay and in Peekskill Bay.[24]

After spawning, the adults generally return to sea. Larvae and young-of-the-year remain in freshwaters and estuaries. Striped bass in the Hudson may remain in the estuary for 2 or 3 years before migrating to the sea. During winter, adults and young are found in the lower regions.

As larvae and young-of-the-year, striped bass feed primarily on microcrustaceans. As they grow, their diet changes from smaller to larger forms. *Gammarus* apparently makes up a major proportion of their diet, but most other microcrustaceans are also taken, and there is evidence that a variety of food is needed for normal growth.[32] Small fish also become an important food item as the fish grow larger.*

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*A great deal of information on the migrations and growth of various life stages of striped bass from and within the Hudson River is available in refs. 19, 22, 24-30, 33-37.

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Appendix G

ADDITIONAL INFORMATION ON COOLING TOWERS CONSIDERED AS ALTERNATIVES

1. INTRODUCTION

Other sections of this Statement discussed the adverse environmental impacts associated with the once-through cooling-water systems at Indian Point and also assessed several alternative cooling systems that would dissipate waste heat to the atmosphere to reduce the quantities of river water required. Of these alternatives, wet natural-draft cooling towers were judged by the staff to be the most viable method. Wet mechanical-draft towers were the second choice. The staff's estimates of the plume behavior, fogging, and salt-deposition characteristics of these two types of towers are summarized in this appendix. In addition, a proposed layout and schedule for cooling towers on the site are presented.

There are several possible modes of waste heat rejection at Indian Point using cooling towers. The staff has considered three cases to be representative and of particular interest in this study:

Alternative A	Units Nos. 1 and 3 operating with once-through cooling and Unit No. 2 operating with a natural-draft cooling tower.
Alternative B	Unit No. 1 operating with once-through cooling and Units Nos. 2 and 3 operating with natural-draft cooling towers.
Alternative C	Unit No. 1 operating with once-through cooling and Units Nos. 2 and 3 operating with mechanical-draft cooling towers.

Alternative C may be considered essentially the same as Alternative B in thermal performance.

In Alternatives A and B it is assumed, for the purpose of this analysis of emission characteristics of cooling towers, that the turbine-generator electrical output remains the same as that for the base design (once-through cooling for all three Units) but that the water flow through the condensers is reduced to provide a higher temperature difference. For Unit No. 2, the flow is reduced from 840,000 gpm to 590,000 gpm, and the temperature rise through the condensers is about 25 F° rather than about 15 F° with once-through cooling. As shown in Table G-1, the heat rejection and the water

Table G-1. Assumed design characteristics for natural-draft cooling towers for the Indian Point Plant[a]

	Individual characteristics	
	Unit No. 2	Unit No. 3
Reactor power, MWt[b]	2,758	3,216
Electrical power, MWe net[b]	873	1,033
Heat rejected from tower, 10^6 Btu/hr		
Condensing water cooling	7,381	8,734
In blowdown water[c]	87	103
Water flowrates, 10^3 gpm		
Condensing water circulation[d]	590	698
Blowdown	12	14
Evaporation and drift	14	17
	Common characteristics	
Design wet bulb temperature, °F	74	
Approach, F°	21.5	
Range, F°	25	
Exit water temperature, °F	95.5	
Entrance water temperature, °F	120.5	
Exit air temperature, °F	109	
Exit air velocity, fps	13.8	
Drift loss, % of total water flow[e]	0.005	
Tower diameter at outlet, ft	220	
Tower diameter at base, ft	445	
Tower height, ft	450	

[a]Based on information from the applicant (ER, IP-3, App. FF, p. VII-1).

[b]Rated capacity for Unit No. 2; maximum calculated capacity for Unit No. 3.

[c]Heat in tower blowdown is based on 95.5°F blowdown temperature and 81°F ambient river temperature.

[d]Condensing water circulation based on 25 F° temperature range.

[e]Value assumed by the staff. The concentration of solids in drift and in blowdown is assumed to be twice that in the makeup water.

flow rates are slightly higher for Unit No. 3 than for Unit No. 2 (primarily because the former is based on maximum calculated capacity rather than rated capacity), but for simplification of the cooling tower studies, the characteristics of a tower for Unit No. 3 have been assumed to be essentially the same as that of a tower for Unit No. 2. See Section G.4 for additional information on characteristics of a cooling tower for Unit No. 3.

For the most part, the service water cooling for the reactor and turbine-generator auxiliary equipment would be by means of once-through river water cooling regardless of the method used to cool the turbine condenser water. (This is a common practice because cooling tower effluent water may be too warm at times to cool certain equipment.)

2. WET NATURAL-DRAFT COOLING TOWERS

A wet natural-draft cooling tower consists of a large reinforced concrete structure, such as that indicated in Fig. G-1, that creates a chimney effect to induce an upward flow of air through falling drops of the water to be cooled. The chimney, or shell, is hyperbolic in shape for aerodynamic reasons and to conserve structural materials. The condenser cooling water is sprayed onto baffles, or fill material, where the water is cooled by evaporative and convective heat transfer to the air. Over 70% of the heat dissipated from wet natural-draft cooling tower is in the form of latent heat; water is evaporated at a rate of about 4 tons/hr per MW of plant electrical capacity. The differential density between the heated air inside the tower and the air outside not only creates the natural draft, but the warm water-laden plume will usually continue to rise for some distance after leaving the top of the tower. Important advantages of natural-draft towers are that plant power is not required to move the air, noise levels are relatively low, and the discharge height above the terrain greatly reduces the possibilities of ground-level mists, fogs, and icing problems. Major disadvantages are the relatively high capital cost and the fact that, from an aesthetic standpoint, the large structures tend to dominate the surroundings.

a. Plume Behavior and Fogging

Many of the important environmental effects of cooling towers can be assessed by study of the plume behavior.

The data used in this study are based on those given by the applicant (ER, IP-3, Appendix FF, p. VII-1) and are summarized in Table G-1. The following weather conditions were assumed for the site:

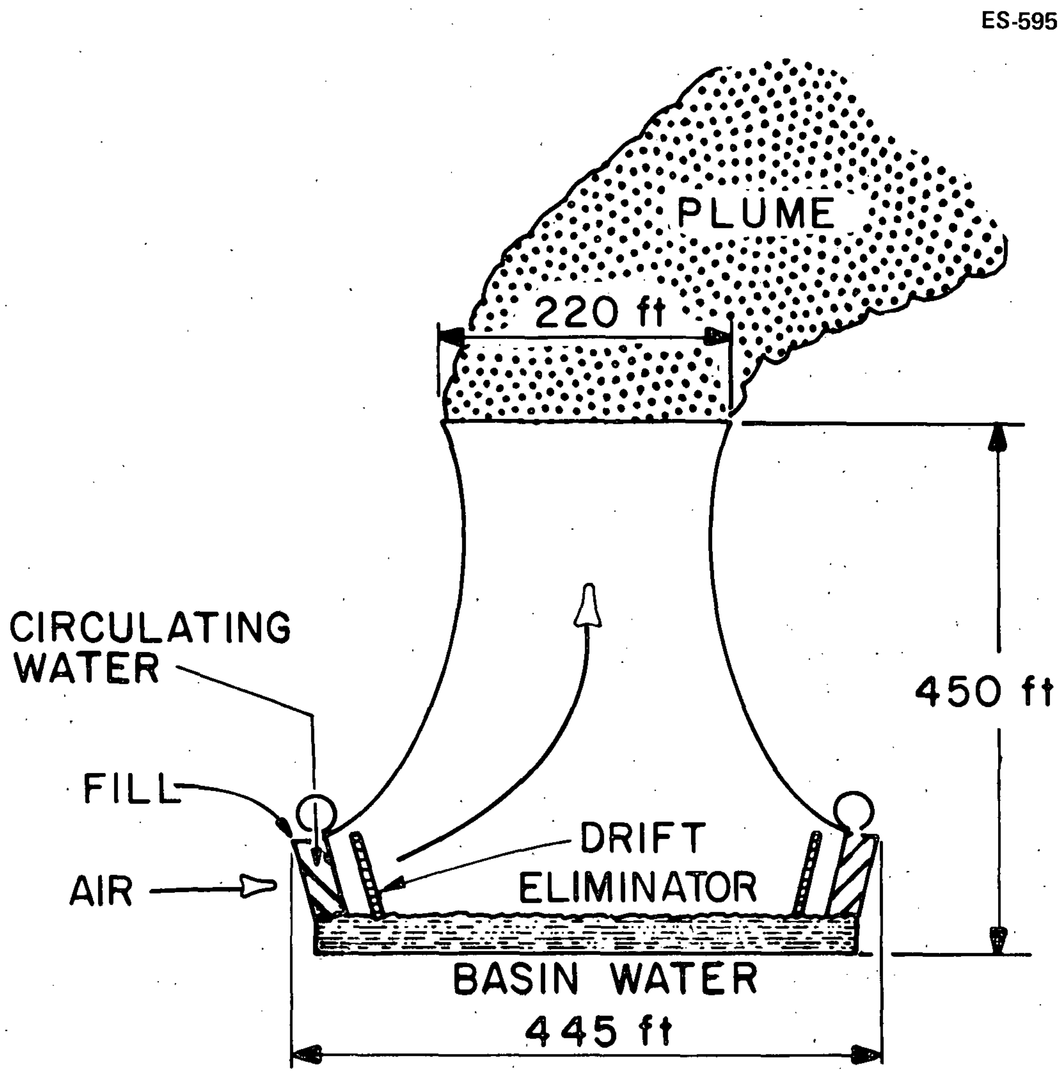

Fig. G-1. Wet natural-draft cooling tower such as might be used for Unit No. 2. The wet natural-draft cooling tower at Unit No. 3 would have a 525-ft diameter base and would be 500 ft high.

Case	Dry bulb temperature (°F)	Relative humidity (%)	Pasquill stability class	Wind speed (mph)
I	75 (summer)	55	B (unstable)	9.4
II	75 (summer)	55	E (stable)	9.4
III	35 (winter)	55	B (unstable)	9.4
IV	75 (summer)	100	E (stable)	2.25

Brigg's[1] plume equations were used to calculate the plume rise and travel for a single tower, and the results are summarized in Fig. G-2.

In the summer, when the ambient relative humidity is low and the atmosphere is unstable (Case I, Fig. G-2), the plume rise will be about 2,380 ft above the base terrain. Under these conditions, the visible plume will disappear within about 500 ft of the top of the tower.

During summer conditions when the ambient relative humidity is low and the atmosphere is stable (Case II, Fig. G-2), the plume rise will be to about 1,510 ft, and the visible plume will disappear within about 500 ft of the top of the tower.

In the winter, when the ambient relative humidity is low and the atmosphere is unstable (Case III, Fig. G-2), the plume behavior is similar to that shown for Case I except that the visible plume will be more persistent due to the decreased moisture-holding capacity of the air at lower temperatures. Although plume lengths are generally longer in winter than in summer, the greater condensation in the plume during the colder months causes the plume to rise to higher elevations than in the summer.

Only the sensible heat is often considered in plume rise calculations, but when large amounts of water vapor are present, neglect of the latent heat released by condensation of water in the plume may cause considerable error in the estimates. Hanna[2] has presented an analytical method for determining the final plume rise which takes into account the effect of condensation. The plume behavior was estimated for the following conditions (Case IV, Fig. G-2): ambient air temperature of 75°F, 100% relative humidity, wind speed of 2.25 mph, and a stable atmosphere (Pasquill Class E). Using Briggs's[1] plume rise equations as modified by Hanna[2] to account for condensation, the plume rise is predicted to be about 3,240 ft, and the centerline of the horizontal plume is about 3,690 ft above the base terrain, as shown in Fig. G-2. Although this predicted plume rise is greater than the 1,000-ft limit of applicability of the Pasquill stability classes, the calculation does indicate that the plume

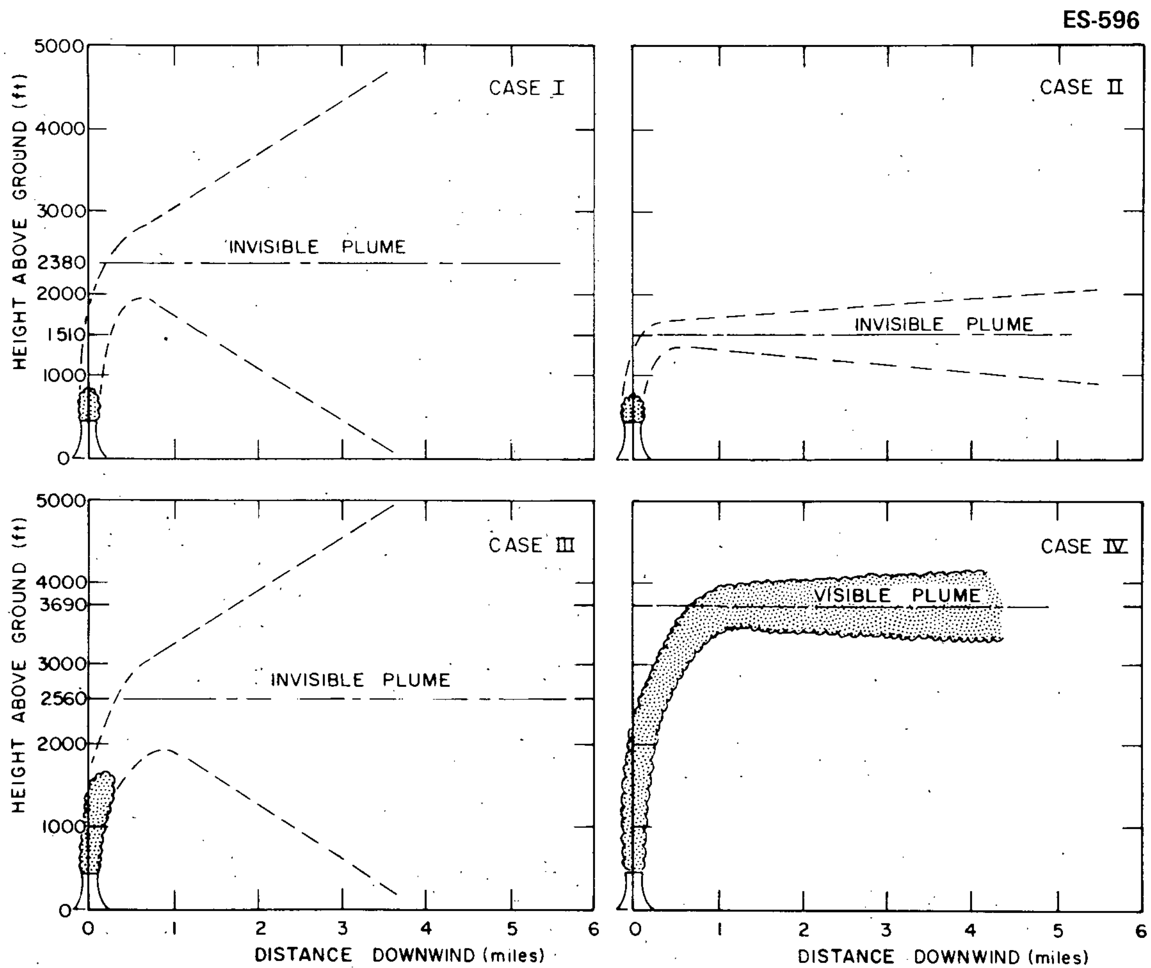

Fig. G-2. Plume height vs downwind distance for natural-draft cooling towers at Indian Point Plant.

from a natural-draft cooling tower in which moisture is condensing will probably penetrate local inversion conditions with little difficulty.

When the relative humidity is high (approaching 100%), the cooling tower plume will evaporate much less rapidly, and moisture may condense in the plume as it rises through the atmosphere. Some of the condensation may fall to the ground, and some may remain suspended in the form of fog. The conditions conducive to fog formation in the plume will probably also produce natural fog in the Indian Point area (tower-produced fog would be but an extension of the naturally occurring phenomenon). The contribution of the tower fog would, thus, be generally indistinguishable from the natural fog in the area and may be but a small part of the total fog present.

The likelihood of fog produced by the Indian Point Plant natural-draft towers reaching the town of Peekskill, located 2.3 miles to the northeast, has been studied by the staff. Using Pasquill's diffusion model[3] with Gifford's modifications,[4] the meteorological conditions supplied by the applicant (see Appendix E), and the wet-bulb dry-bulb temperature frequency distribution at Poughkeepsie,[5] the total increase in fog at the center of Peekskill due to the tower is estimated to amount to less than 4 hr/year. These results support the conclusion of Decker[6] that tall natural-draft cooling towers, when standing alone and fully equipped with drift eliminators, cause "extremely low, or virtually zero" probability of fog obstructing visibility at ground level.

When temperatures are sufficiently low, cooling tower plumes can cause icing, that is, liquid droplets in the plume may freeze and fall to the ground, or condensation and subsequent freezing may occur on cold surfaces. A few qualitative observations of light icing have been reported in the vicinity of cooling towers, but no quantitative methods of predicting these situations are generally accepted. When the temperature is very low (10°F or less), deposition of ice particles or a light snow may occur, but this would probably extend to no more than about five to ten tower diameters from the base of the tower. Condensation in the cooling tower plume in cold weather causes the plume to rise to much higher elevations, an effect that tends to reduce local icing.

With regard to precipitation from a plume, Overcamp and Hoult[7] showed that fallout of water from a natural-draft cooling-tower plume is improbable under normal atmospheric conditions unless the plume interacts with air movements in the tower's wake in such a manner as to bring the plume to the ground, a phenomenon known as "downwash." Since the flow during downwash is turbulent and complex, scaled tests based on nondimensional variables were made by Overcamp and Hoult.[7] The results showed that the cooling tower speed ratio, R, could be expressed as a function of the tower Froude number as:

$$R_{crit} = 0.45\ (Fr)^{2/3} \tag{1}$$

where R_{crit} is the critical speed ratio that will cause downwash, and Fr is the tower Froude number at those conditions. The speed ratio and the Froude number for natural-draft cooling towers are defined as:

$$R = w_o/U \tag{2}$$

$$Fr = \frac{w_o}{\sqrt{\delta g R_o}} \tag{3}$$

where w_o is the tower exit velocity under the specified conditions, U is the wind velocity, g is the acceleration of gravity, R_o is the tower exit radius, and δ is the dimensionless density difference, which is approximately proportional to the absolute temperatures:

$$\delta = \frac{\rho_{in} - \rho_{out}}{\rho in} \simeq \frac{T_{out} - T_{in}}{T_{out}} \quad . \tag{4}$$

For the representative conditions cited above, the Froude number is about 1.005, the critical speed ratio is about 0.45, and the corresponding wind velocity is about 21 mph. One would not expect steady wind conditions of this magnitude except under very unusual weather conditions.

b. Drift and Salt Deposition

Cooling towers supplied with saline water for makeup may cause some salt deposition in the vicinity of the towers due to entrainment of water droplets in the exit air streams. The staff assumed a drift rate of 0.005% of the circulating water flow for the Indian Point Plant towers and a concentration factor of 2 for the solids in the basin water (Table G-1). During the months November to April, the average salt concentration in the Hudson River at Indian Point is about 2.5 ppt, and during the summer months (May to October), it is about 6 ppt during low flow conditions. The droplet-size distribution in the drift was assumed to be the same as that in a similar tower at the Forked River Nuclear Station.[8]

Pasquill's diffusion model[3] was used to estimate the salt deposition from the towers. Using joint wind frequency distributions as a function of atmospheric stability class for 16 compass directions, maximum deposition of circulating water solids from wet natural-draft cooling towers for both Units Nos. 2 and 3 (Alternative B) is estimated by the staff to be about 19 lb/acre per year and is predicted to occur within portions of the 22.5° sector lying approximately two miles south of the site, as shown in Fig. G-3. If a tower is used for Unit No. 2 only (Alternative A), the deposition rates would be as approximately one-half the values shown in Fig. G-3.

3. WET MECHANICAL-DRAFT COOLING TOWERS

Mechanical-draft cooling towers use motor-driven fans to move air through falling water droplets and over the wet fill material. Mechanical-draft towers for Unit No. 2 are estimated[5] to be about 60 ft high by 70 ft wide and in two rows, each about 1,330 ft long. The low profile of mechanical-draft towers can often be screened from public view by the terrain and by suitable vegetation. Another important advantage is the significantly lower capital cost as compared with that for natural-draft towers. The mechanical-draft tower, however, has the disadvantage of appreciable power consumption by the fan motors, relatively high maintenance costs, higher salt deposition rates, more problems with ground-level fogging and icing, and higher noise levels.

a. Plume Behavior and Fogging

Since the plume is discharged at relatively low altitude, it is possible that valley fogs could result from operation of mechanical-draft towers at Indian Point. The staff has estimated the likelihood of fogging, but such factors as the nature of the terrain and the relatively erratic atmospheric conditions close to ground level make the predictions less certain than those for natural-draft towers.

Using Pasquill's diffusion model[3] with Gifford's modifications,[4] the meteorological conditions supplied by the applicant (see Appendix E), the wet-bulb dry-bulb temperature distribution at Poughkeepsie,[5] and towers for both Units Nos. 2 and 3 in operation (Alternative C), the staff estimates the total number of hours of additional fog per year for the sectors shown in Fig. G-4. Fogging conditions were assumed to exist if the ground level moisture content of the plume exceeds the saturation deficit at ambient conditions. As indicated in Fig. G-4, there may be some induced fog from mechanical-draft cooling towers that would affect nearby highways, transportation systems, and residential areas during limited periods of time. In

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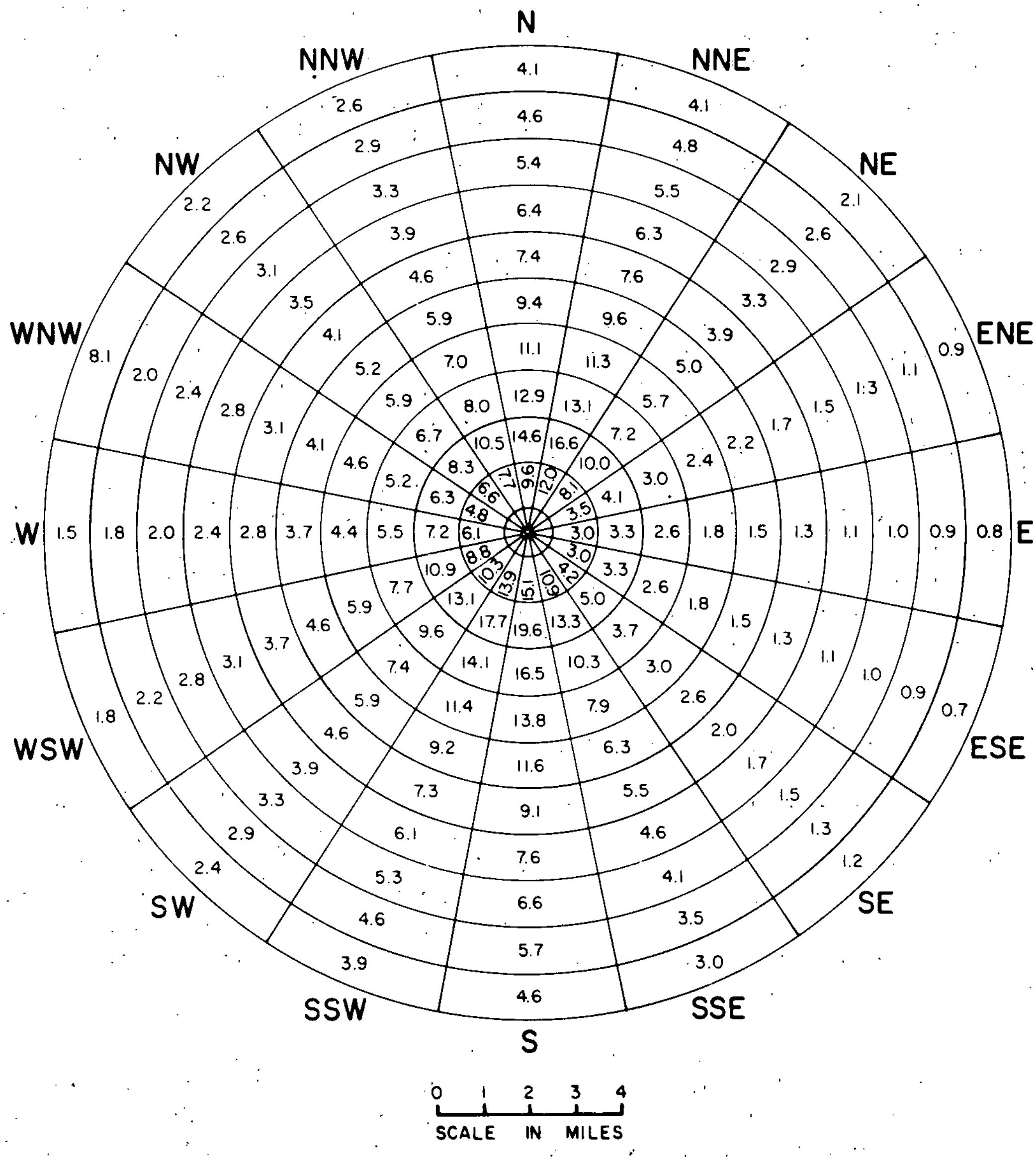

Fig. G-3. Salt deposition rates for wet natural-draft cooling towers at Indian Point for Units Nos. 2 and 3 (Alternative B), in pounds of salt per acre per year.

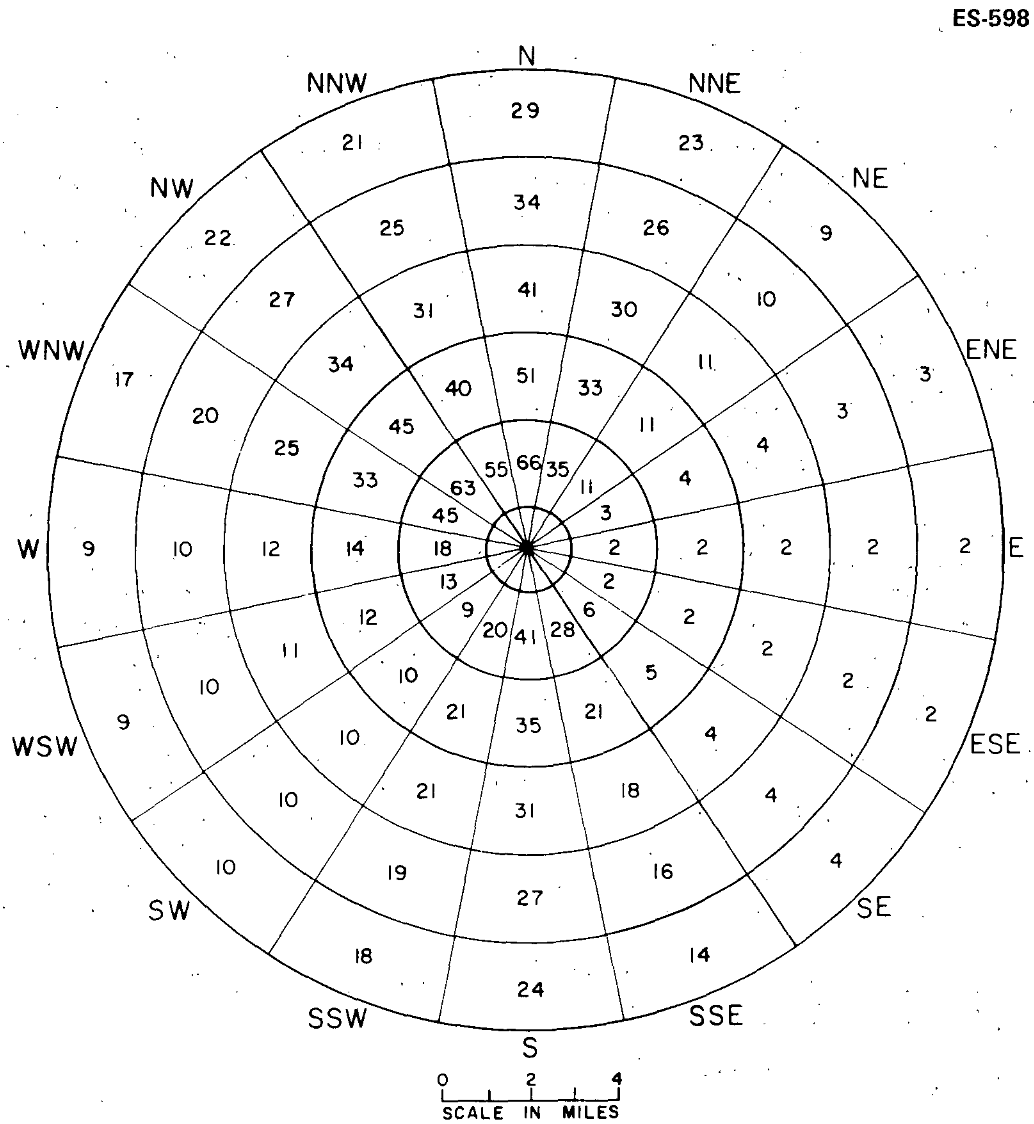

Fig. G-4. Hours of additional fog per year from wet mechanical-draft cooling towers at Indian Point Units Nos. 2 and 3 (Alternative C).

determining the number of hours of additional fogging per year, each combination of wind speed and stability condition was weighted by the frequency of wind blowing in the specified direction.

The increased frequency of fogging at Peekskill due to mechanical-draft towers for both Units Nos. 2 and 3 (Alternative C) was estimated to be about 11 hr/year. This fog would have little effect on the Tappan Zee Bridge because of its distance from Indian Point. Bear Mountain Bridge, located about four miles NNW of the site, might experience about 40 hr/year of additional fog due to the towers. Additional hours of fogging at any other point within a radius of 10 miles may be estimated from Fig. G-4. In judging the impact of this fogging, it should be noted that a large percentage of the additional hours of fogging will occur during the night and early morning due to the high frequency of stable and neutral atmospheric conditions tending to occur at these times.

b. Drift and Salt Deposition

Estimates have been made of the salt deposition from mechanical-draft towers at Indian Point using the drift droplet-size distribution reported by Wistrom and Ovard.[9] Deposition rates were calculated using an approach described by Hosler,[10] and the results for wet mechanical-draft cooling towers for both Units Nos. 2 and 3 (Alternative C) are shown in Fig. G-5. The greater salt-deposition rates calculated for mechanical-draft towers, as compared with those for natural-draft towers, are primarily due to the large differences in the plume rise and the drift particle-size distribution. The maximum deposition rate for mechanical-draft towers is estimated as 2,870 lb/acre per year and is predicted to occur within the southerly 22.5° sector at a distance of less than 0.2 mile from the towers (Fig. G-5).

4. PHYSICAL DESCRIPTION, LOCATION, CONSTRUCTION SCHEDULE, AND COSTS OF COOLING TOWERS

a. General Information

In Sections XI.C and G.1 through G.3, several feasible alternatives to once-through cooling are discussed. The alternatives include closed-cycle, wet and dry cooling towers, and cooling and spray ponds. Each cooling system has advantages and disadvantages. In the Unit No. 2 and Unit No. 3 cases, dry cooling towers were rejected on the basis of technical and economic considerations. They would require greater heat transfer surface area and land area than wet cooling towers, and the higher condensing pressure would be unsuitable for the turbine installed in Unit No. 2 or

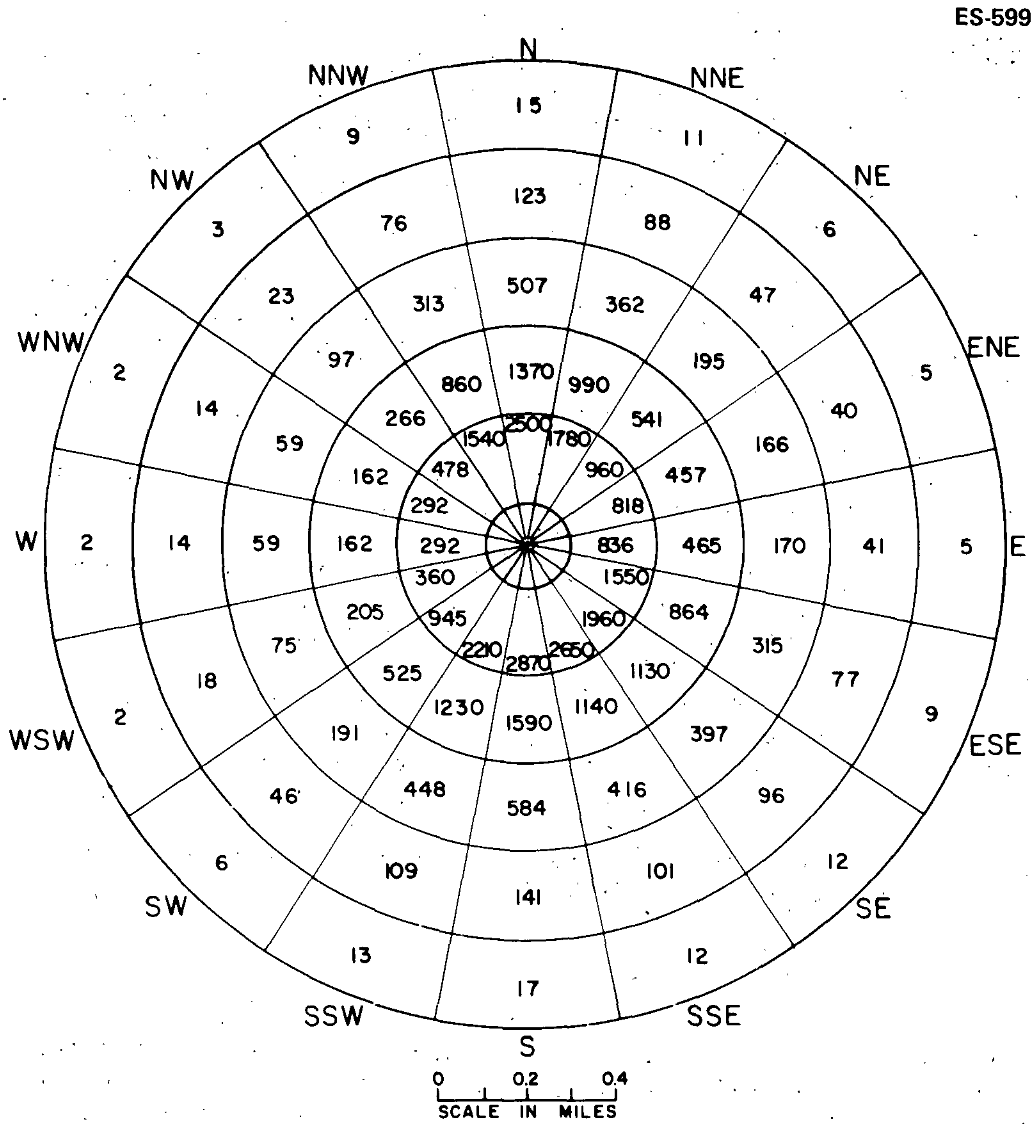

Fig. G-5. Salt deposition rates for wet mechanical-draft cooling towers at Indian Point Units Nos. 2 and 3 (Alternative C), in pounds of salt per acre per year.

Unit No. 3 facilities. Cooling ponds would require an excessive amount of land, and the salt in the drift from spray ponds would be expected to have adverse environmental effects.

The applicant discusses the advantages and disadvantages of alternate cooling systems in a number of testimonies presented in the Unit No. 2 hearing and also in Section 17 of the ER for Unit No. 3. The discussion includes location and physical arrangement of cooling towers, structural modifications, construction schedule, cost estimates (capital, contingency, operating, and maintenance), and design assumptions.

The staff agreed with the applicant and the other parties in the Unit No. 2 hearing that natural-draft wet cooling towers would have the least adverse impact on the environment and would appear to be a more viable method of cooling in comparison with other closed-cycle cooling systems. The applicant first proposed the use of two natural-draft cooling towers but later determined that one larger single tower for Unit No. 2 and one for Unit No. 3 could be more closely coupled to the plants and would be more economical.

In the Unit No. 2 case, the single natural-draft tower would be 445 ft in diameter and 450 ft high, and as such, it would be an aesthetic intrusion into the landscape of the Hudson River valley. The single tower for Unit No. 3 would be 525 ft in diameter and about 500 ft high. As discussed earlier, environmental costs from impacts due to fogging, icing, salt spray drift, and noise would be less for natural-draft cooling towers than for mechanical-draft cooling towers. In the Unit No. 2 proceeding, the staff and intervenors believed that the adverse aesthetic effect of the natural-draft tower would be clearly outweighed by the beneficial effect on the Hudson River fishery.

b. Location of Cooling Towers

Because of the particular topographic characteristics of the Indian Point site and the limited available land area, the location for single towers for both units, as shown in Fig. G-6, was selected for nuclear safety reasons. The towers would be located about 500 to 600 ft from the respective containment buildings. The tower at Unit No. 2 would be at an elevation of 45 ft. The applicant is investigating the optimum location for erection of the towers with respect to engineering practicality and economic justification.

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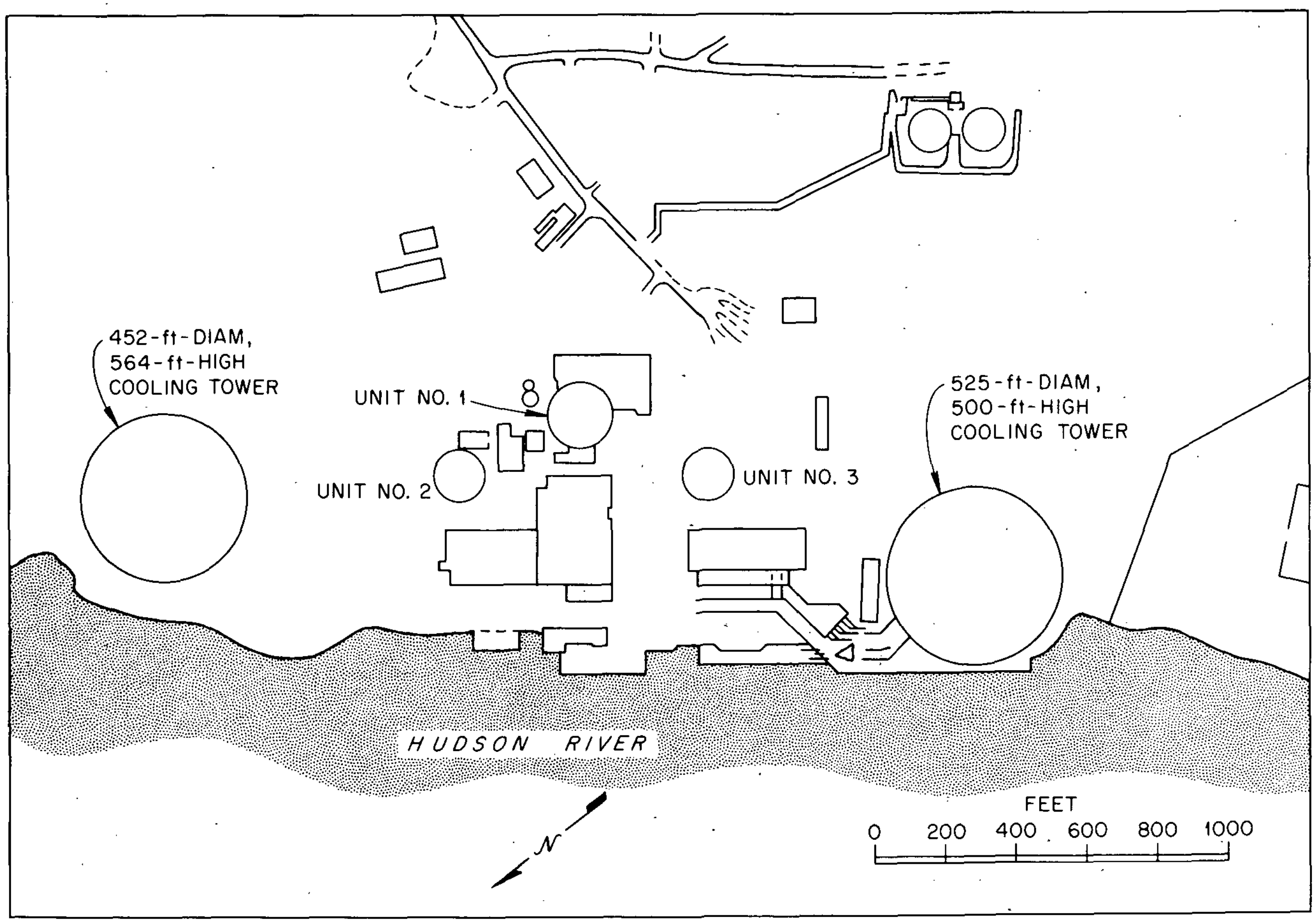

Fig. G-6. Indian Point natural-draft wet cooling towers.

c. <u>Construction Schedule and Details</u>

In the Unit No. 2 proceeding, the applicant proposed three schedules for construction of a natural-draft cooling tower. In the Appeal Board's Decision (ALAB-188), the third schedule was described such that once-through cooling at Unit No. 2 shall terminate on May 1, 1979. In allowing time to cutover the cooling tower into the Unit No. 2 facility, the applicant should be ready to operate Unit No. 2 with cooling towers by December 1, 1979.

The following is a list of major events in the construction of the Unit No. 2 cooling tower. This schedule is similar to that presented by the applicant in its April 9, 1973 testimony and is based on a reasonable time period for completion of each event. A schematic drawing of the schedule is shown in Figure G-7.

1.	Initiation of design study of criteria of cooling tower.	November 1, 1972
2.	Start of environmental study of cooling tower impact.	September 1, 1973
3.	Submittal of environmental report on cooling tower to AEC and other governmental agencies (ALAB-174).	December 1, 1974
4.	Completion of AEC and agency evaluation and issuance of permits.	December 1, 1975
5.	Finalization of engineering design of cooling towers and incorporation of agency comments.	March 1, 1976
6.	Award of contracts for cooling towers.	May 1, 1976
7.	Contractor input into engineering design completed.	August 1, 1976
8.	Completion of mobilization of work force.	June 1, 1976
9.	Start of excavation.	June 1, 1976
10.	End of excavation.	June 1, 1977
11.	Completion of cooling tower foundation.	September 1, 1977
12.	Completion of erection of cooling tower column, shell, and fill structure.	April 1, 1979

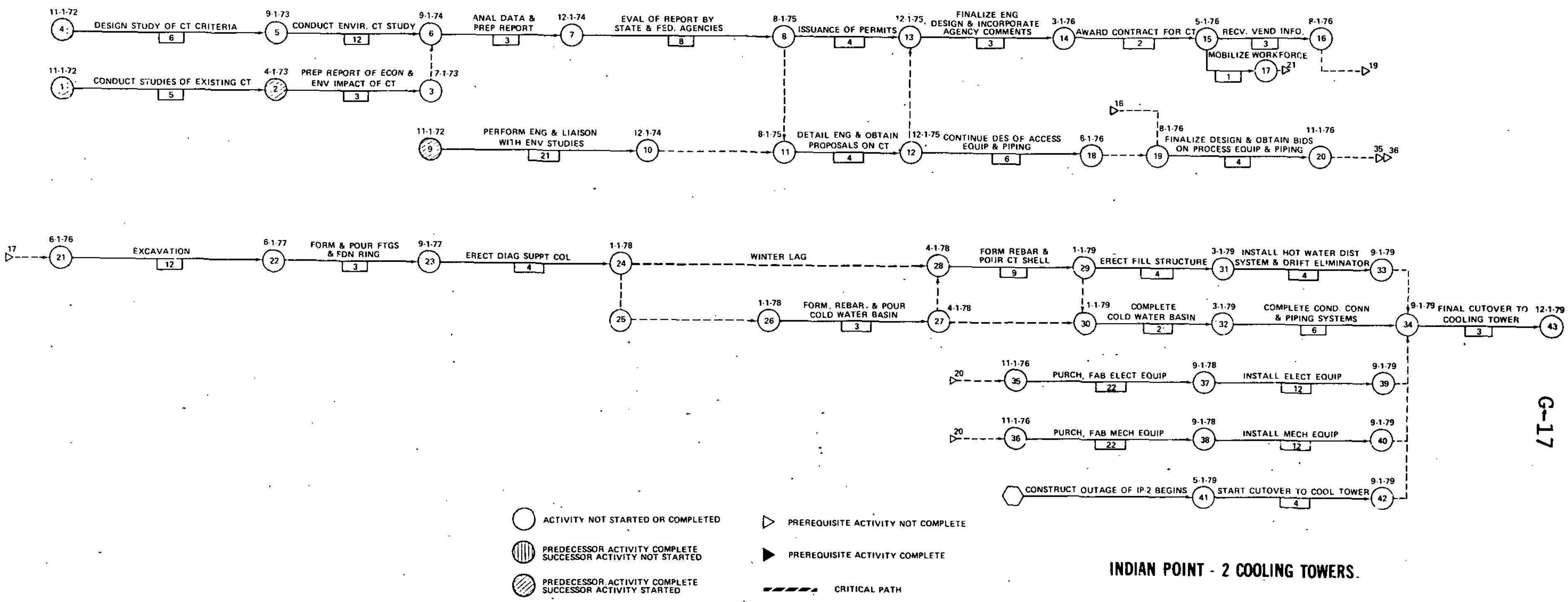

Fig. G-7. Schedule for cooling towers at Unit No. 2.

13. Completion of forming and building of cold water basin. — March 1, 1979

14. Order of electrical and mechanical equipment placed. — November 1, 1976

15. Completion of installation of electrical and mechanical equipment and condenser connections and piping systems. — September 1, 1979

16. Outage of Unit No. 2 begins and starts cutover of tower into plants. — May 1, 1979

17. Completion of final cutover of tower to plant and plant startup with cooling tower. — December 1, 1979

A proposed schedule for construction of a single cooling tower at Unit No. 3 is shown in Figure G-8 and is as follows:

1. Use of Unit No. 2 environmental report to select preferred cooling tower system for Unit No. 3. — June 1, 1975*

2. Completion of governmental approvals including authorization to relocate Algonquin gas pipeline. — June 1, 1976

3. Completion of finalizing engineering design for tower at Unit No. 3. — October 1, 1976

4. Award of contract. — December 1, 1976

5. Receive vendor information. — May 1, 1977

6. Completion of mobilization of work force. — June 1, 1977

7. Start of excavation. — June 1, 1977

8. End of excavation. — June 1, 1978

9. Completion of cooling tower foundation. — September 1, 1978

10. Completion of erection of cooling tower column, shell, and fill structure. — May 1, 1980

11. Order of electrical and mechanical equipment placed. — November 1, 1977

***Assuming issuance of OL on May 1, 1975.**

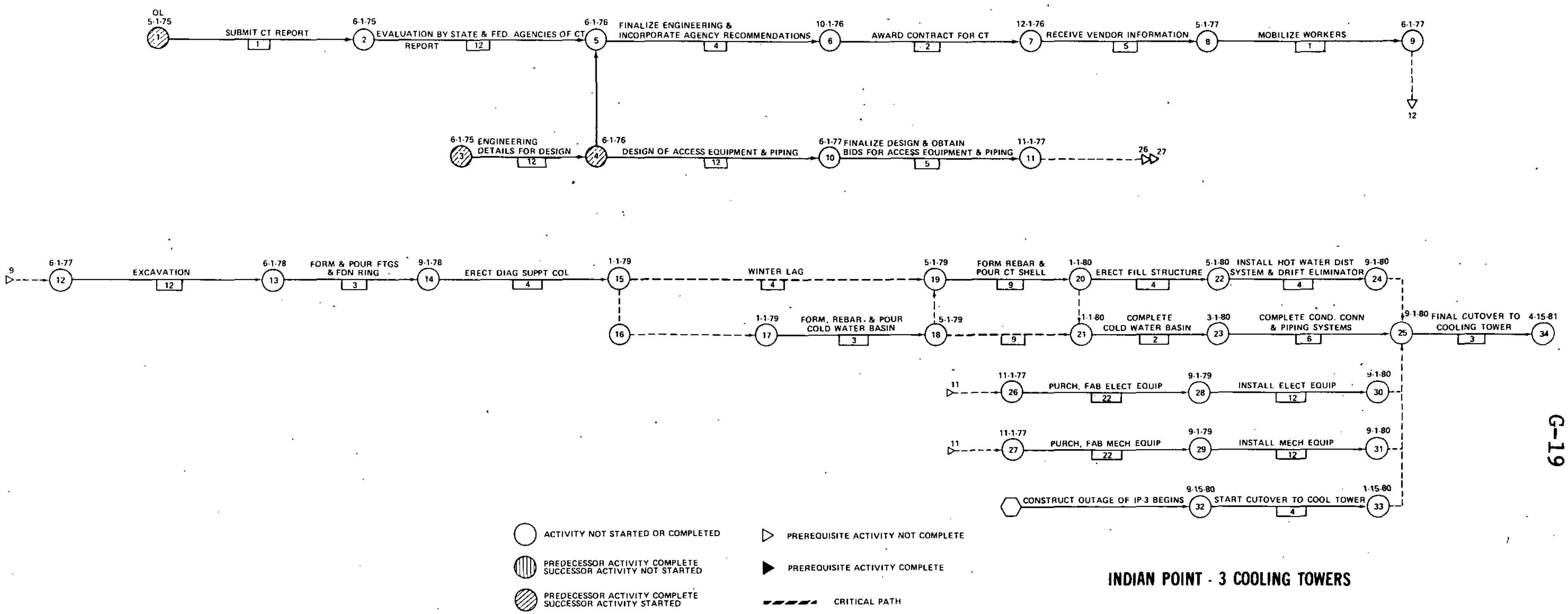

Fig. G-8. Schedule for cooling towers at Unit No. 3.

12. Completion of installation of electrical and mechanical equipment and piping. September 1, 1980

13. Outage of Unit No. 3 begins and cutover of tower into plant starts. September 15, 1980

14. Completion of final cutover of tower to plant and plant startup with cooling tower. April 15, 1981

Necessary flexibility in the schedules for the towers at the two plants should be allowed depending on various circumstances that could arise during the design and construction of the cooling tower. An appropriate extension or, conversely, a reduction in the design and construction schedule could result, depending on unforeseen contingencies.

The applicant discusses the major construction details in the Environmental Report for Unit No. 3, Section 17.3.3. The above schedules allow a year for excavation. In its April 9, 1973 testimony, the applicant discusses the problems associated with excavation for the tower at Unit No. 2 because of the peculiarities of the site. Cover clearing, earth and rock excavation, removal of rubble, and grading would be required. The direct costs for excavation, foundation, and trenching would be about $15.6 million for each tower.

Blasting would be needed to excavate rock. The work for excavation of a cooling tower at Unit No. 2 would be staggered from that required for the Unit No. 3 cooling tower to avoid effects of magnitude of blasting. In addition, both Units probably can be kept operational by having the excavator use necessary precautions during the blasting of the areas for the cooling towers. The natural-draft cooling tower would require the highest foundation loads of various alternatives considered.

In Table 17-2 of the ER for Unit No. 3, the applicant proposed a physical description (size and number of the major equipment, structures, and components required for a single natural-draft cooling tower, including circulating water pumps and piping for the cooling towers considered). This equipment would be ordered for installation during the construction schedule.

During construction of the tower at each Unit, the once-through cooling intake-discharge system would be modified. These modifications include blocking the condenser discharge tunnel to the original discharge canal by using stop logs and constructing a new discharge canal to the circulating water booster pump. Most of the piping from the pump to the cooling element and the return to the intake side of the condenser will be underground except at the immediate connections. The intake structure would be modified to include provisions for supplying makeup water for the closed-cycle cooling system and river water to the service water pump pit. No major changes to the service water system are expected. On the discharge side, provisions for a 22 in. blowdown line with a motor-operated valve will be built to allow discharge of the blowdown, radioactive and chemical wastes to be released to the discharge canal. Related electrical equipment such as motors, pumps, auxiliary transformer, and other equipment as indicated in Table 17-2 of the ER for Unit No. 3 will be installed by September 1979 at Unit No. 2 and September 1980 at Unit No. 3.

The total time allowed for cutover from the towers to the plants is about seven months from the date of outage of each plant with once-through cooling to the date of startup of plants with the cooling tower. Thus, Unit No. 2 should be ready to operate with the cooling tower by December 1979, and Unit No. 3 should be ready by April 15, 1981.

d. Design Characteristics and Operating Considerations

Additional details of the physical description and the applicant's design assumptions for the single towers have been presented in the applicant's April 9, 1973 testimony and Table 17-2 of the ER for Unit No. 3. See Table G-1 for design assumptions used by the staff for its cooling tower analysis. The flow in the Unit No. 2 circulating water system was reduced to 590,000 gpm resulting in a temperature rise across the condensers of about 25 F° rather than 15 F° through the once-through cooling system. The Unit No. 2 tower would be designed for a 74°F design wet bulb temperature and 55% design relative humidity. Details of the design for the Unit No. 2 cooling tower are presented in the applicant's environmental report dated December 1, 1974 for the preferred closed-cycle system, in accordance with the Appeal Board's Decision (ALAB-174) of January 29, 1974.

The Unit No. 3 tower could also be designed assuming a peak wet bulb temperature of 77°F, an approach temperature of 22 F°, and a temperature range of 16.5 F° (equivalent to the temperature rise across the condensers), assuming a total circulating water flow of 870,000 gpm through the system. All the heat absorbed by the cooling water passing through the condenser will be rejected to the atmosphere by the cooling tower. In addition, the condenser terminal temperature difference of 9.5 F° could be assumed. Based on these conditions, a load reduction of 68 MWe could result in a net turbine output of 932 MWe out of a possible 1000 MW turbine rating (gross). Compared with once-through cooling, the incremental generation loss of 58 MWe could result with a single tower at

Unit No. 3 from the increased back pressure to 3.95 in. mercury (abs) exhaust steam pressure. An additional 24.7 MWe of auxiliary power required for circulating water booster pumps would result in a total derating of 82.7 MWe from the closed-cycle natural-draft tower. Another 35 MWe is used for normal plant auxiliary loads such that the net plant output is 872.3 MWe. The applicant also presented information on the yearly average generation loss of 72.7 MWe with a resulting increased net plant heat rate of 11,132 Btu/kWhr.

As stated above, the total flow through the circulating water system was assumed to be 870,000 ppm. Because of the salinity of the river water, the circulating water would be recycled through two cycles. The blowdown rate was based on maintaining the concentration of cooling water at two cycles. The rate would also depend on drift and evaporation. The drift was estimated to be 0.0025%, and the evaporation rate was assumed to be 1.65%. Therefore, the blowdown rate for a single natural-draft cooling tower at Unit No. 3 would amount to 14,333 gpm. The drift would amount to 22 gpm, and evaporation would amount to 14,355 gpm. The total dissolved salts discharged to the river have been estimated by the applicant to be 691 million lb/year and that to the terrain to be 1.06 million lb/year. The temperature rise of the blowdown water would be about 22.5 F° and the total heat discharged to the river would be about 161 x 10^6 Btu/hr. Thus, the natural-draft cooling tower would reduce the heat input in the river by a factor of about 46 in comparison with once-through cooling.

Chemicals have to be used for treatment of the closed-cycle cooling system to reduce scale and to inhibit growth. See Appendix XI-1 in the Final Environmental Statement for Unit No. 2 on details of the chemicals used to inhibit corrosion and control growth of algae in the cooling water circuit. By controlling the pH of the circulating cooling water and operating at only two cycles of concentration, the applicant could avoid the use of additional chemicals for scale control and minimize the discharge of total dissolved solids in the blowdown. The applicant reports that intermittent chlorination and possibly sulfuric acid feeding of the cooling water would be used in the chemical treatment process. The chlorine additions will be controlled by maintaining a residual chlorine in the blowdown of less than 0.5 ppm, and the sulfuric acid feed would be of the order of 1/4 gpm during the summer when chemical concentration of the Hudson River reaches the maximum (ER, IP-3, Appendix FF, p. VI-1). The pH of the blowdown will need to be controlled in accordance with water quality standards for the operation with cooling towers.

e. Costs of the Cooling Tower

As indicated in the Licensing Board's Initial Decision of September 25, 1973, the incremental generating costs attributable to change over to a single natural-draft cooling tower system at Unit No. 2 was estimated by the applicant to include the following costs based on the year 1978.

1. $10.0 million per year for the carrying charges on the investment and maintenance of the cooling tower system.

2. $2.6 million per year for carrying changes on gas turbine peaking capacity to replace the loss in capacity with the closed-cycle cooling system.

3. $3.4 million per year for the additional operating cost of providing power to replace the reduced output with the closed-cycle cooling system.

4. $29.5 million for the additional cost of replacement power during outage time charged against the changeover to the closed-cycle cooling system.

5. $70.6 million for total capital cost of the cooling tower and changes in the piping.

The applicant calculated the total revenue requirement over the life of the plant to cover the additional costs to be $489 million, the present worth of these costs to be $144 million, and the annual levelized cost to be $19.8 million. The Licensing Board assessed the costs and found the annual levelized cost to be $16.5 million for the tower at Unit No. 2. Table 17-3 in the ER for Unit No. 3 shows estimated capital costs and total costs including contingencies for installation of a cooling tower over the period 1973-1976. The total capital costs amount to $58.66 million, including contingencies and escalation. The applicant also estimated $200,000 per year to maintain the fill in the cooling tower, $2 million for additional fuel costs for auxiliary power requirements, and $23 million due to capacity loss. Overall, the applicant estimated $90.46 million [30-year sum present worth based on 1974 dollars for the total incremental generating costs, assuming in service date of 1976). The applicant's annual levelized cost would be about $9.4 million.

The staff assessed these costs and those presented in the applicant's ER for Unit No. 3. The staff found the incremental generating costs for a cooling tower at Unit No. 3 to be about $122 million. The annual levelized cost would be about $13 million. See Chapter XI for further details.

5. ATOMIC ENERGY COMMISSION SUPPORTING ACTIVITIES RELATED TO COOLING TOWERS

The AEC has sponsored extensive research work involving environmental effects of dry and wet cooling towers using fresh and salt water as makeup. Of particular concern to the Indian Point situation is the feasibility of salt water cooling towers. A state-of-the-art report was prepared by Westinghouse Electric Corporation[11] with major emphasis upon the environmental effects. The major topics addressed were:

1. Measurement and control of cooling tower drift.
2. Effects of resulting salt deposition on the surrounding environment.
3. Effects of highly concentrated blowdown discharge.
4. Design considerations related to the corrosive action of salt water on cooling system equipment and the effects of salt water concentration on the thermal performance of cooling towers.
5. Identification of problem areas where further research would be required.

If salt water cooling towers are shown to be environmentally acceptable, they may be used for condenser cooling in many future power plants. Additional efforts of drift and field assessments of the environmental impact of drift deposition as well as the development of codes and standards for the design, construction, operation, maintenance, and testing of salt water cooling towers will be needed.

The magnitude and effect of salt water particles carried out from the updrift of a power plant's salt water cooling tower will be examined in a joint study funded by the Maryland Department of Natural Resources (DNR) and the Atomic Energy Commission (AEC).[12] Estimated cost of the two-year salt drift emissions study is $350,000.

The study will be conducted at the Chalk Point Plant of the Potomac Electric Power Company (PEPCO) on the Patuxent River in Prince Georges County in cooperation with PEPCO. The state will supervise the overall effort, and the AEC will provide technical advice and assistance. The work will be done on a contractual basis.

According to an agreement signed by the DNR and AEC, the jointly supported portion of the study will consist of two phases of a four-phase effort to help determine how salt drift emissions from this type of cooling tower affect the quality of the air and land environments in the vicinity of the power plant.

Phase one of the study, now nearing completion, includes the selection of instruments and field measurement techniques. This phase is jointly supported by PEPCO and the Power Plant Siting Program of DNR.

Phases two and three will consist of equipment installation and conduction of the field measurement program. Phase four will involve analyses of the data acquired.

Under the agreement, AEC will partially support phases two and three and will be entitled to results achieved in phases one and four. The study will provide a demonstration of the drift performance of large natural-draft cooling towers fitted with improved drift eliminators. Favorable drift performance, along with evidence from other ongoing studies that expected drift levels will mean that such salt water cooling tower systems will be acceptable for use in future power plants. This would facilitate the siting of power plants in areas where cooling water supplies have high salt content.

Various tasks of the study will include:

1. Direct measurements of drift rates at the large hyperbolic natural-draft salt water cooling tower at Unit 3 of the Chalk Point power station.

2. Supporting measurements in the tower and power plant needed for analyses and interpretation of the drift measurement data such as air temperatures, water temperatures, plant operating conditions, and water salinities.

3. Acquisition of data from a nearby meteorological tower and atmospheric soundings, as required, for the analyses of general plume behavior and predictions of salt deposition.

4. Detailed meteorological measurements of the cooling tower plume itself to thoroughly characterize plume rise.

5. Analyses of data obtained during the course of the field measurement study.

The PEPCO cooling tower for Chalk Point Unit 3 was expected to be completed in August 1973. However, the cooling tower has not yet been put into operation, because construction of the plant will not be completed until January 1975. Nevertheless, meteorological studies, as well as studies of baseline conditions of the terrestrial (plant) ecology in the vicinity of Chalk Point have been initiated prior to the operation of the cooling tower.[13]

The applicant should find this study of use in determining the feasibility of such salt water towers to the Indian Point situation. The applicant is currently investigating the meteorological aspects of the site in which a 400-ft AGL meteorological tower was erected to collect wind, temperature, and humidity data characteristic of the area. Extensive salt concentration and deposition measurements were also collected. The applicant is supporting research work at B. Thompson Institute to investigate the effects of salt deposition on plant life, and this work is outlined in the Environmental Technical Specifications. The applicant is funding research in cooling tower plume dispersion modeling.

REFERENCES FOR APPENDIX G

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3. Pasquill, F., "The Estimation of the Dispersion of Windborne Materials," *Meteorol. Mag.* 90(1063): 33-49 (1961).

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6. Decker, F. W., "Probabilities of Cooling System Fogging," Atmospheric Science Dept., Oregon State Univ., Corvallis, Oregon.

7. Overcamp, T. J., and D. P. Hoult, "Precipitation in the Wake of Cooling Towers," *Atmospheric Environment*, Pergamon Press, vol. 5, pp. 751-765, 1971.

8. Jersey Central Power and Light Co., Forked River Nuclear Station, Unit 1, Natural Draft Salt Water Cooling Tower — Assessment of Environmental Effects, Attachment 5 to *Forked River Nuclear Station Unit 1 Environmental Report*, Construction Permit Stage, Docket No. 50-363, January 1972.

9. Wistrom, G. K., and J. C. Ovard, "Cooling Tower Drift — Its Measurement, Control and Environmental Effects," Presented at Cooling Tower Institute Annual Meeting, Houston, Texas, January 1973.

10. Hosler, C., J. Pena, and R. Pena, "Determination of Salt Deposition Rates from Drift from Evaporative Cooling Towers," Dept. of Meteorology, Penn. State Univ., 1972.

11. Roffman, A. et al., "The State of the Art of Saltwater Cooling Towers for Steam Electric Generating Plants," Prepared for the U.S. Atomic Energy Commission by Westinghouse Electrical Corporation (WASH-1244, UC-12, February 1973).

12. AEC, Maryland to Examine Effects of Salt Water Cooling Towers — AEC News Release No. R-302, July 24, 1973.

13. Green, R. L., "Chalk Point Cooling Tower Study," Water Resources Research Center, University of Maryland, sponsored by Power Plant Siting Program, Maryland Department of Natural Resources.

Appendix H

DATA AND CALCULATIONS FOR ASSESSMENT OF PREDICTED ELECTRICAL DEMAND

1. CONSUMPTION OF ELECTRICITY BY CLASSES OF USERS

Consumption of electricity by classes of users for the years 1975 and 1980 was estimated by the following methods.

a. Residential

The number of residential customers in a given year can be estimated by dividing the projected average number of persons per household (Table H-1) into the projected population. Historical data indicate that in the applicant's service area about 8% of the total number of customers that would normally be classified as residential are reported in the commercial and industrial category. The estimated number of residential customers is then

$$(0.92) \times \frac{\text{Projected population}}{\text{Average number of persons per household}} .$$

For 1975, (0.92) (8,726,000/2.98) = 2,694,000 customers.

For 1980, (0.92) (8,735,000/2.87) = 2,800,000 customers.

These estimates, when multiplied by the consumption per customer (Table H-2), give the annual consumptions.

For 1975,
2,694,000 customers x 3,926 kWhr/customer = 10,577 x 10^6 kWhr.

For 1980,
2,800,000 customers x 4,912 kWhr/customer = 13,754 x 10^6 kWhr.

b. Commercial and Industrial

Annual consumption in this category was estimated by multiplying the projected employment times the estimated consumption per worker (Table H-3).

For 1975, 4,556,423 workers x 4,817 kWhr/worker = 21,948 x 10^6 kWhr.

For 1980, 4,721,575 workers x 5,923 kWhr/worker = 27,966 x 10^6 kWhr.

Table H-1. Average number of persons per household projected for the New York Urban Region, 1960–2020

Year	Average number of persons per household
1960	3.19
1965	3.19
1970	3.08
1975	2.98
1980	2.87
1985	2.77
2000	2.62
2020	2.60

Source: Regional Plan Association, *New Regional Projections: A Summary,* New York, March 16, 1973, Table 8.

Table H-2. Annual residential consumption of electricity per customer and total personal income, 1972–1980

Year	Total personal income (millions of $)	Consumption of electricity (kWhr per customer)
1972	81,369	3,412
1973	84,332	3,584
1974	87,296	3,755
1975	90,259	3,926
1976	93,675	4,123
1977	97,091	4,320
1978	100,506	4,518
1979	103,922	4,715
1980	107,338	4,912

Table H-3. Annual commercial and industrial consumption of electricity per worker for the years 1972–1980

Year	Consumption of electricity (kWhr per worker)
1972	4,256
1973	4,435
1974	4,622
1975	4,817
1976	5,021
1977	5,232
1978	5,453
1979	5,683
1980	5,923

c. Railroads and Railways

Sales to railroads and railways were assumed to account for about 14% of the applicant's total sales. The annual consumption in this category would then be:

For 1975,

$$0.14 \ \frac{(10{,}577 \times 10^6 \text{ kWhr}) + (21{,}948 \times 10^6 \text{ kWhr})}{0.86} = 5{,}295 \times 10^6 \text{ kWhr.}$$

For 1980,

$$0.14 \ \frac{(13{,}754 \times 10^6 \text{ kWhr}) + (27{,}966 \times 10^6 \text{ kWhr})}{0.86} = 6{,}792 \times 10^6 \text{ kWhr.}$$

d. Total Consumption

For each year, total consumption is considered to be the sum of the previous three categories. For 1975, total consumption will be $(10{,}577 \times 10^6) + (21{,}948 \times 10^6) + (5{,}295 \times 10^6) = 37{,}820 \times 10^6$ kWhr. For 1980, total consumption will be $(13{,}754 \times 10^6) + (27{,}966 \times 10^6) + (6{,}792 \times 10^6) = 48{,}512 \times 10^6$ kWhr.

2. ESTIMATED SUMMER PEAK LOAD

Examination of the 1974 projected capabilities, peak loads, and margins of the New York State interconnected systems through 1983 indicates that the ratio of coincident peak load to annual energy requirements in New York State will be constant at 0.18 throughout the period.

The total annual consumption for a given system is about 90% of the total annual energy requirements, because transmission and other losses consume 10% of a system's output. Therefore, the annual energy requirements for the applicant's system would be:

For 1975, $37{,}820 \times 10^6$ kWhr/(0.9) = $42{,}022 \times 10^6$ kWhr.

For 1980, $48{,}512 \times 10^6$ kWhr/(0.9) = $53{,}902 \times 10^6$ kWhr.

To obtain the estimated summer peak load for the applicant's system, the above annual energy requirements must be multiplied by the constant (0.18) determined for the power Pool. However, this constant must be corrected to reflect the difference in load factors between the system and the power Pool. The ratio of the power Pool load factor to the applicant's load factor was found to be constant at 1.24. The adjusted constant then becomes 0.18 x 1.24 = 0.22, and the estimated peak summer loads would be:

For 1975, 42,022 x 0.22 = 9,245 MW.

For 1980, 53,902 x 0.22 = 11,858 MW.

The effect of the price of electricity on demand was not considered in this analysis because of the relatively short time period involved.

APPENDIX I

COMMENTS ON DRAFT ENVIRONMENTAL STATEMENT

DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY
WASHINGTON, D. C. 20250

RECEIVED JAN 7 1974

JAN 4 1974

Mr. Daniel R. Muller
Assistant Director for
Environmental Projects
Directorate of Licensing
Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Muller:

We have had the draft environmental statement for the Indian Point Nuclear Generating Plant Unit 3, Consolidated Edison Company of New York, reviewed in the relevant agencies of the Department of Agriculture, and comments from Forest Service and Soil Conservation Service, both agencies of the Department, are enclosed.

Sincerely,

F. H. Tschirley

FRED H. TSCHIRLEY
Coordinator, Environmental
Quality Activities

Enclosures

DEPARTMENT OF AGRICULTURE

Forest Service

RE: DRAFT ENVIRONMENTAL STATEMENT - INDIAN POINT NUCLEAR GENERATING PLANT UNIT NO. 3

Little adverse effect on vegetation is anticipated from construction and use of Plant No. 3. If once through cooling does not meet thermal criteria (V-7-17), however, cooling towers (Alternate B) may be used (XI-14). Salt drift from tower plumes (Appendix G 12-15) will probably affect nearby vegetation. We trust that vegetation will be included in the studies mentioned on Page G-14, par. 7.

As an indirect effect of running the plant, there will be a large amount of uranium ore (116000KG) (P.IX-4) processed. What is the effect on vegetation of the air pollution resulting from ore enrichment?

Soil Conservation Service, USDA, Comments on Draft Environmental Statement prepared by Directorate of Licensing, United States Atomic Energy Commission, related to operation of Indian Point Nuclear Generating Plant, Unit No. 3.

1. Page IV-1 - A. SUMMARY OF CONSTRUCTION STATUS - 4th line

   It says, "after which this plant went critical on May 22, 1973." The word critical can be read to imply an unintended meaning. For the ordinary reviewer, clarification of the word critical is needed.

2. Page IV-1 - A.

   We note that Unit No. 3 is presently under construction and is 80% completed. Completion is expected in 1974.

3. Page IV-1 - B. IMPACTS ON LAND USE 1. Onsite Construction

   4th paragraph and the three following paragraphs on page IV-2 seem to say landscaping and vegetative measures are delayed because of construction. In this situation, temporary use of vegetative measures such as grasses and legumes would be appropriate. This might be discussed.

OFFICE OF THE ASSISTANT SECRETARY OF COMMERCE
Washington, D.C. 20230

50-286

RECEIVED
NOV 29 1973
U.S. ATOMIC ENERGY COMMISSION
Regulatory
Mail Section

November 26, 1973

Mr. Daniel R. Muller
Assistant Director
for Environmental Projects
Directorate of Licensing
U.S. Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Muller:

The draft environmental impact statement for the proposed "Indian Point Nuclear Generating Station, Unit No. 3," which accompanied your letter of October 17, 1973, has been received by the Department of Commerce for review and comment.

The statement has been reviewed and the following comments are offered for your consideration.

With regard to the release of routine radioactive wastes to the atmosphere, it is not clear whether the major portion of the releases are sporadic or continuous. In the case of sporadic releases, the application of an annual average atmospheric dilution factor is inappropriate. For example, the gaseous processing system, which is the primary source of radioactivity, involves a minimum gaseous holdup time of 45 days in decay tanks. If this is followed by release to the atmosphere in a few hours, we would consider the source to be sporadic.

- 2 -

Thank you for giving us an opportunity to provide these comments, which we hope will be of assistance to you. We would appreciate receiving a copy of the final statement.

Sincerely,

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

OFFICE OF THE ASSISTANT SECRETARY OF COMMERCE
Washington, D.C. 20230

December 10, 1973

50-286

Mr. Daniel R. Muller
Assistant Director
for Environmental Projects
Directorate of Licensing
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Muller:

The Department of Commerce reviewed the draft environmental statement by the Atomic Energy Commission for the proposed "Indian Point Nuclear Generating Station, Unit No. 3," and forwarded comments to you in our letter of November 26, 1973.

Since that time, additional information has developed which is pertinent to the project. This additional information is offered for your consideration.

The radiological monitoring program, which is described in condensed form, does not include the analysis of benthic animals (page V-138-139). In the subject report, reference is made to the applicant's Environmental Report, which also does not include benthic animals. The program will be modified in the Technical Specifications, but these modifications are not described.

The environmental monitoring section of the subject report should include a summary table giving monitoring details and a location map.

We hope these comments will be of further assistance to you in the preparation of the final statement.

Sincerely,

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20201

NOV 30 1973

RECEIVED DEC 3 1973

50-286

Mr. Daniel R. Muller
Assistant Director for Environmental Projects
Directorate of Licensing
Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Muller:

The following comments are based upon reviews performed by our regional office in New York and the Bureau of Radiological Health concerning the draft Environmental Impact Statement on the Indian Point Nuclear Generating Station, Unit 3.

1. Indian Point Nuclear Generating Plant, Unit 3 is the third of three reactor plant installations to be constructed and operated on the same site. Units 1 and 2 are already constructed and in operation. The draft statement includes consideration of the cumulative effect of all three reactors in operation.

2. From information contained in this draft statement, it appears that this third unit can be constructed and operated without undue health impact on the population as a result of radiation exposures or discharges of radioactivity to the environment. The report notes that in order to meet the AEC "as low as practicable" criteria, it will be necessary to modify the radioactive waste treatment facilities. The report prescribes a date of spring 1975 to accomplish completion of this modified radioactive waste treatment facility. This is an appropriate recommendation.

3. The report discusses doses to the population which might reasonably be expected from an incident occurring at the reactor site. The derivation of these doses and the postulation of the types and frequency of incidents which might occur appear reasonable. The projected doses are not excessive; in fact, based on the estimates and calculations in the report, doses to individuals at the site boundary would be well below the maximum permissible doses derived from 10 CFR, Part 20 of the AEC Regulations for normal operations. The estimated dose to populations within a 50-mile radius of the site would be a small fraction of the population dose from natural background, as expressed in man-rems.

4. Section E.1.d. states that the solid wastes will eventually be shipped to a licensed burial facility. The specific burial site may not yet have been identified and such burial sites may be covered by other impact statements, but it is suggested that a discussion of the capacity of burial sites to handle the material from this plant, perhaps as a percentage of existing burial site capacity, be included in this statement.

5. Exposures from transportation of radioactive materials to and from the plants is discussed. These are very small exposures and are based on realistic assumptions. The question of transportation accidents is discussed, but in very general terms. However, the discussion is adequate and as concise as is possible based on the current information from the history of transportation accidents.

6. Considering the protection of fish, fish food at the plant site, it is recommended that the applicant study alternatives to the presently designed once-through cooling system for the plant--namely, the use of cooling towers in order to reduce the volumes of water pumped from the river and entraining fish. The applicant is told to design and install an alternate cooling system within the next four years to remedy this situation. This appears to be a sound recommendation.

Sincerely,

Paul Cromwell

Paul Cromwell
Acting Director
Office of Environmental Affairs

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

50-286

In reply refer to:
PEP ER 73/1405

DEC 13 1973

Dear Mr. Muller:

Thank you for your letter of October 17, 1973, requesting our comments on the Atomic Energy Commission's draft environmental statement, dated October 1973, on environmental considerations for Indian Point Nuclear Generating Plant, Unit No. 3, Westchester County, New York.

General

This Department is extremely pleased with the generally thorough and indepth coverage of the environmental effects which are expected to occur as a result of this project.

The indepth analysis performed by the AEC staff and the resulting conclusions and specific recommendations are evident throughout the document. The AEC deserves recognition for this outstanding draft environmental statement.

Our comments relate to several significant generic concerns for nuclear powerplants, the time required for the conversion to closed-cycle cooling, and other suggestions that would reduce the environmental impacts or improve the environmental statement. They are presented according to the format of the statement or according to specific subjects.

Timing of the Closed-Cycle Cooling System

The regeneration cycle of many fish species of importance to sport and commercial fishing interests is long; for example, the striped bass require about 6 years. If the closed-cycle cooling system for Units 2 and 3 are not operating prior to May 1, 1978, the effects of once-through cooling would be experienced by striped bass and other

aquatic organisms in the Hudson River through 1984. These effects could be devastating. We strongly recommend that AEC reconsider this deadline of May 1, 1978.

The applicant has been fully aware for years of the general concerns for adverse impacts on aquatic life, including those of the Atomic Energy Commission. It does not appear to be in the public interest to delay the closed-cycle operation of units 2 and 3 until 1978 if there is a reasonable possibility that such a system could be operating prior to this date.

Our letter of December 4, 1972, to you recommended the installation of closed-cycle cooling for unit 2 by July 1, 1975. It appears to us that if appropriate action had been undertaken at that time unit 3 could have begun its closed-cycle operation by the summer of 1976 rather than two years later.

Every effort should be made to minimize unnecessary further damage to the fishery resources of the Hudson River. Consideration should be given to requiring interim operation standards to be implemented at Indian Point. Criteria have been developed for the operation of the Bowline Point Generating Station downstream and across the river from Indian Point, which are designed to reduce the mortalities associated with impingement and entrainment during peak periods of fish activity in the area. Bowline Point criteria could be used as a model for criteria to be applied at Indian Point.

The Site

This section should be expanded to include a description of the existing and future proposed steam electric generating facilities which will be constructed by the utilities including the proposed pump storage project at Storm King. Other agencies such as the New York City Transit Authority have proposed development of additional steam electric powerplants. The City of New York is considering diversions of water for municipal and industrial purposes. Descriptions of these existing and future proposed projects are necessary to adequately describe the cumulative impacts of man's use of the Hudson River estuary.

Geology and Geography

The brief description of geology and geography, presented on pages II-15 and II-16, is inadequate for evaluating whether the geologic and seismic conditions and the physical properties of the natural materials on which the plant is founded have been investigated in sufficient detail. The history of earthquakes in the region has been briefly summarized but the seismic-design criteria for plant construction and the methods of their derivation are not included. This inadequacy could be alleviated if the geology and seismology have been taken into account according to AEC's "Seismic and Geologic Siting Criteria for Nuclear Power Plants" (10 CFS 100, Appendix A, Federal Register, Vol. 36. No. 228, Nov. 25, 1971). If this has been done we suggest that it be indicated along with a reference to the AEC Criteria.

Macroinvertebrates

Compared with extensive detail found in sections dealing with fish species, plankton, etc., the benthic section on macroinvertebrates and benthic organisms appears to be deficient. We suggest that this section recognize that due to pollution control programs, the quality of the water has improved in recent years. This is evident by the reappearance of blue crabs in the lower Hudson River in the vicinity of Indian Point.

Impacts of Station Operation on Land Use

We have been aware of the applicant's intentions of providing recreation opportunities on its site for some time. It is indicated on page V-2 that a Master Land Use plan has been developed for the plant site and that the 80-acre woodland recreational facility will be available for public use. We are pleased with this planning and suggest that a description of these plans, including a timetable for implementation should be included in the final statement.

Effects on Historical Landmarks

No existing or proposed units of the National Park System will be adversely affected by the proposal. It does not appear that any site registered as a National Historic, Natural, or Environmental Education Landmark or any site listed as eligible for such registration will be adversely affected.

We are pleased that evidence of consultation with both the Advisory Council on Historic Preservation and the State Historic Preservation Officer both of which reveal an effort to comply with Section 106 of the National Historic Preservation Act of 1966 and Executive Order 11593.

Thermal Effects on Water Uses

Anticipated impacts of thermal effluents on aquatic biota in the Hudson River appear to have been exhaustively analyzed. However, little or no information is included in the effect of the raised water temperature on other uses of the river water upstream and downstream from Indian Point, particularly at points between 90 and 120 miles downstream of Troy, New York. It is recognized that the effects will be partially inseparable from those of other powerplants such as the Lovett and Bowline fossil-fuel plants, and that the effects would presumably not be significant after May 1, 1978, when a closed-cycle cooling system would become operational. However, it is suggested that assurances be given that thermal effects evaluated in the statement include effects on other industrial uses of the water, particularly the important use of the water as a coolant.

Cumulative Impacts

We believe it imperative, when considering impacts on fish and wildlife resources, that all units operating or planned on the Hudson River estuary be considered. The fishery loss associated with steam-electric power plants withdrawing water from the river should be discussed more thoroughly. Such an overall analysis of impacts would be more informative than a discussion of only the Indian Point Nuclear Generating Station's impacts.

The principal emphasis of the biological impacts have related to the effects on striped bass resources. Many pages of testimony have been presented, both pro and con, as to the significance of thermal pollution, chemical impacts, entrainment, and impingement on the resources of the Hudson River. Much of this testimony is centered on whether or not installation of a closed-cycle cooling system is necessary to prevent unacceptable adverse effects on the striped bass population. The AEC has recognized and we concur that the effects on other species are equally as important although not as much information has been presented.

Transmission Facilities

It is stated on page V-4 that chemical treatment shall be used only after consultation with recognized experts in this type of work. Since no specific chemicals are mentioned, it must be emphasized that the applicant should consult the Environmental Protection Agency, the New York Department of Environmental Conservation and the Bureau of Sport Fisheries and Wildlife of this Department when chemical control of vegetation or pests is contemplated.

Sampling Methods

Three important considerations which tend to reduce the reliability of the fish count studies of impinged fish are discussed on page V-36. We suggest that a fourth factor be considered. The data collected in substantiation of air current use is suspect because, as pointed out by MRPC in their letter of July 16, 1973, to Consolidated Edison, the air current creates a positive outflow away from the screen. Fish which have already been damaged or killed by impingement are thus moved out into the river rather than onto the traveling screens to be enumerated. We understand that the applicant has designed studies to determine the extent of this problem.

It appears that the AEC staff has evaluated extensively the studies and study techniques accomplished at Indian Point. However, it appears that the efficiency of gear used in capturing various species of larvae, juvenile and adult fishes by various consultants who have worked on the river should receive additional consideration. Certain types of gear such as beach seines to enumerate striped bass may be found to be inappropriate.

Chemical Discharges

Due to the recognized detrimental environmental impacts of chlorine on the aquatic environment, consideration should be given to the elimination of this element from powerplant effluents. Although an alternative biocide system is discussed on page Xl-50, the feasibility of this alternative at Indian Point 3 is not given. We are aware that the discharge of chlorine after the closed-cycle cooling system is in operation will be greatly reduced.

Solid Radioactive Wastes

The solid radioactive wastes are described as evaporator concentrates from the liquid waste processing system along with spent resins, filter sludges, air filters, miscellaneous paper and rags. It is estimated that about 1,000 drums, having an estimated total activity of approximately 4,900 curies, will be shipped offsite annually to a licensed burial facility at Morehead, Kentucky. We think that the impact evaluation would be greatly improved if it specified the kinds of radionuclides, their physical states, their concentrations in wastes, and the estimated total volume of wastes for the expected operating life of the plant.

We also suggest that the statement include an evaluation of the ultimate disposal sites for all radioactive wastes generated by Unit 3. The statement should also include Federal and State Licensing provisions, criteria, and responsibilities for the site in regard to : (1) determination of the hydrogeologic suitability of the site to isolate the wastes of the Indian Point Station from the biosphere; (2) surveillance and monitoring of the site; and (3) any remedial or regulatory actions that might be necessary during the period in which the wastes will be hazardous.

Major Accidents

The environmental effects of Class 9 accidents which would result in both air and water releases of radioactive materials should be described along with the potential impacts on human life and the remaining environment as long as there is any possibility of occurrence. The consequences of an accident of this severity could have far-reaching effects on land and in the Hudson River estuary which could persist for centuries affecting millions of people.

The recent bulging of the steel liner for the containment used at Indian Point No. 2 dramatically displays the significant problems associated with nuclear plants and also the very real potential for major accidents.

Alternative Fish Protection Measures

The second sentence, paragraph 2, page Xl-51 should read 0.5 fps rather than 0.5 ppm.

Environmental Costs

The Pollution Committee of the American Fishery Society, Southern Division, in 1970 published a report entitled, "Monetary Values of Fish," which described cost of fish replacement. Although these values do not reflect the true environmental costs, they may be useful in arriving at a minimal dollar value of fish resources impacted by power-plants. As an example, replacement costs for white perch range from 5 cents per fish, 1 inch long up to 60 cents per fish, 12 inches long. These values are more appropriate to use than values of adult fish to the sport and commercial harvest because of problems relating to estimating the survival of fishes through various life history stages and the value of fish which have been incorporated into food webs. They would be of much more value than those values included in Table XI-15 which places a relative value on the magnitude of resource losses.

Table A-6

Footnote a. indicates that the river temperature at the mouth is 70°F. Data compiled by NOAA in National Ocean Survey publication 31-1, "Surface Water Temperature and Density for North and South America" indicates that the mean monthly temperatures near the Battery for the months of July and August have been 71.4°F and 73.2°F respectively.

We hope these comments will be helpful in the preparation of the final environmental statement.

Sincerely yours,

William O. Vogely

Acting Deputy Assistant Secretary of the Interior

Mr. Daniel R. Muller
Assistant Director for Environmental Projects
Directorate of Licensing
ATomic Energy Commission
Washington, D. C. 20545

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Mr. Daniel R. Muller
Assistant Director for Environmental Projects
Directorate of Licensing
Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Muller:

This is in response to your letter of October 17, 1973 addressed to Mr. B. O. Davis concerning the draft environmental impact statement for the Indian Point Nuclear Generating Plant, Unit 3, Westchester County, New York.

The Department of Transportation has reviewed the material submitted. We have no comments to offer nor do we have any objection to the project.

The opportunity to review this project is appreciated.

Sincerely,

R. I. PRICE
[illegible] Guard
[illegible] of Marine
[illegible]
By [illegible] Commandant

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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Regulatory Mail Section

OFFICE OF THE ADMINISTRATOR

Mr. L. Manning Muntzing
Director of Regulation
U.S. Atomic Energy Commission
Washington, D.C. 20545

Dear Mr. Muntzing:

The Environmental Protection Agency has reviewed the draft environmental impact statement issued in conjunction with the application of Consolidated Edison Company for an operating license for Indian Point Nuclear Generating Plant, Unit 3. In general, we agree with the conclusions and recommendations of the AEC staff concerning this project, except as discussed in the attached detailed comments. Regarding the draft statement, we believe it represents one of the best efforts to date to assess the impacts of a nuclear power facility, particularly with respect to impacts on aquatic biota.

While the existing liquid and gaseous waste treatment systems for Indian Point Units 1, 2, and 3 are not sufficient to limit radioactive discharges to levels that are consistent with the provisions of 10 CFR Part 50 and Regulatory Guide 1.42, the applicant is modifying these systems in order to provide adequate treatment. In general, the proposed modified systems are expected to limit radionuclide releases and offsite doses to levels within those proposed in Appendix I to 10 CFR Part 50. Possible exceptions are the potential doses to a child via the cow-milk and inhalation exposure pathways originating at or near the site boundary.

Since the present once-through cooling system will not enable the Indian Point Unit 3 to operate in compliance with applicable water quality standards for the State of New York and will result in severe (possibly irreversible) impacts on aquatic biota in the Hudson River, we agree with the AEC staff's recommendation that Unit 3 be converted to closed-cycle

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cooling. The proposed May 1, 1978, completion date, however, may not be acceptable either from the standpoint of fishery protection or with respect to the Federal Water Pollution Control Act Ammendments of 1972 (FWPCA)-which calls for July 1, 1977. We suggest, therefore, that consideration be given to expediting the installations of the closed-cycle system and, considering the impact that may occur during the interim operation of the once-through systems, that EPA be provided with details of the "plan-of-action" to be developed for the interim period as soon as available. All pertinate factors, including impacts and FWPCA requirements, will be considered by EPA prior to action on a discharge permit for this unit under the National Pollutant Discharge Elimination System (NPDES) instituted by the FWPCA.

In light of our review of this draft statement and in accordance with EPA procedure, we have classified the project as ER (Environmental Reservations) and rated the draft statement as Category 1 (Adequate). We would be pleased to discuss our classification or comments with you or members of your staff.

Sincerely yours,

Sheldon Meyers

Sheldon Meyers
Director
Office of Federal Activities

EPA# D-AEC-06117-NY

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ENVIRONMENTAL PROTECTION AGENCY

Washington, D.C. 20460

December 1973

ENVIRONMENTAL IMPACT STATEMENT COMMENTS

Indian Point Nuclear Generating Plant Unit No. 3

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INTRODUCTION AND CONCLUSIONS

The Environmental Protection Agency has reviewed the draft environmental statement issued by the U.S. Atomic Energy Commission in conjunction with the application of Consolidated Edison Company for a license to operate Indian Point Nuclear Generating Plant, Unit 3. This unit is now nearing completion at the Indian Point site located in Westchester County, New York on the Hudson River. The following are our major conclusions:

1. With the exception of gaseous radioiodine releases, the proposed modified gaseous and liquid waste treatment systems for Units 1, 2, and 3 are expected to be capable of limiting radionuclide releases and, therefore, the related offsite doses, to levels within the guidance of the proposed Appendix I to 10 CFR Part 50. Based on EPA's independent analysis, the thyroid doses from radioiodine via both the cow-milk child and inhalation pathways at or near the site boundary exceed the guides in the proposed Appendix I and the interim Regulatory Guide 1.42. Thus, the applicant should develop a program to identify the location of milk cows and monitor the critical dose pathways in order to assure that the real doses are maintained within the provisions of applicable regulatory limits and guides throughout the lifetime of the plant.

2. The thermal discharges from Indian Point Units 1,2,and 3, using once-through cooling, will result in violation of applicable New York State water quality standards for the Hudson River. Specifically, surface width and cross sectional temperature rise criteria will be exceeded and the maximum surface temperature criteria of 90°F (32.2°C) may also be exceeded. Dissolved oxygen concentrations in the Hudson River are already, at times, below New York State standards. The addition of a thermal discharge from Unit 3 to the River will likely cause a further deterioration in this water quality parameter. These factors underscore the need for thermal pollution control measures at Indian Point.

3. We agree with the AEC recommendation that cooling towers be installed at Indian Point Unit 3 as the AEC has previously recommended for Unit 2. The May 1, 1978, compliance date that is proposed, however, may not be acceptable either from the standpoint of fishery protection or compliance with the requirements of the Federal Water Pollution Control Act Amendments of 1972 (FWPCA). The four-year interim period to May 1978 with operation of Indian Point Units 1, 2, and 3, using once-through cooling, coupled with the operation of other plants on the

Hudson will result in serious and possibly irreversible depletion of aquatic biota. For example, fish losses due to impingement, and egg and larvae destruction due to entrainment, have been and will be substantial enough that the elimination of white perch and striped bass populations as viable fisheries is probable. The FWPCA requires the installation of "Best Practicable Control Technology Currently Available" by July 1, 1977. We suggest, therefore, that consideration be given to expediting the installation of the closed-cycle cooling system so that it can be ready for operation by July 1, 1977, or sooner, if possible. In addition, since it is possible that the irreversible point for some species could be reached before 1978 or even July 1, 1977, we concur with the AEC staff that the applicant should develop a "plan-of-action of operating procedures and design of the once-through cooling system to...minimize detrimental effects on aquatic biota...during the interim period...."

4. All jurisdictional and environmental factors will be considered when EPA evaluates the application of Consolidated Edision Company for a permit for Unit 3 under the National Pollutant Discharge Elimination System (NPDES)-as instituted by Section 402 of the FWPCA. In particular, impacts from thermal discharges, impingement, and entrainment will be used to develop special conditions for this permit. In this regard, we would like to be provided with the details of the "plan-of-action" to be developed for the interim period as soon as available and, in any case, prior to EPA's action on an NPDES permit.

5. With respect to the total Indian Point station, the AEC favors the alternative that calls for cooling towers for Units 1 and 2, and continuance of operation of Unit 1 with once-through cooling. Regarding Unit 1, however, EPA will be evaluating its impact, based on the requirements of the NPDES permit program, to determine what actions may be necessary to protect aquatic biota.

RADIOLOGICAL ASPECTS

Radioactive Waste Management

The radioactive waste treatment systems for all three units at the Indian Point site are to be intertied with the planned modifications to the Unit 1 liquid waste management system. Therefore, it has been necessary for us to include consideration of all three units in our review. The existing liquid and gaseous waste treatment systems for Indian Point Units 1, 2, and 3 are not capable of limiting radioactive discharges to levels that are consistent with the provisions of 10 CFR Part 50 and Regulatory Guide 1.42, since there is no provision for treating effluents from the steam generator blowdown from all three units and no current capability to control gaseous iodine from the Unit 3 auxiliary building and containment. However, in an effort to comply with the AEC's 10 Part 50 regulations, the applicant is modifying the waste treatment systems to provide treatment for these effluents. In general, the proposed modified systems are expected to limit radionuclide releases and, subsequently, offsite doses to levels within those proposed in Appendix I to 10 CFR Part 50, with the exception of the potential doses to a child via the cow-milk and inhalation exposure pathways at or near the site boundary.

Operating experience at other reactors which employ a 2 gallon per minute (gpm) waste evaporator (Ginna, H. B. Robinson), has shown that it is not possible to attain the design decontamination factor and/or flow rates assumed for this size evaporator. Although the operational problem may be characteristic of specific types of evaporators, there is insufficient information to make this determination. The final statement should provide a discussion of the type of evaporator provided for Unit 3 and a discussion of its characteristics compared to those in operating plants which have experienced evaporator problems. Sufficient detail should be provided to assure that the Indian Point Unit 3 evaporator will perform up to its design characteristics, so that the liquid radioactive effluent can be considered to be "as low as practicable" using "state-of-the-art" technology.

In view of the liquid radioactivity actually released during normal operation of Unit 1 and the near-term (to 1975) effluent projections for Units 2 and 3, it is possible that applicable regulatory guidelines may be exceeded by the individual units. We stress the importance of the utility's full utilization of the available waste treatment capabilities until the modifications are completed.

Dose Assessment

Our calculations for milk ingestion doses to the thyroid of a one-year-old child are in reasonable agreement with those of the AEC. For example, for consumption of milk produced by the nearest cow (11.2 kilometers (7 miles) from the plant), we calculated a thyroid dose of about 5.4 mrem/yr, while the AEC's corresponding estimate was 5.5 mrem/yr for all three units utilizing the proposed modified waste treatment systems. Based on these results, it is evident that the thyroid dose via the grass-cow-milk pathway is expected to be within the provisions of Regulatory Guide 1.42 by a factor of about three. However, locations of the nearest potential pastures have not been identified. In the final statement, the nearest potential pastures should be identified and the corresponding thyroid doses via milk consumption at those locations should be given. For example, our calculated thyroid dose to a four-year-old via this pathway is in the range of 20 mrem/yr at the site boundary, for the modified waste system case. To ensure that the thyroid dose due to inhalation and also milk consumption does not exceed the provisions of Regulatory Guide 1.42, the applicant should develop a program to identify actual pastures and children residing at or near the site boundary as part of the operational environmental surveillance program. These measures should be described in the final statement. Also, the analytical sensitivity of the environmental sampling program should be developed to be capable of detecting the exposure levels given in Regulatory Guide 1.42. Furthermore, in order to assure that employees at the visitor's center do not receive doses in excess of those suggested by the proposed Appendix I to 10 CFR Part 50 and Regulatory Guide 1.42, appropriate monitoring systems should be provided in the visitor's center. This is particularly important relative to potentially excessive thyroid exposures.

The EPA expects that the results from current and planned joint EPA-AEC and industry cooperative field studies in the environs of operating nuclear power facilities will greatly increase knowledge of the processes and mechanism involved in the exposure of man to radiation produced through the use of nuclear power. We believe that, overall, the cumulative assumptions utilized to estimate various human doses are conservative. As more information is developed, the models used to estimate human exposures will be modified to reflect the best data and most realistic situations possible. Based on the results of these cooperative studies, it is possible that the scope and extent of present environmental monitoring programs may be relaxed.

Transportation

EPA, in its earlier reviews of the environmental impact of transportation of radioactive material, agreed with the AEC that many aspects of this problem could best be treated on a generic basis. The generic approach has reached the point where on February 5, 1973, the AEC published for comment in the Federal Register a rulemaking proposal concerning the "Environmental Effects of Transportation of Fuel and Waste from Nuclear Power Reactors." EPA commented on the proposed rulemaking by a letter to the AEC, dated March 22, 1973, and by an appearance at the public hearing on April 2, 1973.

Until such time as a generic rule is established, EPA is continuing to assess the adequacy of the quantitative estimates of environmental radiation impact resulting from transportation of radioactive materials provided in environmental statements. The estimates provided for this station are deemed adequate based on currently available information.

Reactor Accidents

EPA has examined the AEC analysis of accidents and their potential risks which the AEC has developed in the course of its engineering evaluation of reactor safety in the design of nuclear plants. Since these accident issues are common to all nuclear power plants of a given type, EPA concurs with the AEC's approach to evaluate the environmental risk for each accident class on a generic basis. The AEC has in the past and still continues to devote extensive efforts to assure safety through plant design and accident analyses in the licensing process on a case-by-case basis. EPA, however favors the additional step now being undertaken by the AEC of a thorough analysis on a more quantitative basis of the risk of potential accidents in all ranges. We continue to encourage this effort and urge the AEC to press forward to its timely completion and publication. EPA believes this will result in a better understanding of the possible risks to the environment.

We are pleased to note in the draft statement the discussion of the Reactor Safety Study and the commitment for timely public presentation of its results. If the AEC's efforts indicate that unwarranted risks are being taken at the Indian Point station, we are confident that the AEC will assure appropriate corrective action. Similarly, if EPA efforts related to the accident area uncover any environmentally unacceptable conditions related to the safety of the Indian Point station, we will make our views known. Furthermore, the discussion of the potential consequences of the failure of radioactive waste systems is recognized as a significant improvement which is responsive to EPA's request that plant specific consideration be amplified in individual draft statements.

NON-RADIOLOGICAL ASPECTS

According to the draft statement, Unit 3 of the Indian Point Station employs a pressurized water reactor which will produce up to 3,025 megawatts thermal (MWt) with a design power level of 3,216 MWt "...anticipated at a future date." As proposed by the applicant, condenser cooling for this unit will be accomplished by a once-through system withdrawing cooling water from the Hudson River utilizing a separate intake and discharging heated water back into the river "...via a common (i.e. used by all three units) discharge canal and submerged multiport diffuser."

In our opinion, the once-through system will not permit Unit 3 to operate in compliance with either existing or proposed thermal standards for the State of New York, especially when considered in the light of thermal loads imparted by Units 1 and 2 as well as other sources along the river. Also, this system will undoubtedly lead to significantly increased and serious impacts on aquatic biota due to thermal, impingement, and entrainment effects.

In addition to the above, the once-through design will probably not be in conformance with certain provisions of the Federal Water Pollution Control Act Ammendments of 1972 (FWPCA). Specifically, Section 301 of this Act requires that cooling systems of steam electric plants employ the "Best Practicable Control Technology Currently Available" by July 1, 1977, and the "Best Available Technology Economically Achievable" by July 1, 1983. Although a description of these terms (embodied in effluent limitations for this type of facility) has not yet been promulgated by EPA, it is likely that some form of closed-cycle cooling will be required, particularly in those situations where such a system is obviously the best alternative environmentally. All jurisdictional and environmental factors will be considered when EPA evaluates the application for a permit under the National Pollutant Discharge Elimination System (NPDES) instituted by Section 402 of the FWPCA. In particular, impacts from thermal discharges, impingement, and entrainment will be used to develop special conditions which will be imposed by EPA in issuing a permit for Unit 3.

It should be noted that a reconsideration of the requirements of the FWPCA, as they apply to the thermal component of a discharge, may be allowed by the Administrator of EPA (or if appropriate the State) under Section 316(a) of

the Act, if it can be demonstrated by the applicant that less stringent requirements will "...assure the protection and propagation of a balanced, indigenous population of shell-fish, fish, and wildlife in and on the body of water into which the discharge is made."

This possibility notwithstanding and without pre-judging the permit application, we concur with the AEC recommendation that cooling towers be installed on Indian Point Unit 3. The May 1, 1978, date specified in the draft statement for completion of this system, however, may not be acceptable from the standpoint of adequate protection of aquatic biota since, considering electrical energy demands in the region, the plant will be permitted to operate with once-through cooling during the interim period. Nor will the date be consistent with the July 1, 1977, compliance date specified in the FWPCA. Therefore, we suggest that consideration be given to expediting the construction schedule where possible to meet the 1977 date or earlier and that the final statement detail those procedures that will be taken during the interim operation to minimize the impacts on the Hudson River fishery. If it is not feasible to reduce power at Unit 3 during critical periods to protect equatic biota, some structural and operational mitigating measures may be possible. Several such measures are discussed in the context of our comments in the following pages.

With respect to the total Indian Point station, the AEC favors the alternative that calls for cooling towers on Units 2 and 3, and continuance of operation of Unit 1 with once-through cooling. Regarding Unit 1, however, EPA will be evaluating its impact, based on the requirements of the NPDES permit program, to determine what action may be necessary to protect aquatic biota.

Biological Effects

As mentioned previously, in our opinion, the operation of Indian Point Unit 3 in conjunction with Units 1 and 2 during the interim period, when combined with other electrical generating facilities on the Hudson River, will have a serious adverse impact on the aquatic biota of the River. With regard to Unit 3's operation, these effects will be due to operation of the plant's once-through cooling system and will result not only from thermal effluents but also from the cooling water intake configuration which will lead to excessive impingement and entrainment rates. These effects are discussed in turn below.

Impingement on intake screens

In an earlier AEC impact statement issued on Indian Point Unit 1, it was recognized that fish impingement rates are a function of both flow and velocity through the intake structure. Figure V-4 in the present draft statement (which was also presented in a previous statement for Unit 2), illustrates this point. It can be seen that the impingement rate increases drastically at the plant site for velocities greater than 0.9 fps (0.28 mps). The intake velocity across the screens at Unit 3 will be 1.5-2.0 fps (0.46-0.61 mps) under full flow conditions. The question then arises as to why the applicant did not utilize such information in the final design of the intake structure. A better design could have resulted in an intake configuration with a lower intake velocity and consequently a reduced impingement rate. In this regard, it should be noted that the importance of reducing environmental damage of this nature is addressed in the FWPCA. Section 316(b) of the Act provides that the "...location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impacts."

Although the applicant estimates that the total annual kill from impingement at all three Units will be 2.6×10^6 fish per year, the AEC staff estimates that this figure may be low for a number of reasons, among which is the fact that the figure does not include peaks resulting from large-scale periodic kills. EPA believes, however, that from previous data submitted, the above estimate may be very low. To this point, in the final statement for Indian Point Unit 2, it was estimated that the winter kill at Unit 2 alone would be about 30,000 per day, which translates to 5.5×10^6 over the 6-month winter period. It would probably not be too unreasonable to estimate a total annual kill of 8×10^6 at Unit 2. This would be equivalent to about 20×10^6 at all 3 units, a figure 7 times higher than that given in this draft statement. This point is reinforced by Raytheon data which show about 1.3×10^6 fish killed in only 2 months of data collection. The AEC should attempt to clarify this discrepancy in fish kill estimates in the final statement. In addition, considering the magnitude of the impingement problems likely to be experienced at Unit 3 during the interim period, the final statement should indicate the means by which intake design changes and plant operations will be utilized to reduce excessive impingement rates.

With respect to this goal, the AEC staff proposes that the applicant be required to monitor impingement and indicates that the "Environmental Technical Specifications will place a maximum number on daily fish kill in order to limit kills." In other words, the applicant will be expected to monitor impingement kill rates and to reduce flow when a given number is reached. We are skeptical that this procedure will be effective considering that this unit will supply base load capacity to a system that is purported to be, during some periods of the year, already overtaxed terms electrical demands. Thus, the final statement should only indicate those realistic measures that will be taken to assure that impacts due to impingement kills will be minimized.

It should be noted that the applicant, in an effort to reduce kills on the travelling screens, has installed fixed screens in the front portion of the intake structure of Unit 1. This has reduced the impingement problems on the travelling screens, but it would seem, though, that the problem has been transferred to the fixed screens. Documents reviewed by EPA to date appear to indicate that little is known about the effectiveness of the fixed screens in prevention of impingement mortalities. If this is not the case and data exists to show that fixed screens are truly effective in reducing such mortalities, it should be presented in the final statement and a reason given for not installing this device on Unit 3 during its interim period of operation with once-through cooling.

Entrainment

Entrainment is and will continue to be a major problem at Indian Point, particularly during the interim period. The draft statement addresses this problem, but the AEC staff's approach is limited and may well be underestimating the overall picture by concentrating too extensively on the effects on the striped bass. For example, the draft statement does not adequately cover a significant decline in the White perch that has occured since the early 1960's. If, as seems likely, a major contributing factor in this decline was the operation of Unit 1, then combined operations of all three units promise to accelerate this trend. Since the same problem exists for yet other species (e.g., tomcod, shad, and alewife), it is important that decisions concerning the schedule and manner of replacing the present once-through cooling systems be based on analyses that include species in addition to the striped bass.

With respect to the analyses of the impacts on the striped bass population, the AEC staff estimates that reductions of eggs and larvae moving past the plant will range from 43 to 72%, if the combined effects of all plants in the area are considered, including those caused by Indian Point operating at full capacity. Although the draft statement does indicate that such losses could result in the bass population deteorating "...beyond the point of rehabilitation," we are concerned that it has been assumed that irreversible conditions will arise only if operation of the three units with once-through cooling were to persist well beyond the period allotted for installation of closed-cycle cooling on Units 2 and 3. It is possible that the irreversible point could be reached before 1978 or even July 1, 1977. Thus we concur in the recommendation of the AEC staff that the applicant develop a "plan-of-action of operating procedures and design of the once-through cooling system... to minimize deterimantal effects on aquatic biota in the Hudson River to a practicable minimum during the interim period...." We suggest, however that the details of this plan be submitted to EPA for review as soon as they are available and, in any case, prior to EPA's action on an NPDES permit application for Unit 3.

Returning to a consideration of other species, if the effects of impingement and entrainment are great and if there is a short time lag between hatching and recruitment to the adult population, then population effects in these other species may be even more significant than those exhibited by the striped bass population. Thus we question the argument that a 5 year "test" period before installation of a closed-cycle system(s) is warranted because there is a 4 to 6 year lag before egg and larval destruction will result in a decline in adult bass population. In our opinion, any such test period should be predicated on one of the other important species, for example the white perch discussed previously. The final statement should discuss this point.

Physiochemical Parameters

The major concerns in this area are the effects of operations on dissolved oxygen (DO) and chlorine concentrations in the receiving water.

In the draft statement it is stated that: "The Hudson River near Indian Point has a relatively low load of decomposing matter." This would seem to be contradicted by the range of ambient summertime dissolved oxygen levels

in the receiving water (3-11 mg/l). An ambient DO of 3.0 mg/l would indicate a very high loading of the water with putrescible organics. No BOD data were reported in the statement; if this were included in the final statement, we would be better able to judge the possible severity of the thermal enhancement of biochemical oxygen demand. Also, the discharge of an appreciable mass of dead organisms (as will certainly occur here) can only serve to increase the BOD in the thermal plume.

The waters into which the Indian Point plant discharges are classified as "SB" under the New York State regulations. The present regulations for this class specify a minimum of 5.0 ppm (mg/l) of dissolved oxygen. Since combined discharges of all 3 units at Indian Point will further lower DO values, which are already in violation of regulations during certain seasons of the year, plant operations will further contravene the New York regulations for dissolved oxygen. The final statement should discuss this problem.

According to the statement, "Chlorination of the once-through cooling system for either Unit 2 or Units 1 and 3 may result in discharging cooling water containing up to 0.5 ppm (mg/l) of residual chlorine." It is also stated that, "The (AEC) staff will require that the total residual chlorine concentration at the point of discharge into the Hudson River shall not exceed 0.1 ppm (mg/l)." As was the case with fish kills on the intake screens, the applicant will also be required to monitor chlorine residual. The final statement should contain actual operating data from Units 1 and 2 in this regard. From previous documents it seems that the chlorine residual from Unit 1 alone has at times exceeded 0.5 mg/l (ppm). In light of this fact, further evaluation is needed that combined operations at Units 1-3 will yield no more than 0.1 mg/l (ppm).

We agree with the AEC staff that chlorination should be performed during peak tidal flows and daylight hours. We also feel, however, that due to uncertainty as to actual chlorine residuals which might result from combined operations, alternate means of condenser cleaning should be reevaluated and the results discussed in the final statement.

Thermal Discharge

The data contained in the statement indicate that the thermal plume at Indian Point will not comply with either present or proposed New York State thermal criteria.

It is predicted that under severe operating conditions the entire surface width of the river will experience temperature rises greater than 2.2 °C (4°F). This would be in contravention of present New York regulations, which stipulate that a temperature rise of this magnitude shall not take place over greater than 2/3 the surface width. New York regulations also stipulate that surface temperatures shall not be greater than 90°F (32.2°C) at any point in an estuary. We agree with the AEC staff's reservations as to whether this requirement will be met. To better evaluate this situation it would be helpful if the AEC included actual operating data in the final statement with respect to the thermal plume resulting from operation of Units 1 and 2.

EPA believes that there is significant potential at the site for recirculation of the heated effluent. The combined discharge is located only 152 m (500 ft) downstream of the intake openings for Unit 3. The final statement should discuss the potential for recirculation of heated effluent during incoming and slack tidal cycles and the effect of this recirculation on the ability of the plant to meet thermal standards.

In order to reduce impingement, during the time when ambient water temperature is 4.4°C (40°F) or less, 60% recirculation of flow will take place in accordance with a directive from the State of New York. Given that this procedure will reduce impingement, it may also, however, aggravate the already unacceptable thermal discharge effects. The statement contains information indicating that the cross-section requirement of the New York regulations will be violated. They stipulate that no greater than 50% of the cross-section of the river shall be impacted by the 4°F (2.2°C) isotherm. The thermal plume will exceed this limitation most of the time. Thus, it appears that the only way New York State criteria will be met is by conversion of Unit 3 to closed cycle cooling.

ADDITIONAL COMMENTS

During the review, we noted in certain instances that the draft statement does not present sufficient information to substantiate the conclusions presented. We recognize that much of this information is not of major importance in evaluating the environmental impact of the Indian Point station. The cumulative importance, however, could be significant. It would, therefore, be helpful in determining the impact of the plant if the following information were included in the final statement:

1. According to the draft statement, the liquid effluents from steam generator blowdown will be released directly into the environment without treatment, if the blowdown contains activity below a predetermined value. The final statement should provide the criteria for such untreated discharges and should indicate if such untreated releases are taken into account in Table 5-6 of the draft statement.

2. Ventilation air from the turbine building, Unit 1 flash tank vapor (via Unit 1 roof vent) and Unit 3 flash tank vapor (via Unit 3 roof vent) will not be monitored. Also, it is not clear from the draft statement whether turbine building drains will be monitored. The final statement should discuss how AEC Safety Guide 21 criteria can be met without monitoring. If monitoring or sampling provisions are not to be included, the AEC should discuss in the final statement exactly how the radioactivity in the discharges will be quantitated, so that environmental dose assessments and station release records will reflect the total station impact on the environment. It appears that the Unit 3 flash tank vapor via the Unit 3 roof top vent is not accounted for in the list of radioiodine source terms in Table 5-9. This source term should be given in the final statement, and the dose evaluations correspondingly modified.

3. On Page 5-121 in the draft statement, the AEC states that the ventilation air from the fuel storage buildings will be treated by a charcoal adsorber only if the radioactivity in the air is above a present value. The specific criteria for utilizing the charcoal adsorber should be given in the final statement.

4. The final statement should specify the estimated percent of operating time that plant load will exceed the percolation capacity of the sand filter beds. This excess would be bypassed directly to the river. If the bypass time is significant, consideration should be given to enlarging the capacity of the beds.

FEDERAL POWER COMMISSION
WASHINGTON, D.C. 20426

50-286

December 13, 1973

Mr. Daniel R. Muller
Assistant Director
for Environmental Projects
Directorate of Licensing
Office of Regulation
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Muller:

This is in response to your letter of October 17, 1973, requesting comment on the AEC's Draft Environmental Statement related to the proposed issuance of an operating license to the Consolidated Edison Company of New York, Inc. for the Indian Point Nuclear Generating Plant, Unit No. 3 (Docket No. 50-286), located in Westchester County in the State of New York. Two operating nuclear generating units are located on the site.

These comments by the Federal Power Commission's Bureau of Power staff are submitted in compliance with the National Environmental Policy Act of 1969, and the August 1, 1973, Guidelines of the Council on Environmental Quality, and are directed to the need for the capacity of the 965-megawatt Indian Point Unit No. 3, and related bulk power supply matters.

In preparation of these comments, the Bureau of Power staff has considered the AEC's Draft Environmental Statement, the Applicant's Environmental Report and Supplements thereto, related reports made in accordance with the Commission's Statement of Policy on Reliability and Adequacy of Electric Service (Docket No. R-362); and the staff's analysis of these documents, together with related information from other FPC reports. The staff generally bases its evaluation of the need

for a specific bulk power supply facility upon long-term considerations as well as upon the load supply situation for the peak load period immediately following the availability of the new facility. It should be noted that the useful life of Indian Point Unit No. 3 is expected to be 30 years or more. During that period the unit will make a significant contribution to the reliability and adequacy of the electric power supply in the Applicant's service area.

The Applicant is an electric utility, whose service area includes New York City and the major portion of Westchester County. The Applicant is a member of the Northeast Power Coordinating Council (NPCC), which coordinates the planning of members' bulk power generating and transmission facilities for the regional area which includes New England, New York, and the Canadian provinces of New Brunswick and Ontario. In addition, the Applicant is a member of the New York Power Pool (NYPP), the operating pool for the State of New York, which coordinates the planning and operation of the members' generating and transmission facilities. NYPP has established a regional reliability standard which requires each member system by 1975 to maintain an installed reserve capacity at least equal to that required to provide an 18 percent reserve margin during its most recent annual peak load period. NYPP utilizes centralized economic dispatch techniques to operate the members' bulk power facilities on a single control area basis.

The discussion and conclusions regarding the need for the capacity of the 965-megawatt Indian Point Unit 3, contained in the AEC's Draft Environmental Statement, are concurred in by the staff of the Bureau of Power. The capacity, load, and reserve data presented in the draft environmental statement agree with the latest information available to the staff, and demonstrate the need for the unit on the Applicant's, the NYPP, and the NPCC systems.

Since the publication of the draft environmental statement, fuel oil supplies from the Middle East have been curtailed. With the exception of 1,130 megawatts of baseload nuclear capability, the Applicant's baseload and peaking generating capability is dependent upon oil and natural gas fuels. About

3,350 megawatts of oil-fired baseload capacity could be converted to pulverized coal fuel, if an adequate coal supply could be established. However, in view of the impact that the current oil shortage is having on the electric utility industry, it seems prudent to make use of nuclear power sources to the extent possible.

The discussion of alternatives to the Indian Point Unit 3 and associated transmission lines is considered adequate.

The Bureau of Power staff concurs with the conclusion that new capacity such as that represented by the 965-megawatt Indian Point Unit 3 is needed to meet the projected load requirements and provide reliability of bulk power supply in the power supply areas involved.

Very truly yours,

F. A. Phillips
Chief, Bureau of Power

50-286

RONALD W. PEDERSEN
FIRST DEPUTY COMMISSIONER

STATE OF NEW YORK
DEPARTMENT OF
ENVIRONMENTAL CONSERVATION
ALBANY

December 17, 1973

Dear Sir:

The State of New York has completed its review of the "Draft Environmental Statement Related to Operation of Indian Point Nuclear Generating Plant Unit No. 3", (Docket No. 50-286). The statement was prepared by the Commission's Directorate of Licensing and issued in October 1973.

In preparing the attached comments, we have taken into consideration the views of all appropriate State agencies including the New York State Atomic Energy Council and the Office of Parks and Recreation. Many of the comments are quite detailed and directed to very specific points in the draft environmental statement with the intent of clarifying and improving the Commission's final environmental statement. While we have many comments on this statement, it is felt the draft environmental statement is an exceptionally well prepared document.

The Staff conclusion requiring a closed-cycle cooling system on Unit 3 is similar to the Staff position on Indian Point Unit No. 2, which was upheld in the decision of the Atomic Safety and Licensing Board. Since the combined environmental impact due to the operation of Units 1, 2, and 3 cannot be fully assessed at this time, and since the cost of a closed-cycle cooling system retrofit on the Indian Point Units is very expensive, it is felt that the Commission Staff conclusions are appropriate, but should be modified to provide that whenever Con Edison believes it has accumulated information which can demonstrate that the operation of Unit No. 3 in conjunction with Units 1 and 2 will not result in an unacceptable, long-term irreparable damage to aquatic biota, or contravene the water quality standards of the State of New York, the applicant should be allowed to seek appropriate modification to the operating license.

Particular attention should be devoted to our specific comments concerning seismology and geology. It appears that the most recently available information has not been utilized.

Thank you for providing the State with the opportunity to comment on this environmental statement.

Sincerely,

[signature]

Enclosure

United States Atomic Energy
Commission
Washington, D. C. 20545

Attention: Deputy Director for
Reactor Projects,
Directorate of Licensing

COMMENTS OF THE STATE OF NEW YORK ON THE U. S. ATOMIC ENERGY COMMISSION "DRAFT ENVIRONMENTAL STATEMENT RELATED TO THE OPERATION OF INDIAN POINT NUCLEAR GENERATING PLANT UNIT NO. 3: (DOCKET 50-286)

1. General Comment - In the proceedings for a construction permit for Nine Mile Point Unit No. 2, the Commission has recently ordered the Atomic Safety and Licensing Board (ASLB) to consider the conservation of energy.
   It is therefore appropriate to include a thorough discussion of the conservation of energy in the Final Environmental Statement for the Indian Point Unit No. 3.
2. General Comment - The Commission staff should consider alternate use of the rejected heat from plant operation. In this time of energy crises, the wasteful disposal of heat which could be used for heating homes and businesses, used in the production of food, etc., does not appear to meet those goals of NEPA presented in the FOREWARD.
3. General Comment - Appropriate meteorological and climatological data (Section II.E.4) have been compiled and presented for the environmental impact evaluation. These data have been compiled over several years since Indian Point Unit No. 1 was first planned. However, the continuous maintenance and compilation of data has not been as conscientious as it should have been and so, there are gaps in the data. It is to be noted that updating of the meteorological observation program is planned for subsequent detailed evaluation of cooling tower impact.
   The diffusion analysis techniques used are in accordance with conservative procedures established by the U. S. AEC.
4. General Comment - The evaluation of impact on climate (Sections V.B.1 & 2) is based on once-through cooling and hence is limited to the potential formation of fog on the warm water surface and shoreline.
   The evaluation of impact on air quality (non-radioactive) addresses the appropriate control agency standards of ambient concentrations and emissions. However, it is not clearly indicated that these standards are met when the superheater and all of the boilers are operating.

5. General Comment - The report mentions the effect on aquatic life due to the heated water. There should be more discussion of the effects on aquatic life when there is a shut down of a unit and the heated discharge is diminished or completely stopped.

6. General Comment - The preliminary evaluations of the alternative heat dissipation systems (Sections XI.C.1 - 5) are appropriate and it is indicated that further comprehensive evaluation of a preferred closed-cycle cooling system will be conducted based upon current research programs by the AEC and a revised environmental monitoring program to be conducted at Indian Point specifically directed toward this evaluation.

7. General Comment - Inadequate information is given in the Draft Environmental Statement to assess the noise impact that the operation of Unit 3 will have on the adjacent community. To determine the effect on the adjacent community it is necessary to compare predicted plant levels with existing ambient levels and criteria for determining human response to noise.

Existing Ambient Levels

An adequate sampling of existing ambient sound levels must be obtained for all areas of potential impact. Such a sampling should consider daily, weekly and seasonal variations. The ambient noise survey referenced in the Draft Environmental Statement reports statistical sound level data obtained on two winter weekdays at six locations.

Predicted Plant Levels

Since the proposed license may require eventual conversion to closed cycle cooling, predicted plant levels should be developed not only for Unit 3 with once-through cooling but for the proposed alternate cooling methods as well. Predictions should consider directionality of the source due to plant layout, and abnormal sound propagation due to terrain, prevailing winds in the river valley, and due to other atmospheric conditions since there is a "high probability of inversions occurring" (page V-5). The Draft Environmental Statement reports simply that "no significant additional noise levels will be created by operation of Unit No. 3 along with the other two units"

(page V-3); no sound levels are given for Unit 3 with once-through cooling. Sound levels are reported for two alternate cooling methods; 50dBA at 2500 feet for natural-draft wet cooling towers, and 50dBA at 5000 feet for mechanical-draft wet cooling towers. Inadequate attention is given to directionality of the source and abnormal sound propagation.

Transmission Line Noise

Since the operation of the Indian Point Stations will necessitate "upgrading of transmission facilities" (page IV-3), specifically, increasing some transmission line voltage from 138KV to 345KV, an analysis of noise and other environmental effects of the higher voltage line should be included in the Environmental Statement.

Human Response to Noise

Since the Statement recommends comparison with HUD criteria, the appropriate form for presenting information on human response to Indian Point Unit 3 noise is a series of contours delineating the areas which are unacceptable, normally unacceptable, normally acceptable, and acceptable. The study referenced by the Draft Environmental Statement gives only the total area within the normally unacceptable contour, and the number of residents presently living within that area.

8. Page i Summary and Conclusions -

What is meant by the following statement on Page i: "The proposed action will be interrelated to other actions taken by other Federal agencies such as the Environmental Protection Agency in regard to granting or denying application for discharge permits by the New York State for the other power plants on the Hudson River."

9. Page ii Summary and Conclusions -

Estimated dates for completion of the 80-acre forested park, completion of the new visitors center, transfer of 14 acres to Village of Buchanan, and development of the marina should be stated. Also, the present status of these lands should be discussed.

10. Page iii Summary and Conclusions 3.f. - Since the Federal licensing is complete for the proposed Cornwall Pumped Storage Plant, the environmental effects from operation of the Cornwall plant must be included with those of Danskammer, Roseton, Lovett, and Bowline and Indian Point to ascertain the synergistic effects that power plants have on the Hudson River in this area.

11. Page viii Summary and Conclusions, 5. - Since the action to be taken is administrative, consideration should be given to other administrative alternatives, such as, issuance of a provisional operating license instead of a full-term license.

12. Page I-8 - Future Environmental Approvals - It is stated that discussions are underway for obtaining a 401 certification pursuant to the Federal Water Pollution Control Act Amendments of 1972. A 401 certification was issued by the N.Y.S. Dept. of Environmental Conservation on September 24, 1973 for full power operation of Unit 2.

13. Page I-10 - The description of the composition and functions of the Hudson River Policy Committee is in error. Connecticut has not been a member of the Committee for several years. The Technical Committee is a subordinate committee created by and serving at the pleasure of the Policy Committee. The Policy Committee does not serve as a Study Steering Committee for the Indian Point work. The Committee does not outline ecological studies and present its conclusions and recommendations to Con. Edison. The Committee does review proposed work as presented to it by the Company and advises as to its "quality and importance to providing information on fisheries impact" (P. 3 of A.G. Hall's letter, Jan. 11, 1973).

14. Page II-3, Section II, The Site, - It is noted that the applicant plans to build a new visitor's center near Unit No. 1 and to maintain an 80 acre forested area and lake for recreation in the northern portion of the site. This statement should be expanded to note when the applicant proposes to initiate action to accomplish this intent, and when the facilities are projected to be available for public use.

15. Page II-5, Regional Demography and Land Use - The Stewart Air Force Base has been decommissioned and the bulk of the facility transferred to the Metropolitan Transit Authority and is now known as the Stewart Airport.

16. Page II-15, Section II. E.3 - Certain aspects of the discussion on geology and seismology are inadequate. The 1971 New York State Geology Map was not used in preparation of this draft environmental statement. This map is the most recent presentation of geologic formations of the area. It shows large significant faults near the Indian Point Site.

The details of the drilling logs by Paige and Fluhr are not shown. In the absence of such information it must be assumed that sound geotechnical data is not available. The Fluhr and Paige analyses appear in conflict with that in Section 2,7 of the applicants Final Facility Description and Section II.E.3 of this draft environmental statement regarding rock strength, grouting, and local changes in rock formation. The discussions presented in this statement are in apparent contradiction of the consultants recommendations.

In summary, the site geologic and seismologic investigations appear inadequate and the Commission staff presentation concerning these topics is equally deficient. In reviewing the applicants reports, the recently issued staff Safety Evaluation, and this draft environmental statement, we notice there has been a lack of, or neglect of, information.

It is recommended that the Commission staff reassess the geology and seismology:

1. Referring to an article in the bulletin of the Seismological Society of America, Volume 58, No. 2, pages 681-687 published in April 1968 and titled "Seismology In the Vacinity of the Ramopo Fault, New York-New Jersey."
2. Referring to an article in the Journal of Geographical Research, Volume 788, No. 5, February 1973, "Seismic Wave Attenuation and Magnitude Relations for Eastern North America."
3. Require rock stress analysis be performed at and near site (e.g. by means of overcoring in deep boreholes).
4. Require Re-examination and Detailed logging of all boreholes to determine the depth extent of jointing, and possibly mapping of the joint patterns to determine what stresses have been released.

5. Establishing a quadrilateral system of surveyed points across the river and across the Ramopo Fault to ascertain if there is any small movement.

17. Page II - 15, Section II, the Site - Under Geology and Geography it is noted that the three reactors are built on a hard, dark grey, metamorphosed diomitic limestone. It is recommended that this sentence be changed to read "the three reactor plants" or "all structures" are built on a hard, dark grey, metamorphosed diomitic limestone. The fourth sentence notes that the bedrock is more than capable of carrying any load that will be placed on it at the site. This statement should be expanded to note the approximate load which the bedrock will support and the actual load which is imposed.

18. Page II-16, Section II, The Site - The State has commented in the past on the Indian Point site regarding the inadequacy of the geologic and seismologic investigations conducted by the applicant. The State Geological Survey's position regarding the content of the Geology and Geography section (Pages II-15 and II-16) of the Draft Environmental Statement is that it is not adequate for evaluation purposes. For example, Paragraph 2 on Page II-16 is essentially a quote from comment 13 provided to the U. S. AEC by the New York State Department of Environmental Conservation on June 1, 1972 relating to the Draft Environmental Statement for Indian Point Unit No. 2. Although that statement of geology was quoted, the comments relating to additional seismic and geologic investigations were apparently ignored. These comments, which still apply to the site and to Indian Point Unit No. 3, are reiterated as follows:

a. For power plant siting an investigation should be made involving a seismic monitoring program with analyses of focal mechanisms to determine whether the motions observed correlate both geographically and geometrically with known faults. It can be anticipated that this kind of study will be required for future site investigations and that more detailed geologic mapping will be required.

b. The Environmental Statement should include detailed geologic investigations of the entire region to fill in the gaps in existing data. The geologic reports by T. W. Fluhr, P. E., and S. Paige by themselves are not considered to be

sufficient for basing decisions on power plant siting in the region around Indian Point.

In addition, no discussion of the seismology of the site and the area is included in the Draft Environmental Statement. In Dr. W. R. Stratton's letter of May 16, 1973 to the Chairman of the U. S. AEC he indicated a need for seismic hazard evaluation in the Eastern USA. Thus, seismic data should be included in the Final Environmental Statement for evaluation purposes.

19. Page II-20 - The section describing the ecology of the site and the environs should be expanded. Ecological parameters such as diversity indices, biomass, productivity and indices of stability should be discussed. Such ecological parameters would aid in assessing the effects of thermal and radiological discharges.

20. Page II-20, Section II, The Site - The discussion under terrestrial ecology should note that the applicant has stated that no rare or endangered species of plants or animals were found during their site survey or their literature search regarding the site area.

21. Page II-29 - The section on background radiological characteristics states there are no conspicuous natural sources. There are small areas to the north and northwest within a 5 mile radius of the site where the maximum external radiation level measured by New York State was 5 times normal background due to natural radioactivity. It may be well to identify these locations as they may be attributed to the operation of the plant at some later date. An ARMS survey similar to those done for other sites is recommended. The sources of radioactivity, such as cosmic radiation, that comprises the 125 millirems /yr measured dose rate should be identified.

22. Page II-30, Background Radiological Characteristics - It is stated that the New York State Department of Environmental Conservation has also carried out periodic checks since 1958 on samples taken from various locations surrounding the site. This statement should be revised to indicate that the monitoring program was conducted by the New York State Department of Health until mid-1970, and thereafter by the New York State Department of Environmental Conservation.

23. Page II-31 - Table II-4 lists selected representative sample data from the Radiological Environmental Monitoring Program taken in the area of Indian Point Unit No. 1. It would be well to identify the dates of these data as Indian Point Unit No. 1 operated during periods of high fallout and some of the activity reported may be attributed to other than plant operation.

24. Page III-1, Section III, The Plant - The second paragraph notes that cooling water is withdrawn from the Hudson River at a maximum rate of 840,000 GPM through pumps at full capacity and at 30,000 GPM for service water purposes. This Section should be expanded to note the number of cooling water and the number of service water pumps which are required and installed for this maximum flow. It should also be noted that the cooling water pumps are two speed.

25. Page III-1, Section III.B - External Appearance - The Draft Environmental Statement should discuss the external appearance of the transmission facilities associated with the plant and their visual intrusion on the neighboring communities.

26. Page III-5, Figure III-2 - The service water pump should be labled, since it is discussed in various paragraphs of Section III.

27. Page III-6, Section III, Intake System - It is stated that there is only one service water pump for Unit No. 3. This section should discuss how service water is provided to wash the traveling screens if the service water pump is out of commission.

28. Page III-9, Section III.E.2 - Intake System - It should be stated whether the traveling screens will be continually rotated or only periodically rotated. The velocity of the water used to clean the traveling screens should be stated. Also, the draft environmental statement should discuss the effects of severe weather conditions on the operation of the intake system. For example, can the traveling screens be operated during severe winter conditions or will they ice up? Also, when the traveling screens remain idle in severe cold weather, can they be immediately operated or is there a delay time due to ice buildup on the screens and drive mechanisms?

29. Page III-13, Section III, Discharge Structure - It is stated that ten of the twelve installed exit gates will be manually adjusted to provide a discharge water velocity of at least 10 FPS under any combination of units in operation and for different river

conditions. A discussion should be included which describes how it is known that adjustment of the gates results in an exit velocity of at least 10 FPS.

30. Page IV-4, Section IV, Impacts on Water Use - This section notes that air bubblers to reduce fish impingement were required by New York State to be installed at the intakes in front of the fixed screens for Units No. 1 and 2, but that none are presently at the Unit No. 3 intakes. It is felt that this section should be expanded to note the general effectiveness of the air bubblers and whether or not it is anticipated that they will be installed at the Unit No. 3 intakes.

31. Page V-1, Section V.A.1. - Aesthetics - The Commission's condition of operation of an alternate closed-cycle cooling system required of the applicant will impose a further visual impact on the environs which should be considered.

32. Page V-3, Section VI.A. 3 - Noise - One of the most predominant sources of noise at the site is the outdoor loud speaker system. Noise levels associated with this system should be determined and once construction is complete, consideration should be given to eliminating or minimizing use of this outdoor system.

33. Page V-3, Section V.A. 5 or Section V.B. 2 - Transmission Facilities - The Environmental Protection Agency, on page 18 of its comments concerning the Draft Environmental Statement relating to Indian Point Unit 2, suggested a discussion of the production of ozone by the high-voltage transmission lines. It is understood that research is being performed under contracts from the electrical power industries and EPA to answer the ozone production question. A discussion should be presented in this statement concerning ozone production and the results of these studies to date. Also, the statement should contain a discussion of, or references to, problems of induced electricity to structures in the vicinity of EHV transmission lines.

34. Page V-6, Section V.B. 2 - Paragraph 4, indicates the expected contribution to the environmental concentrations from "the boilers of all three units". This seems to indicate that the superheater is not included in this evaluation. If this is so, then the evaluation is deficient. If the superheater is included, then the statement should indicate this.

35. Page V-6, Section V.B. 2, paragraph 6 - Quantitative evaluation compliance with the emission standards is presented only for the superheater. The evaluation for "total amounts of all non-radioactive emissions" should be presented quantitatively.

36. Page V-21, Table V-3 - Footnote (c) should indicate that the New York State Department of Environmental Conservation is the agency requiring collection of all chromium discharges.

37. Page V-28, Section V.C. 4 - Although the velocity of water entering the intake structure may have a minimal effect on boating activities, the impact of the facilities on the Hudson River fishery may have indirectly a greater effect on boating activities on the Hudson River.

38. Page V-33, Section V.D. 2.a. - If, with a similar intake design Units 1 and 2 necessitated the use of fixed fine screens at the intakes, it appears that at least fixed fine mesh screens should have initially been designed for the Unit 3 intake.

39. Page V-36, Section V.D.2.a - The statement is made,"In summary, although the impingement problem has existed at Indian Point Unit No. 1 since operation began in 1962, some 10 years ago, the applicant still has neither determined the causative factors nor elucidated any methodology that will establish the cause-and-effect relationships controlling the impingement at Indian Point." It is felt that a methodology that will establish the cause-and-effect relationships controlling the impingement at Indian Point should be ascertained by the Commission staff and the studies incorporated in the Environmental Technical Specifications for these plants.

40. Page V-52, 4th paragraph - This statement may attribute a greater influence to temperature as a factor in selecting spawning site than is justified when considering other factors such as salinity.

41. Page V-55, Section V.D.2.c (3) - The report mentions the possibility of low dissolved oxygen (D.O) in the effluent plume. However, there is no discussion on the effect to the D. O. content in downstream waters. There have already been recorded in the summer months some values of D. O. at Verplanck less than the 4.5 ppm figure noted in the report. The Department of Environmental Conservation maintains an automatic

sampling station at Verplanck and a complete record of the data may be obtained. The report mentions that aerators could be used in the discharged cooling water to alleviate low D. O. The ability of water to hold oxygen diminishes as the temperature rises. It is also noted that the ability of water to hold oxygen also diminishes as the concentration of chlorides increases. During the low flow summer months the chloride concentration in the Hudson River at Indian Point would be at its peak. Therefore, because of the high temperature and high chloride concentration expected, the placing of an aerator in the heated water could have very little effect on D. O. content simply because the effluent water will not have the ability to hold any additional oxygen.

42. Page V-65, Section V, Chemical Discharges - The last paragraph states that chromium discharges will be collected and treated prior to any release in the river. This statement should be expanded to note the concentration of chromium expected to be discharged and the effect of the release on the aquatic biota of the river.

43. Page V-100, Section V, Liquid Wastes - This paragraph notes that if the radioactivity exceeds a predetermined value, the discharge will be automatically stopped by a valve on the discharge line and the liquid effluent will be recycled for further treatment. It is felt that this statement should be expanded to note this predetermined value and, in addition, note that there is an audible alarm (Environmental Report) associated with the radioactivity approaching this predetermined value.

44. Page V-103, Section V. D.2.e - It is not clear why the Commission staff allow programs in the Environmental Technical Specifications which are considered misleading, at best. For example on P.V-102 it is stated that "The Environmental Technical Specifications will detail the specific sub-programs"; while on P.V-103 it is stated about aquatic research programs which are part of the Unit #2 Environmental Technical Specifications:

> "In effect, the applicant has formulated his hypothesis in a way that allows the applicant to derive benefit from poor experimental design or careless execution of the required sampling."

Page V-104, 2nd paragraph - We agree with AEC staff on the need to continue the

the research program to show compliance with the Technical Specifications and to monitor biological effects.

45. Page V-III, Figure V-17 - It is not clear from the Figure whether the liquid radioactive waste from the waste condensate tanks and from the blowdown treatment equipment flows into a common header or each flows directly into the discharge canal. In addition, the automatic stop valves discussed on Page V-100 should be shown in each discharge line.

46. Page V-113, Section V, Steam Generator Blowdown - The last paragraph states that the turbine building drains will be discharged to the discharge canal without treatment. This statement should be expanded to note that these drains are not radioactive, and to describe how non-radioactive pollutants such as lube oil are prevented from being discharged to the river via the turbine building drains.

47. Page V-142, Transport of Solid Radioactive Wastes - The applicant estimates that from 5 to 10 truckloads of waste will be shipped from Unit No. 3 annually. Using these values as a basis, the U. S. AEC estimates that an average of 23 truckloads will be shipped from Units Nos. 1, 2, and 3 each year. It is further noted, however, that using present experience of operating reactors, the U. S. AEC estimates that about 50 truckloads of waste will be shipped from Units Nos. 1, 2, and 3 each year. It is not clear why the lesser figure (23 truckloads) alone is used in Section 2.C (pages V-145 and V-146) and in Table V-17 "Summary of annual exposure..." (page V-147) to estimate annual exposure of humans during the transport of radioactive waste.

48. Page V-142, Section V.F.b - It is stated under "Transport of Irradiated Fuel" that the applicant estimates "at most three fuel elements per cask" will be shipped. The present shipping cask designs will only accept one pressurized water reactor spent fuel element in a cask designed for shipping by truck. Therefore, the number of truck shipments would be 170 per year rather the 57 predicted by the staff.

49. Page V-143, Principles of Safety in Transport - This section states "The procedure the carrier must follow in case of accidents include segregation of damaged and leaking packages and the notification of the shipper and the DOT." It is not clear

whether "segregation" is meant to imply physical handling of the damaged and leaking packages, or simply having personnel avoid contact with the damaged and leaking packages.

50. Page V-145, Irradiated Fuel - It is noted that, for combination truck-rail shipments, the U. S. AEC staff estimates that during transfer of the cask from the truck to the rail car, four men might work for an hour at an average distance of 6 ft., and might receive individual doses of approximately 10 mrem/hr. Using 26 such shipments from all three units, the AEC has estimated a total dose of 0.840 man-rem for the freight handlers. It appears that this total dose figure should be 1.040 man-rem.

51. Page VI-9, Severity of Postulated Transportation Accidents - It is noted that an extensive program has been carried out over the past several years by which emergency personnel have been advised of procedures to follow in accidents involving radioactive materials and other hazardous materials. New York State concurs in the need for training of these emergency personnel. It is considered that the significant details of this training program should be expanded upon in the Draft Environmental Statement, and that the plans for carrying out this training on a continuing basis should also be discussed.

52. Page VII-1, VII-5, etc., Section VIII - One of the adverse environmental effects which cannot be avoided is noted to be the discharge of toxic amounts of residual chlorine or chloramines to the Hudson River incident to prevention of fouling of the circulating water system, and significantly the condenser tubes. It is recommended that this section be expanded to include a discussion of why high pressure water flushing and/or mechanical cleaning cannot be employed to prevent the cooling system from becoming fouled.

53. Page VII-2, 2nd paragraph - If the facility alone will have an adverse visual aspect; the addition of two cooling towers will greatly compound this impact.

54. Page VIII - 3, 12 Line - We are not aware of any evidence to date by which to evaluate the significance of a reduction in other fish populations, such as white perch.

55. Page VIII 3, Last Line - We agree that two years of post-operational experience with once-through cooling will not be adequate to assess the long-term impacts of this method.

56. Page X-16, Section X.H, Assessment of Predicted Demand - This Section should contain a discussion of the effects of the present energy crisis on the Con Edison service territory. The results of an effective national energy conservation program and possible shifts from gasoline powered vehicles to electric powered modes of transportation should also be included.

57. Page X-18, Section X.I, Applicant's Ten-Year Plan - This Section should reference the "1973 Report of Member Electric Corporations of New York Power Pool and the Empire State Electric Energy Research Corporation pursuant to Article VIII, Section 149-B of the Public Service Law, August 1973." This report, although needing improvement, is the most recent and comprehensive discussion of the State electric corporations' long-range plans.

58. Page XI-1, Section XI.A.1., Purchased Power - The power from the James A. FitzPatrick Nuclear Power Plant will not be available for purchase until at least its initial operation which will be mid-1974 at the earliest.

59. Page XI-17, Section XI.C.3c. - The staff should include a fourth alternative heat rejection combination of the Indian Point Units which would consider operating all three units with a natural draft-cooling tower.

60. Page XI-18, Section XI.C.3.c.(1)(a) - An obvious location for disposal of the overburden and spoil would be the quarry on the Verplanck Site.

61. Page XI-18, Section CI.C.3.c.(1)(b) - The once through cooling system as noted in the Draft Environmental Statement may seriously impinge upon the natural production of recreationally important fish. This could have a serious impact on the estimated 26,000 people fishing in the Lower Hudson Valley on the average summer Sunday. Cooling towers however, may have direct impacts on Bear Mountain State Park. The towers would intrude visually into more than 1000 acres of the park.

An additional negative condition is the possible defoliation of Bear Mountain and Hudson Highlands State Park by the saline spray from wet cooling towers. The report by the Directorate of Licensing of the United States Atomic Energy Commission fails to account for the effect of the prevailing southerly winds on the distribution of the spray from the cooling towers.

The Hudson Valley is unique in that a tongue of forest types indigenous to the South intrude northward. These forest types are particularly susceptible to salt damage.

Further studies should be undertaken to determine the impact of wet cooling towers in this regard.

62. Page XI-23, Section XI, Mechanical Draft Towers - The second paragraph notes that in the staff's opinion the deposition of approximately 2.025 LBS/acre per year of drift salts from mechanical-draft cooling towers at Indian Point will have a negligible impact upon ground water supplies. The basis for the staff's opinion should be provided, particularly since the second paragraph on Page XI-29 notes that the wells in the area are relatively shallow.

63. Page XI-44 - We agree with staff assessment of the proposal to mitigate damages through stocking.

64. Page XI-51, Section XI, Alternative Fish Protection Measures - In the second paragraph, 0.5 ppm should be corrected to read 0.5 FPS - (editorial).

65. Page XI-53, Section XI.H.1. - Justification should be given for the "conservatively estimated" 15% annual forced outage rate in view of Con Edison's past forced outage rates for Indian Point Units land2.

66. Page B-12, 3rd paragraph - This is not the most comprehensive data available on spawning actibity; extensive collections were made in 1973.

67. Appendix C - Radiation Effects on Aquatic Biota should be expanded to take into account the low dilution expected with the operation of cooling towers.

DETAILED COMMENTS BY THE ATTORNEY GENERAL ON THE

DRAFT ENVIRONMENTAL STATEMENT BY THE DIRECTORATE OF LICENSING UNITED STATES ATOMIC ENERGY COMMISSION RELATED TO OPERATION OF INDIAN POINT NUCLEAR GENERATING PLANT UNIT NO. 3 FOR

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

Docket No. 50-286

December 17, 1973

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I. General Comments

A. Introduction

In the past few years, Congress has enacted the National Environmental Policy Act of 1969, 42 USC § 4321, the Clean Air Act Amendments of 1970, 42 USC 1857-18571, the Federal Water Pollution Control Act Amendments of 1972, 33 USC 1251-1376, and several other important pieces of legislation designed to preserve and protect the quality of our natural environment. This recent awakening was for the most part due to a realization that our natural resources were being despoiled and exhausted, and that the public interest required an end to such destruction. The Atomic Energy Commission, in its environmental statements and ultimately in its licensing decisions, must conform to the mandate of these laws.

In general, the State of New York agrees with the recommendations and conclusions of the Staff as contained in its Draft Environmental Statement. The Staff recognized that operation of Indian Point 3 with once-through-cooling would cause unacceptable levels of mortality of aquatic organisms through impingement, entrainment, and thermal pollution (summarized in DES V-105-108). Almost identical calculations of the effects of Indian Point 2 prompted the Atomic Safety & Licensing Board to order Consolidated Edison to install a cooling tower for that facility. Thus, except for the specific comments contained herein, the State of New York supports the recommendations and conclusions of the Staff's Statement.

B. The Limitations of Modeling

The Staff and the Applicant have attempted to determine the behavior and abundance of organisms in the Hudson River and to predict the adverse effects that the plants' intrusion will have on the Hudson River ecosystem.

The problem with the Staff's modeling approach is that it is limited to predicting only the direct effects of nuclear power plant operation on aquatic biota in the Hudson ecosystem. As for the indirect adverse effects, the models offer little information. The long-term effects of temperature changes, possible shifts in the demographic patterns of the estuary, the effects on one organism resulting from the decimation of other organisms, are examples of

unquantifiable indirect effects. Very little data exists on the indirect effects, and because of the necessity for measuring the nature of these effects over the long-term, it would be impossible to calculate them in the time available. Moreover, if long-term studies were undertaken, there would still be unpredictable effects due to the limitations of our present knowledge.

Because of the impossibility of measuring all of the possible indirect adverse effects that this huge project may have upon the Hudson ecosystem, the Attorney General urges the Staff to recognize the limits of its ability to predict the totality of environmental damage through modeling and to point out in its FES that any model predictions of adverse environmental inpact from Indian Point 3 must of necessity be underestimations.

II. Comments on AEC Staff Analysis of Multi-Plant Impact

A. Introduction

The Attorney General supports the inclusion of the multi-plant analysis in the Indian Point 3 DES. However, we believe that the analysis was imcomplete in that it ignored many existing facilities which affect the Hudson River ecosystem. More important still was the Staff's exclusion of the effects of future facilities on the Hudson which will be operating during the life-span of Indian Point 3.

The applicant opposed consideration of the multi-plant analysis for Indian Point 3 as late as March of 1973, although its consultant Dr. Lawler thought it important to consider the effects of the Lovett and Danskammer plants in his October 30, 1972 testimony (Page 3) "Effect of Entrainment and Impingement, etc." concerning Indian Point 2. This mode of analysis was later expanded by the Indian Point 2 Licensing Board (TR 10010-10023) to include the Bowline and Roseton power plants, both of which were in the process of construction at that time. Multi-plant analysis is necessary, as Dr. Lawler states, "to develop an analytical means to evaluate the potential for direct loss from both entrainment and impingement of eggs, larvae, and juveniles, and also the potential impact of that loss on the adult population of striped bass in the river." (ibid. 2)

In the Indian Point 2 proceedings a mathematical model was developed to predict "...quantitatively the number or percentage of organisms in any stage that may be removed from the river system each

-4-

year, and secondly and more importantly, the ultimate, long-term impact of this removal on the river fishery population" (ibid., 76). On the basis of these simulations of reality, decisions could then be made about the one modifiable parameter, power plant operations.

The Staff's report fails to account for the effects upon the estuary of Con Edison's Cornwall Pumped Storage Project (Storm King) recently licensed by the FPC and under construction some 13 miles upstream from Indian Point 3. The Storm King project is a prime example of how the Staff's multi-plant analysis should be augmented to include other industrial and municipal facilities that will be operational during the useful life of Indian Point 3. Moreover, enough data already exists on the estuarine effects of Storm King to allow the Attorney General to provide an example of how the multi-plant analysis can be expanded. The following discussion points up the severity of Storm King's impact on those same species that will be adversely affected by operations at Indian Point 3. The impact from Indian Point 3's once-through-cooling system will obviously be rendered even more severe if the Hudson River fisheries are being decimated by other sources.

-5-

B. Description of the Storm King Plant

The applicant's pumped-storage generating plant at Storm King will withdraw from and return to the Hudson approximately 3.4 billion cubic feet of water per week, or four times more water than Indian Point's three power plants combined. At least 24 billion BTU/day will be discharged into the water while it is passing through the Storm King plant. Pressure within the system may vary between 30 and 560 psi, most of the change occurring at the turbine. Passage of organisms through the system will result in substantial mortality since no safeguards against impingement or entrainment have yet been specified for the Storm King facility.

C. Impingement at Storm King

Although no intake screening at Storm King has as yet been specified, it can be assumed that numbers of juvenile fish of various species will be impinged on whatever devices are utilized. If no screens are used, mortality will occur in the transportation of fish up to the reservoir and back down to the river.

One task for the Staff is to describe and quantify the mortality that Storm King will cause to juvenile fish. The Staff can use impingement data from the

Danskammer and Indian Point plants as guides for Storm King. Account must be taken of Storm King's intake portals which are adjacent to shoal areas in Newburgh Bay, areas which the applicant claims are attractive to juveniles. The resultant impingement figures for Storm King should be compared to standing crop estimates for species in that section of the river and factored into the multi-plant model of effects on striped bass and white perch. This will result in a reasonable prediction of fish available for impingement at Indian Point 3.

D. Entrainment at Storm King

Withdrawal of river water at Storm King will carry vast numbers of fish eggs and larvae, and other forms of aquatic biota, through the system. The turbulence and pressure changes should result in substantial mortalities for each age group of aquatic species. The Staff should attempt to quantify the level of mortality in the light of its discussion in the DES (V-42-66) succinctly stated at V-53: "It is quite possible that pressure changes may be a more important factor than temperature."

Of special interest here is the Carlson-McCann Report (HRFI) prepared in 1969 in reference to striped bass eggs, larvae, and young of the year. This report indicates that on a seasonal basis 12.2% (page 43) of the striped bass larvae and 4% (page 41) of the striped bass eggs in the Cornwall segment of the Hudson will be withdrawn daily. On the basis of this report the operation of the project in only two weeks will withdraw over 80% of the larvae and 40% of the eggs present in the segment. Similar effects can be predicted for other species.

The Staff should consider these data in the Hudson River striped bass model presented for Indian Point 3. If a significant mortality occurs upstream from Indian Point 3, the additional effects of Indian Point 3 must be considered even more unacceptable than indicated in the DES.

E. Thermal Effects at Storm King

The operation of the Storm King project will consume 3 kws of electricity for pumping while producing only 2 kws during generation. Most of this energy difference is released as heat to the

water, about 24 billion BTU/day, raising the temperature of the discharge 1.11° F. The Staff should include these data in the multi-plant thermal model to arrive at a more reasonable far-field thermal prediction.

Storm King should be given the same consideration as other power plants along the Hudson whose impact has already been assessed by the Staff in the DES. It would be irresponsible as well as totally irrational for the Staff to blind itself to the effects of one plant on the Hudson ecosystem while considering the effects of all other plants on that same ecosystem.

COMMENTS ON AEC STAFF ANALYSIS
OF THERMAL EFFECTS

A. Introduction

The flow regime and mixing characteristics of the Hudson River at Indian Point are extremely complex. For example, during the twice-daily tidal floods, heated water from the plant discharge will tend to flow upstream with the tide. Since the tidal flow is more dense than the fresh-water flow, the upstream flow occurs predominately in the lower layer of the river. Discharges from the plant are principally in the upper-layer and travel predominately downstream. Overall, a temperature rise occurs upstream of the discharge canal, as well as downstream, as shown in the attached Q.L.M. model (Fig. 1). Similar patterns of temperature rises and downstream temperature decay gradients must exist for all point sources of thermal discharge in tidal mixing zones.

B. Federal and State Criteria

The Staff states (DES V-8, A-3) that the applicant must meet New York State Water Quality Criteria. The applicable State Regulation, 6 NYCRR 704.1(b)(4), defines those criteria in terms of 3 standards:

FIGURE 12

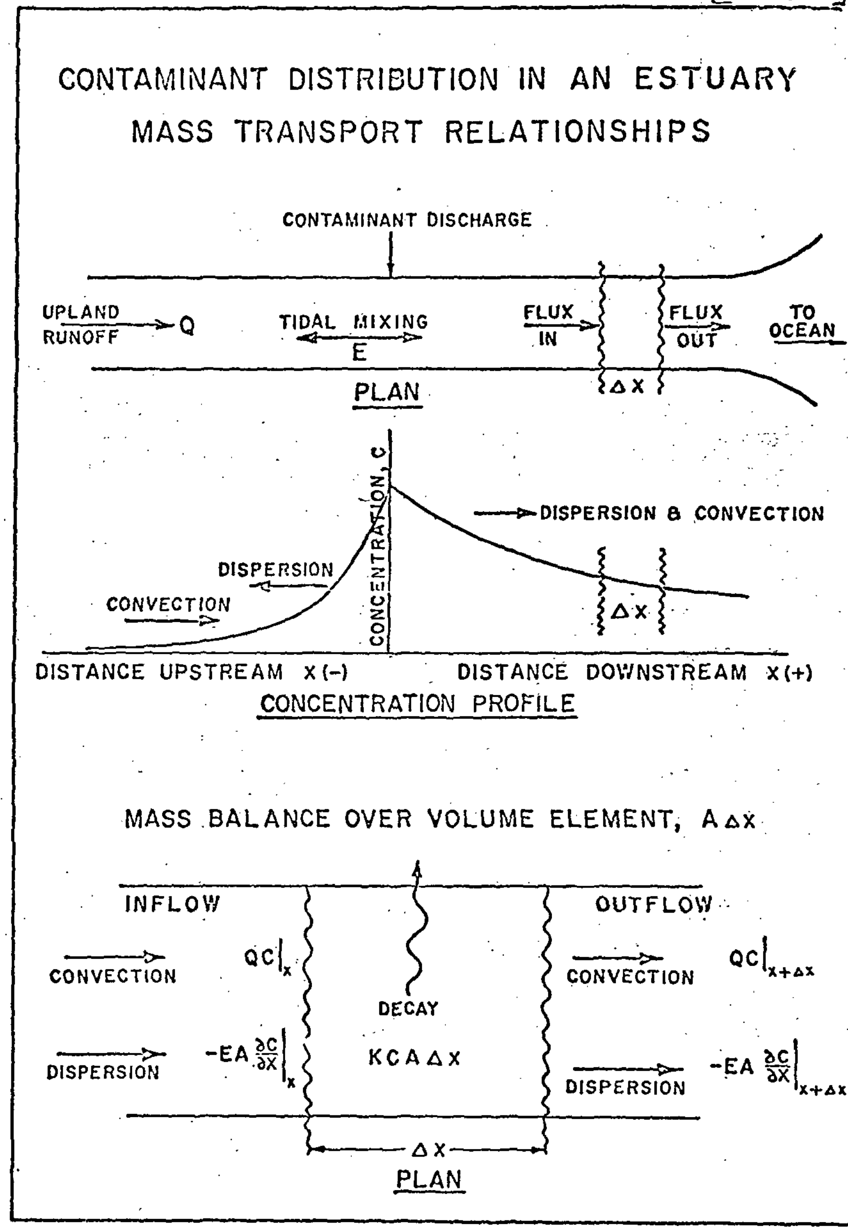

Figure 1

1. Surface temperature no hotter than 90°F.
2. 50% of the cross-section including 1/3 of the surface no hotter than 4°F above the ambient (natural) temperature of the estuary, or a maximum of 83°F, whichever is less.
3. During July through September, if the ambient surface temperature is more than 83°F, at no point in the passageway described above shall the temperature be above 84.5°F.

The Staff's thermal analysis indicates that under many conservative input conditions, the operation of once-through cooling will contravene all three parts of the State's Water Quality Thermal Criteria (DES, A-14, 26). Moreover, even with a cooling tower at Indian Point 2 (Alternative A) the resultant once-through operation of Indian Point Units 1 and 3 will contravene Part 2 and 3 of the State criteria.

The Staff's predictions of thermal effects need more adequate parametric tables. The intermediate field thermal model was not discussed in terms of the results of the far-field model. Similarly, no connection was made between the results of the near-field model and the results of the other two models. Connecting these would form another set of parametric tables far more meaningful than those presented.

For example, it would be useful to know what effects on the near and intermediate-field models would result from an 86°F. intake temperature as indicated by the far-field model. The intermediate-field model would then show that Parts 1 and 2 of the State criteria would be violated (over 50% of the cross-section will be raised 4°F. or more to at least 90°). Looking to the near-field model, it would predict approximately a 6°F. rise in the surface discharge plume or about 92°F. violating Part 1 of the criteria.

Finally, as discussed below in section D, this massive heating of the estuary will be exacerbated by ambient ocean temperatures which were under-estimated by the Staff by at least 3°F.

C. The Staff's Model

The Staff, in assessing the probability of compliance of Indian Point 3 with State criteria, used a far-field model which includes most sources of heat of artificial origin contributing to the river. The sources in the staff's model included:

Danskammer Plant
Roseton Plant
Indian Point Plants 1, 2 and 3
Lovett Plant
Bowline Plant

While this model did take into account the complex mixing characteristics of a tidal estuary, it neglected to take into account the many industrial and municipal discharges that now exist or can be foreseen to exist over the useful life of Indian Point 3. Similarly, the thermal effects of anticipated power plants on the Hudson River were also left out. The projected Storm King pumped storage plant, for example, would add 24 billion BTU/day to the Hudson, 1/7 the heat of Indian Point 3 (See page 11). Some information on existing major discharges can be found in the Q.L.M., "Hudson River Water Quality and Waste Assimilation Capacity Study", (December, 1970). These additional thermal imputs should be included in an updated FES model.

D. The Staff's Far-Field Model

As in the striped bass recruitment model which appeared in the FES for Indian Point 2, the Staff's far-field thermal model suffers from incomplete presentation of supporting data upon which its conclusions are based. Without this material, it is impossible to recompute the predictions of the DES on pages A-21-25.

Secondly, there were no "ambient" temperature curves included in figures A-4 through A-7 which would connect the assumed ambient temperature of 80°F. with the ocean temperature in the Battery. Such curves were presented in the Indian Point 2 proceedings in a "Preliminary Study . . ." by M. Siman-Tov, February 8, 1973, figs. 3-6. Without information on what the water temperature would be in the lower Hudson before the addition of heat of artificial origin it is impossible to predict the extent of non-compliance by the applicant with State Thermal criteria, since the criteria is based on an "artificially unheated" standard.

Thirdly, the Staff mistakenly assumed the average water temperature of the ocean at the Battery to be 70°F. The National Ocean Survey has tabulated the surface temperature of the Battery since 1927. The most recent long-term means between 1927 and 1971 at that station are 71.4°F. for July and 73.2°F. for August. These figures are only means. Higher average temperatures exist for individual weeks and for individual months during hot, dry years. Additional information compiled by the New York City Department of Water Resources, the Annual Harbor Survey, indicates even higher average temperatures during 1973. The model should be amended to include such data on a time-dependent basis. A parametric study should then use the amended model with reference to various cool-wet years and hot-dry years.

E. The "Ambient" Temperature Profile

Only after the predicted temperature profiles for the lower Hudson River are calculated can the natural temperature of the river be calculated. This task is impossible at the present with the absence of an "ambient" temperature profile in the DES.

Without an accurate far-field model prediction of the intake water temperature, verification of the plant's compliance with State thermal criteria is impossible. There is no place on the Hudson where a true "ambient," relative to Indian Point, can be physically measured. All temperature measurements above and below Indian Point will be "polluted" with heat from other sources in the process of decay. (See Figure 1).

Incidentally, physical on-site monitoring of thermal pollution is impossible. One classical means of measuring heat discharge employs infra-red aerial monitoring. However, this will only compare the discharge plume to the already elevated intake temperature. Actual temperature readings of the Hudson would both be impractical and inaccurate. Simultaneous readings of the river temperature from its source to its mouth, on lateral and verticle cross-sections, is totally unfeasible.

Moreover, even if such were possible, present thermal discharges would make the data worthless as an "ambient" temperature guide.

F. Thermal Effects on Biota

The biological effect of waste heat discharge on the various organisms of the Hudson estuary was considered by the Staff at XI-38 and V-49 - V-53. The presentation inadequately considered the preferential and lethal temperature of various species of aquatic biota. The staff should refer to studies such as the Gift-Westman Study, "Responses of Some Estuarine Fishes to Increasing Thermal Gradients" June, 1971, and recent data by Dr. R.E. Loveland on the thermal responses of benthic organisms in Barnegat Bay. The DES also failed to consider the effects of thermal pollution in its cost-benefit analysis. Some attempt was made to consider the magnitude of the thermal problem at V-52. This method should be expanded to quantify some negative value for this additional source of adverse environmental impact.

Despite the shortcomings outlined above, we want to thank the Staff for the outstanding work that they have done in preparing this draft statement. The Attorney General is of the same opinion as the Staff that a closed-cycle cooling system must be installed at Indian Point 3 as soon as possible in order to protect the Hudson River biota from serious adverse harm.

BEFORE THE UNITED STATES

ATOMIC ENERGY COMMISSION

In the Matter of	)	
	)	
Consolidated Edison Company of New York, Inc.	)	Docket No. 50-286
[Indian Point Station, Unit No. 3]	)	

CERTIFICATE OF SERVICE

I hereby certify that I have served document entitled "Detailed Comments by the Attorney General" by mailing copies thereof first class and postage prepaid to each of the following persons this 17th day of December, 1973:

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December 14, 1973

RECEIVED DEC 20 1973

U. S. Atomic Energy Commission
Washington, D. C. 20545

Attention: Deputy Director for Reactor Projects, Directorate of Licensing

Gentlemen:

On behalf of the Hudson River Fishermen's Association and the Save-Our-Stripers I enclose a memorandum of comments on the Draft Environmental Statement prepared by the regulatory staff of the Atomic Energy Commission with respect to Indian Point Unit No. 3, Docket No. 50-286, application of Consolidated Edison Co.

These comments have been in preparation for some time but because of technical difficulties in our offices here we have only been able to mail them out today. We respectfully ask that you give them appropriate consideration.

Very truly yours,

Nicholas A. Robinson
Attorney for the HRFA
and SOS

NAR:sl
Encl.

BEFORE THE UNITED STATES
ATOMIC ENERGY COMMISSION

---------------------------------------x

IN THE MATTER OF

CONSOLIDATED EDISON COMPANY
OF NEW YORK, INC.
(Indian Point Station, Unit No. 3)

Docket No. 50-286

---------------------------------------x

COMMENTS ON DRAFT ENVIRONMENTAL STATEMENT BY HUDSON RIVER FISHERMEN'S ASSOCIATION AND SAVE OUR STRIPERS

Preliminary Statement

This memorandum of comments is submitted to the U.S. Atomic Energy Commission, Directorate of Licensing, pursuant to notice published on October 23, 1973, 38 (No. 203) FEDERAL REGISTER 29243, so that the issues treated herein may be fully considered in the preparation of the Final Environmental Statement to be issued by the A.E.C. under the National Environmental Policy Act of 1969 ("NEPA"), 42 USC 4321 and the A.E.C.'s regulations in Appendix D, 10 C.F.R. Part 50.

These comments concern the "Draft Environmental Statement by the Directorate of Licensing, United States Atomic Energy Commission, in relation to operation of Indian Point Nuclear Generating Plant Unit No. 3"["DES"] dated October 1973 and released October 16, 1973 for the

A.E.C. by George W. Knighton, Chief, Environmental Projects Branch #1, A.E.C. Directorate of Licensing.

The Hudson River Fishermen's Association ("HRFA") and Save Our Stripers ("SOS") are parties in the above captioned matter brought on by the Consolidated Edison Company of New York, Inc. ("Con Edison" or "Con Ed") involving Indian Point Nuclear Generating Plant, Unit No. 3 ("I.P.3"). HRFA and SOS petitioned for and were given leave to intervene by Order of the Atomic Safety and Licensing Board.

HRFA and SOS are interested in preserving the aquatic resources of the Hudson River, especially the striped bass and other fish. These interests prompt both groups to press the following concerns in connection with the DES:

A. Every possible and practical measure must be taken to protect the Hudson's aquatic resources as conditions precedent to Con Edison operating I.P.3.

1. Unless new techniques are found to reduce impingement of young-of-the-year fish at the intake screens, Con Ed must reduce operations to avoid fish kills.

2. To avoid massive destruction of phyto-plankton, zooplankton and eggs and larvae of many fishes from entrainment in Con Ed's proposed once through cooling systems, assuming use of natural draft cooling towers a closed cycle cooling system must be installed for I.P.3 by May 1, 1977 or as soon as possible, and an operating permit should be delayed until such towers are operational.

3. Alternatively, to minimize irreversible adverse impact between such time as an operating permit is granted and cooling towers are operational, Con Edison should be required to restrict I.P.3 operations during the critical spring spawning period. Such restrictions could include compensating for reduced operation by I.P.3 by (1) electricity use conservation and (2) securing alternative sources of electrical power.

B. These measures are required because of the substantial injury which once-through cooling will cause to the Hudson's acquatic resources.

1. The impingement and entrainment figures given to date are minimal and support the requirements for both cooling towers and restricted operations.

2. The commercial and recreational sport fishing economies of the Hudson River, the Atlantic coastal region and Long Island must be protected against the irreversible losses which unconditional operation of I.P.3 would cause.

3. The Hudson River is a priceless natural resource, a productive breeding area for resident fish species and migratory oceanic species such as striped bass, shad and herring. The unique value of this resource must be fully protected for present and future generations in our country.

4. Complete assessment of the environmental impact of I.P.3 requires examination of Con Ed's Cornwall (Storm King Mountain) proposed pump storage generating plant as well as all other major water uses near I.P.3.

5. The cumulative impact of I.P.3 over Indian Point Unit No. 2 ("I.P.2") justifies natural draft cooling towers for I.P.3 on the same facts as I.P.2.

While the DES gives these issues careful and perceptive attention, nonetheless the DES fails to examine adequately all aspects. Before the final environmental statement is released, more comprehensive analysis must be set forth concerning (i) impingement and means to minimize adverse impact, (ii) need for cooling towers, including Cornwall (Storm King Mountain) influence, (iii) construction time for cooling towers, (iv) reduced operation before cooling towers are operational, and (v) cost/benefit justification for cooling towers, reduced operation and other measures to conserve and preserve the Hudson's aquatic resources.

HRFA and SOS will comment on the DES with respect to each of these five issues here.

At the outset HRFA and SOS stress that the DES is largely a very competent and thorough document. It is far superior to the draft environmental statement issued for I.P.2, and it has taken into account the extensive expert evaluation which the I.P.2 licening proceedings produced. The A.E.C. Regulatory Staff is to be commended for its work and its recommendation requiring a closed cycle cooling system for I.P.3.

I. Impingement Damage Must Be Curbed

The DES properly establishes impingement as a major potential problem involving substantial fish kills for I.P.3 based on the experience with Indian Point Unit 1 ("I.P.1"), (pp. V-29-37). The DES acknowledges that "the precise cause of the impingement problem is not completely understood." (p.V-31).

While the New York State Department of Environmental Conservation has required Con Ed to recirculate 60% of its flow when ambient water temperatures are 40° F. or lower for I.P.1 and I.P. 2 (p. V-33) and although Con Ed has air bubble screen devices in operation (p. V-29), it is not clear that any measures will in fact eliminate impingement fish kills. Con Ed's Fish Advisory Board (p. V-36) does not appear to have offered any solutions.

Indeed air bubble screens have not proven effective. See W.A. Maxwell, "Fish Diversion For Electrical Generating Station Cooling Systems," N.U.S. Corp. S.N.E.-123 (1973); J.R. Clark, "Electric Power Plants In The Coastal Zone: Environmental Issues" at V-2, V-7 and V-54 (American Littoral Society and Striped Bass Fund 1973). Moreover, Con-Ed's Fish Advisory Board (p. V-36) does not appear to have offered any solutions.

The impingement problem is over a decade old since it began with I.P.1. Con Ed has shown an inability to cope with this problem.

The FES must set forth the possible parameter of losses from impingement for white perch, striped bass and other fish. It must estimate both the short term and long range environmental impact from impingement.

The DES recommendation that Con Ed submit a plan including "means of reducing . . . impingement on the intake structures" by July 1, 1974, appears unrealistic. (p. XI-74). Con Ed has no plan. The FES should independently explore impingement and make recommendations. NEPA requires nothing less. Such analysis by the AEC Regulatory Staff is necessary to consider environmental impact "to the fullest extent possible," as required.

Among the aspects of impingement requiring discussion is the effect of a common intake structure and different means of design to minimize intake velocities. Avoidance devices employing light, sound or electrical techniques and guidance devices such as louvers must be scrutinized. Traveling screens and lift baskets must be analyzed. The effect of a previous rock dyke in front of intake structures must also be studied. Since Con Edison has indicated that it is exploring these techniques, so should the Regulatory Staff. See "Applicant's Responses to Interrogatories from Hudson River Fishermen's Association and Save Our Stripers" at 66-68 (Nov. 30, 1973).

The reduced flow and protection against impingement which cooling towers afford (p. XI-30) should be further examined as well in light of the analysis of other impingement-avoidance techniques. Reduced winter intake should be explored also. A cooling water intake flow velocity of .5 feet/second (1/3 m.p.h.) has been recommended as the most appropriate standard for open cycle cooling systems in order to minimize intake fishkills. See J.R. Clark, <u>supra</u> (1973) at p. VIII-2.

II. Cooling Towers Are Needed At I.P.3.

A. The Incremental Adverse Impact on Fish from I.P.3 Requires Cooling Towers.

Closed-cycle cooling has been mandated for I.P.2. In the DES, the AEC Staff concludes that the same must be required for I.P.3. This requirement in the DES is not only consistent but crucial if the aquatic resources of the Hudson are to be preserved.

The impact from operation of I.P. 1 and I.P.3 with once-through cooling is slightly greater than that estimated for I.P.1 and 2 operating with once-through cooling. (p. XI-46.) The reasons for mandating closed-cycle cooling at I.P.2, therefore, provide commensurately greater cause for mandating closed-cycle cooling for I.P.3.

If I.P.1 and I.P.3 are both allowed to operate with once-through cooling, while only I.P.2 has closed-cycle cooling, there will be an estimated annual loss of 1.6 million fish from impingement; an estimated reduction of 15 to 44 percent in striped bass juveniles due to entrainment; the possibility of detrimental effects from waste heat, reduced oxygen levels and chlorine; the probability that the combined effects of impingement and entrainment over several years would substantially decrease the populations of other fish species. (p. XI-46.) By making a comparison of these predictions with those where I.P.3, as well as I.P.2, operates with cooling towers - either mechanical or natural draft - one can easily

see the substantial incremental impact I.P. 3 will have unless cooling towers are required.

If I.P. 2 and I.P. 3 both operate with cooling towers, there will be an estimated annual loss of .6 million (vs. 1.6 million) fish from impingement; an estimated reduction of 6 to 21 percent in striped bass juveniles due to entrainment (vs. 15 to 44 percent); a high potential for a much greater reduction of detrimental effects from waste heat, reduced dissolved-oxygen levels and chlorine; a sizeable reduction in the probability that the combined effects of impingement and entrainment over several years would substantially decrease the striped bass fishery and a parallel reduction in similar effects that would possibly cause a substantial decrease in the populations of other fish species. (pp. XI-46, XI-47.)

The Staff's analysis clearly shows that unless closed-cycle cooling is required, the complex estuarine environment of the Hudson River will be severely impacted from long-term operation of I.P.3. It is therefore essential that operation of the plant guarantee an acceptable limit to the environmental costs by installation of a closed-cycle cooling system.

B. Cornwall (Storm King Mountain) Must be Reviewed in order to understand the impact I.P.3 will have.

The complete assessment of the environmental impact of I.P.3 requires an examination of the impact of the Cornwall pumped storage project ("Storm King") as well as of the other power plants already located in the Hudson River. In order to accurately portray the environment in which I.P.3 will be operating, the AEC must look to the present and reasonably foreseeable effects on the estuary which are being or will be caused by other installations. Any other course fails to analyze I.P.3's impact on the environment as it is or will be.

The DES has predicted the impact of other installations on the Hudson River aquatic life, but states only that the operating of Storm King, which is expected to be operating by 1979, "would substantially increase these predictions." (pp. V-48, V-49.) No further analysis is given, nor is any attempt made to quantify the impact.

Storm King has been licensed by the FPC and, as the DES recognizes, is scheduled to begin operation in 1979. During the hours it is in operation, it will withdraw from the Hudson River more than twice as much water as I.P.1 and 2 combined. Predictions have been made by the AEC Staff and others that the plant might well withdraw something in the range of 30 to 40 percent of all the striped bass larvae in the Hudson River. Goodyear at I.P.2 hearings, Tr. 9324-30; Affidavit of John Clark in Support of HRFA Petition to FPC for Hearing and for Order Modifying Operation of Pumped Storage Project, February 7, 1973, at p.4; Affidavit of Dr. Charles Hall in Support of Scenic Hudson Preservation Conference Petition to FPC to Reopen and for Further Hearings

in the Storm King Proceeding, March 21, 1973 at p.5. In addition, Hall predicted that mortality of at least 50 percent of those eggs and larvae withdrawn would not be unlikely. Hall Affidavit at p.6. Such reductions in striped bass juveniles flowing from operation of Storm King make installation of closed-cycle cooling at I.P.3 all the more imperative, since its operation with once-through cooling would further reduce the striped bass fishery and could result in its demise altogether.

The likelihood that Storm King will have a substantial adverse impact on the Hudson River fishery is supported by the AEC Staff's recent revelation that the 2.8 percent withdrawal rate which was predicted by the "Hudson River Fisheries Investigation 1965-1968" (Carlson-McCann Report) and used by the FPC in drawing its conclusion of minimal plant impact when it issued the license for Storm King, represents not an annual withdrawal rate as was previously thought, but a daily withdrawal rate. AEC Staff at ORNL, Storm King Analysis Requested of Senator A. Ribicoff, December 3, 1973.

Inclusion in the FES of an analysis of the impact Storm King is likely to have on the striped bass fishery should be facilitated by the fact that the AEC has agreed to do a 6 month study of just this for Senator Ribicoff. See Letter of Dr. Dixie Lee Ray to Senator Ribicoff, October 31, 1973.

III. Construction Time for Cooling Towers Must be Advanced

The DES would recommend permitting use of a once-through cooling system until May 1, 1978 (p. XI-72). This period of time is excessive given the current state of the art for closed cycle cooling systems by natural draft cooling towers.

The DES fails to show why such a long period is required. The system should be mandated for completion by May 1, 1977, assuming an operating permit may be granted by the end of 1974 with natural draft cooling towers required.

The Con Ed construction time estimates must be scrutinized independently by the A.E.C. Regulatory Staff and discussed in the FES. The design time needed should largely be satisfied by Con Ed's preparations in connection with I.P.2, and actual construction should substantially overlap.

A rigorous and tight construction schedule for cooling towers must be required. Con Edison should not build in a cushion at the expense of the fish. Con Ed's poor record of construction efficiency should be a basis for a strict construction deadline, not an extensive one.

The DES should explore further the time periods within which Con Edison could provide cooling towers. Such cooling towers are required for I.P. 2, the question of economics of time and expense in constructing both unit's closed cycle cooling systems must be discussed.

IV Reduced Operation is Necessary Each Spring at I.P.3

In order to protect the spawning in the area of I.P.3, as a minimal requirement until a closed cycle cooling system becomes operational, I.P.3 should not be permitted to function at all during the peak spawning season for the striped bass and other fish on the Hudson River estuary. This is necessary to minimize the damage to aquatic resources from impingement and especially entrainment. The DES should examine this alternative.

Subject to annual variation, the period from the end of April through July represents the period of peak losses of larvae and eggs because of entrainment (pp.V-37-49; App. 13) Con Ed should plan to use energy sources other than I.P.3 during this critical period. If interim operation with base design is allowed at all, the DES should explore what can be done to limit operation in the April-July period for each year before closed cycle operates.

V. Cost/Benefit Evaluation Must Be Scrutinized

HRFA and SOS have no quarrel with the DES conclusion that, by the most careful cost/benefit analysis set forth, cooling towers must be installed at I.P.3. The recommendation that interim operation be allowed until 1978 with once-through cooling, however, cannot survive a close cost/benefit analysis.

The benefit, presumably, is the availability of I.P. 3 generated electricity. Even assuming Con Ed can operate I.P. 3 without breakdowns so that the electricity would actually be available, a careful review of the off-setting costs would reveal that the costs outweigh the benefits.

A. COSTS -

The effect on aquatic resources of once-through cooling of I.P. 1, 2 and 3 operating together without cooling towers has been set forth in the DES. It appears for impingement (Table X1-6 at X1-31) and entrainment (Table X-12 at X1-43). The effect is that described as the base design.

Based on Con Ed's minimal estimates for 3 years of I.P. 1, 2 and 3 once through cooling (actually a fourth year of I.P. 1 and 2 together exists also), 28,600 lbs. per year of fish would be impinged, or

2,600,000 actual Fish. Over three years this sum is 858,000 lbs. or 7,800,000 Fish. Taking only the striped bass as an example, a substantial number of fish will be lost, with greatest impact being when those fish mature and their numbers are not available for recreational fishing or spawning, added to this already significant loss are the cumulative entrainment losses for the three years. Assuming 100% mortality on entrainment with once through cooling base design, the mean predicted reduction of striped bass juveniles due to entrainment was between about 23% to 58% (Fig. XI-3, p.XI-34). Adding the cumulative impact of all plants other than Storm King the 100% mortality assumption on base design rises to about 43% to 74% (Fig. XI-4, p. XI-36).

Taking the mean predictions of mortality for base design with 100% mortality assumed at 43% of all striped bass juveniles (p.XI-32), the interim once-through cooling will reduce substantially the available striped bass stock. Adding all plants except Storm King this loss of juveniles results in a mean prediction of 62%, up 14%.

On balance, over half of the striped bass for at least a three year period would be lost. Since fish egg and larvae measurements are difficult to make, the estimate may in fact be much higher. The maturation period for striped bass is some four-six years; accordingly, at the end of the interim period the first adverse impact on commercial and

recreational striped bass fishing on the Hudson and off the Atlantic Coast and Long Island would be felt.

The adverse economic impact on recreational striped bass fishing is ignored by the DES. In weighing the costs of interim operation at base design of I.P. 3 with I.P. 1 and 2, this impact must be considered.

The striped bass is one of the most sought after game fish in the area off New York and along the Atlantic Coast. The fish prefer waters near shore and are seldom found more than several miles away. The pressure on striped bass from increased numbers of anglers, commercial haul seining, pollution, insecticides and run-offs, and most significantly the losses from once through cooling at existing Hudson River power plants, has reduced the catch significantly in recent years. At stake here, therefore, is avoiding a new and substantial adverse impact. As Edward Raney noted, "Wallace and Neville (1942) have outlined the persistent problems of the [striped bass] fishery and have focused attention on the factor of removal of the striped bass by man --- the only important factor which is immediately controllable." E.C. Raney, "The Life History of The Striped Bass", 14 Bull. Bingham Oceanogr. Coll. #1 (1952).

"Man" here is Con Edison. The Company must install cooling towers and must not use I.P. 3 without cooling towers because of the harm which will result if 50% of striped bass are eliminated for each of three years running.

Such a fish loss would injure the conservatively estimated 160,000 striped bass anglers in New York. See D. G. Dewel and J.R. Clark, "The 1965 Saltwater Angling Survey", Dep't of Interior, Bur. of Sportfisheries and Wildlife, Resource Publ. #67 (July 1968). The number of these fishermen increases by 6.7% annually. I.M. Alperin, R.V. Miller, P.R. Nichols, and J.E. Sykes, "Striped Bass," Marine Resources of The Atlantic Coast Series, Atlantic States Marine Fisheries Comm., Leaflet No. 8 (1966). It is clear that well over 200,000 fishermen seek recreation from the striped bass in New York alone.

Each such striped bass angler spends large sums for supplies and equipment. An average of $9.00 a day money spent per striped bass angler was estimated in 1959, as both the Department of the Interior (Fishing Leaflet #592) and the Department of Fish and Game of the State of California. Even without adjusting this figure for the inflation of the last two decades, with a minimum of 16 days of fishing a year as a conservative estimate, each fisherman contributes $144 a year to the economy in pursuit of striped bass, or $28,800,000 a year for a conservative estimate of all New York's stiper fishermen before inflation adjustments.

The value of the striped bass must be figured in terms of such expenditures for charter boat operators, bait and tackle dealers, motel owners, gasoline stations, restaurants and taverns, food stores, dealers and manufactures of boats; special clothing, and the like.

The value of these market components cannot be ignored. With adjustments for inflation, the annual striped bass fishermen contribute in excess of $80,000,000 to the State's economy.

The DES must evaluate how much interim I.P. 3 operation with once through cooling before closed cycle cooling is installed would cut into this striped bass recreational fishing industry. A 50% reduction in available fish would cut into the economy and into the ability of the fish to regenerate its numbers.

It would be a tragic blow if cooling towers were required only to go into operation too late to avert massive reductions in fish because of once through cooling for 3-4 years. The DES must come to grips with this issue.

Such an economic analysis reveals the full worth of the resource. The 1970 Saltwater Angling Survey (U.S. Bureau of Commerce National Marine Fish Service) must be studied to bring the analysis more current. The value of the striped bass fish alone has been computed for the North and Middle Atlantic at from $59 to $146 million per year. The Hudson-supported striped bass fishery in fish alone totals $75.4 million annually. J.R. Clark, "Testimony on Effects of I.P. Units 1 and 2 on Hudson River Aquatic Life" (Docket 50-247, Oct. 30, 1972) pp. 2-4. To these raw fish figures, the DES must evaluate the economic multipliers if true costs are to be established.

B. Benefits

The benefits also need scrutiny during the interim period before cooling towers operate. Con Edison's need for the power which I.P. 3 can provide should compel an earlier installation of cooling towers, rather than a later date. Indeed, it should compel the earliest possible date. In the meantime, Con Edison should supply the power it needs from alternative presembly abailable sources.

Con Edison's position is not as bleak as might appear.

The DES review in Chapter IX on the need for power could usefully be compared to the soon to be released report of the Regional Plan Association and Resources For The Future establishing that the metropolitan New York area including Westchester uses 6.4% of the nation's energy although 10% of the nation's people live here. 35.1% of all energy goes to transportation, 28.9% to residential uses, 24.9% to commercial and public facilities and 11.1% for industry. This is below the national average figures. See Regional Plan Association Resources For the Future,"Regional Energy Consumption" (1973).

To supply the portion of these demands which is Con Edison's responsibility, it is improving its transmission capabilities by 1975 and thus can purchase power (Table X-2, p X-2).

The DES concedes (at p. XI-2) that "It would appear that adequate net import capability exists to make purchased power a viable alternative to Indian Point Unit No. 3." It notes that as inavailable Con Ed capacity could require I.P. 3 between 1973-75 nonetheless (Table X-9 and X-10, p. X-25, p. XI-3).

The DES does not, however, factor in the energy conservation measures now in effect and soon to be required by the N.Y.S. Public Service Commission. It must include these.

The DES also fails to consider the facts set forth by the City of New York as to Con Edison's additional generating capacity. While estimated with respect to the energy potential of Con Edison's Cornwall (Storm King Mountain) plant site, the facts are directly relevent to alternative power sources during the construction of cooling towers for I.P. 3. The N.Y.C. Environmental Protection Administration report establishes that Con Edison could save fuel oil by linking new gas turbines to wasteheat boilers to produce steam for both electrical power and steam heat. While the N.Y.C.E.P.A. report is framed in the 1980-1992 Cornwall (Storm King Mountain) time frame, the same facts should have been treated in the DES with respect to the 1973-75 time frame. See N.Y.C. Environmental Protection Administration, "An Alternative to Storm King" (November 30, 1973).

Since Con Edisons predicted peak load over the next few years is always within the total system capacity (Fig. X-6, p. X-23), it hardly seems justified on a cost/ benefit analysis to endanger the striped bass population and striped bass recreational and commercial fishing economy by permitting interim operation of I.P.3 before cooling towers are installed. Even if outages reduce total capacity, the alternative power sources available to Con Edison should be used to get it through the next short period until I.P.3 has a closed-cycle cooling system.

Conclusions

The extensive losses which will result from even a short period of operation of I.P.3 with once-through cooling cannot be accepted. The DES is deficient in failing to closely examine this issue. Similarly, the DES should review intensively the entire impingement problem rather than simply pass the burden back to Con Edison whose experience hardly commends it for such a review. The cooling towers should be operational by May 1977 at the latest, and if Con Edison cannot meet such a deadline the plants should not operate with closed cycle cooling after May 1, 1977. Finally, Con Edison must curb operations during the spring spawning season in order to protect the striped bass and other fish resources of this priceless natural resource, the Hudson River estuary.

Dated: New York, New York
December 10, 1973

Respectfully submitted

Hudson River Fishermen's Association
Cold Spring, New York

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December 24, 1973

Mr. L. Manning Muntzing
Director of Regulation
U.S. Atomic Energy Commission
Washington, D.C. 20545

Re: Indian Point 3
Docket No. 50-286

Dear Mr. Muntzing:

Con Edison respectfully submits the following comments on the Draft Environmental Statement by the Directorate of Licensing related to the operation of Indian Point Nuclear Generating Plant Unit No. 3 (DES). We hope these comments will be useful to the AEC's Regulatory Staff (the Staff) in its preparation of the Final Environmental Statement. Detailed comments are set forth in an appendix. We would like to make the following principal observations.

1. DES Fails To Analyze Whether There is Time To Complete Studies

The DES, despite its bulk, fails to address the principal issue in contention between Con Edison and the Staff--that is, whether there is time to complete the ecological study program prior to making the decision whether or not to build cooling towers.

During the course of the hearing on Indian Point 2 it became very clear that the presently existing data were inadequate. Witnesses of unquestioned honesty and integrity reached extremely diverse conclusions because of different assumptions made in the face of lack of good data. It would seem obvious that the only way we will know the impact of the plant is to start Unit 2 and also Unit 3 and make careful measurements of important biological parameters. Then we will know impacts instead of assuming them. Con Edison has designed and is implementing an ecological study program which will make these measurements.

Although the Staff has criticized this program, we suggest it is completely inconsistent to predict massive biological damage on the one hand and then say that a study program as extensive as that undertaken by Con Edison may not detect any damage. Clearly the program will detect damage of the dimensions postulated by the Staff.

The critical question then becomes whether, in the event serious damage should occur, there is time to complete this program without creating an irreversible adverse impact on the aquatic resources of the Hudson River. The DES does not address this question. If the study program shows that the Staff's worst estimates are true, closed-cycle cooling systems can then be installed and the biological systems of the river would recover from the adverse impact. Numerous instances exist of recovery of biological systems after much more extensive destruction than is postulated by the Staff. The Staff has not considered whether the prevention of a possible short-term diminution of aquatic resources justifies making the cooling tower decision now. We submit that the economic costs of such an approach clearly outweigh the environmental benefits, which at the present time are speculative in nature.

Also the Staff agrees that the hatchery program can mitigate any damage from such interim plant operation (XI-46*), and Con Edison has expressed a willingness to effectuate such a program. Accordingly, no valid reason is presented in the DES for denying Applicant the opportunity to complete the ecological study program prior to making the decision on cooling towers.

2. Bias in Analysis of Biological Impact

A. Existence of Bias

Con Edison is deeply distressed at the obvious bias that permeates the estimate of biological impact of plant operations. In this respect the DES can hardly be considered a realistic assessment of environmental impacts, as specified by the National Environmental Policy Act (NEPA). Rather, the

* All similar references are to pages of the DES.

Staff has strained to find indications of damage or potential damage from plant operations and has systematically rejected all evidence, no matter how clear the data may be, that the plant will not damage the aquatic environment.

We note in this regard that the Commission's proposed regulations for environmental considerations require a discussion of "probable" environmental impacts. Proposed Reg. §51.20(a). The DES does not analyze environmental impacts in terms of probable impacts. For example, the crucial conclusion on impact of the plant on striped bass populations refers to "a high potential" of damage and does not say whether or not this potential is probable. (v.) Furthermore the analysis that backs up this conclusion has even more "possibles", ("may", "could", "potential", etc.) than "probables."*

The bias principally occurs in Section V. D. 2 where the Staff analyzes the plant's potential for biological damage and concludes that such potential damage is unacceptable. Here the Staff rejects all data favorable to the Applicant's position. This is particularly surprising because, in the Indian Point 2 proceedings, the Staff consistently rejected subjective statements on environmental impacts offered on behalf of Applicant regardless of the qualifications of the persons making those qualitative judgments and asked that it be furnished with data. Now the Staff ignores the data.

Although many of these items are noted in the appendix, we will describe a few examples:

a. The Staff's inconsistent use of the results of New York University studies. The Staff relied on NYU data to show damage to phytoplankton by chlorine (V-63), and ignored NYU data on temperature tolerance of phytoplankton at Indian Point which showed no adverse effect, (Testimony of Gerald J. Lauer on Effect of Operation of Indian Point Units 1 and 2 on Hudson River Biota,

* For example, see pages v item 2; v item 3; vi item 4(c); V-78 third par.; V-81 first par.; V-91 par. 2; V-95 par. 2; V-95 par. 3; V-95 para. 4; and V-96 par. 2.

October 30, 1972), choosing instead, to support its prediction of serious adverse effects on phytoplankton by data from unspecified plants under unspecified conditions (V-71).

b. In Table V-4 (p. V-47) the Staff fails to take into account extensive information obtained for the Applicant by NYU and supplied to Staff on the temperature tolerance of aquatic species found in the Hudson River. In choosing to ignore the NYU data, Staff has instead elected to rely on data garnered from sources other than specific studies of the Hudson River.

c. The Staff's treatment of the potential plant impact on American shad. Two years of daily counting and classification of fish collected from the Indian Point intake screens have established that rarely are shad collected from the screens. Two years of entrainment studies have failed to find any shad eggs entrained in the plant. Nevertheless, in several places the Staff states that the plant will have an adverse impact on American shad from impingement and entrainment. (V-78; V-91.)

B. Source of Bias Is Approach Contrary to Scientific Standards

The scientific and particularly the biological analyses contained in the DES reflect not only bias but are contrary to standard scientific principles: i.e., basing conclusions on all pertinent data. Examples are indicated throughout the appendix. Basically the emphasis of the DES on the mathematical biological model reflects a preoccupation with a new and untested technique without adequate recognition of its fundamental limitations. As noted above, the question of irreversibility of adverse impacts during the time necessary to carry out the study program is ignored.

The Staff's approach to the study program which, in effect, rejects the utility of standard biological research methods, also reflects this problem. The Staff concedes that no five-year research program no matter how competently designed and executed can satisfy the Staff's requirements. (V-103 to 104.) A more scientific approach would recognize that it is not necessary to understand every biological interaction in the ecosystem to analyze plant impact. Ecosystem measurements before and after startup of the plant should provide a sufficient indication for decision making.

3. The Staff Makes a Wrong Decision by Using Wrong Procedures

A. Unusual Burdens of Proof

The problem of rational decision making is compounded by the Staff's selection of the standards for the burden of proof. The Staff states that Applicant must "conclusively demonstrate" that operation of the Indian Point plant will not have an unacceptable adverse impact on the fisheries supported by the Hudson River. (V-97.) Where does the AEC Staff obtain the concept that this must be conclusively demonstrated? Nowhere in NEPA nor in the Atomic Energy Act is such an unusual standard set forth for environmental review. Furthermore, the fact that Applicant is being required to prove a negative makes the burden virtually impossible to meet.

The Staff is well aware of the fact that scientists do not talk in these terms. Applicant cannot present as a witness a responsible scientist who would ever say that something has been "conclusively demonstrated" not because our case is weak but because scientists don't use this language. Scientists generally speak in terms of confidence levels based on the range of data, and the ecological study program has been designed to reach such conclusions.

In summary the Regulatory Staff is saying that in the absence of Applicant's ability to conclusively demonstrate a negative proposition, the environmental decisions must be made on the basis of unproven but most conservative assumptions. This is not only legally wrong because it is not authorized by any statute, but it is also bad as a matter of public policy. Translated into action, this policy means that the environment must in every case be protected from all potential sources of damage regardless of cost or the value of the damage. This is not a policy enunciated by any act of Congress. If carried out in all governmental actions, it would create a serious misallocation of our resources, which we are all painfully learning are not unlimited.

Our nation has enough existing environmental problems which need attention that our efforts should not be diluted by premature decisions involving such a vast and irretrievable commitment of resources. Since a large number of problems exist which are not being addressed because of lack of funds, they should clearly have priority over eliminating hypothetical potentials for environmental harm. In a community which is suffering from lack of adequate funds for hospital facilities, mass transit, drug problems, rodent control and many other similar matters, it seems indefensible to spend $38 million per year for cooling towers at the two units at Indian Point without the need having been established therefor.

B. <u>Different Standards for the Environmental Problems of Cooling Towers</u>

The problems of the Staff's approach are made even more acute when the alternative the Staff proposes has adverse environmental impacts of its own, i.e., natural draft cooling towers. Environmental impacts of this alternative cannot be "conclusively demonstrated" any more than can the environmental impacts of the present once-through cooling system. The Staff therefore "reverses its field". Gone are the most conservative assumptions when analyzing environmental impacts of cooling towers. In these sections, as noted in the appendix, the Staff based its analyses on conclusory statements and data much less definitive than the data it has rejected in analyzing the impact of the once-through cooling system.

Thus the decision is made on the basis of artificially constructed standards of proof rather than a careful analysis of the large quantities of available information on actual environmental impacts. In this case the result is a decision which is not only "environmentally conservative", but is very likely environmentally wrong. Applicant considers it terrible from a strictly environmental point of view to impose on the people of the Hudson Valley the irreversible and irreparable adverse environmental impacts of large cooling towers at Indian Point on the basis of the Staff's compounding of most conservative assumptions with respect to the once-through cooling system.

C. <u>Decision Should Be Based on Analysis of Benefits and Costs</u>

The decision on cooling towers should be made on the basis of a rigorous analysis of realistic benefits and costs. All decision making whether governmental or private is essentially made by balancing costs against benefits and this is precisely what the AEC has been ordered to do. (<u>Calvert Cliffs' Coordinating Committee Inc. et al.</u> v. <u>USAEC</u>, 449 F.2d 1109 (D.C. Cir. 1971).)

The Staff has failed to base its decision on this difficult analysis and has elected instead to base its decision on the principle that all adverse environmental impacts should be minimized. This is easier for the Staff, since it closely resembles its nuclear safety standard that radioactive releases should be kept as low as practicable.

Although the appendix to this letter notes examples of how the Staff has applied this concept, it is clearly revealed on Pages XI-46 to XI-48 where the Staff presents the summary and conclusions of biological impacts. On these pages the Staff assumes adverse impacts must be minimized without purporting here or anywhere else in the DES to weigh the real social costs of these adverse impacts. Plant mortality by itself is equated with social cost with no attempt being made to relate these impacts to aquatic populations having significant value to society, except to some extent in the case of striped bass, in which case there is no attempt to quantify the value to society of a diminution in the fishery. Quantifying commercial and recreational values of a fishery is not a new problem and the Federal Government has for many years had a Congressionally-approved method for doing this.

Furthermore, a proper benefit-cost analysis specifically requires a realistic assessment of the benefits and costs. The bias that permeates the DES, discussed above, makes a proper balancing impossible.

The result of the Staff's failure to perform a proper benefit-cost analysis results in imposing a large financial burden on the people of New York City and Westchester who will pay for the two cooling towers an amount properly estimated at not less than $38 million per year. It also imposes on the local community the serious, irrevocable, adverse environmental impact of the towers themselves. The benefit-cost analysis must contain a clear explanation of what they will receive for this money and environmental burden. The elimination of potential and hypothetical damage to aquatic resources, which have not been quantified in any meaningful way, would not appear to offer any reasonable explanation.

Very truly yours,

Carl L. Newman

Carl L. Newman
Vice President

Enc.

APPENDIX

TO

COMMENTS OF CON EDISON

ON

DRAFT ENVIRONMENTAL STATEMENT

RELATED TO THE OPERATION OF

INDIAN POINT NUCLEAR GENERATING PLANT

UNIT NO. 3

1.	Page i, Item (2), par. 2	License request for Unit 3 is for 965 MWe and 3025 MWt. All calculations should be based on these values, and not on the 1033 MWe employed by the Staff.
2.	Page iii, Item (3). f	In stating its conclusion that the thermal discharges from Indian Point Units 1,2, and 3 may exceed the state thermal criteria, the staff gives no indication of the qualifications on this conclusion. On page V-11 of the DES the staff states "In assessing the results of the thermal discharge studies, it should be emphasized that the estimates are strong functions of the values of the input parameters, which are largely based on judgement and need verification by more field data than are now available." So as not to be misleading, a similar qualifying statement should be made here.
3.	Page iii, Item (3). f	On page V-17 of the DES the staff acknowledges the conclusion and position of the applicant that: A) "The scarcity of field data available makes the modelling difficult," (as demonstrated by the disagreement between the Applicant's physical and mathematical model predictions.) B) "The applicant will carry out a thermal plume program" which will "enable the applicant and staff to predict more accurately the thermal plume characteristics." C) The applicant "intends to operate the Indian Point facility so that the addition of Indian Point thermal discharges to the existing Lovett and Bowline discharges will not create a violation of the State thermal criteria. However, on Page iii, Item f, the staff describes the applicants' conclusion as being simply "that the thermal discharges from Unit Nos. 1,2, and 3 will meet the New York State thermal criteria." This oversimplification is misleading, and the true position of the applicant, as indicated above, should be given here also.

4. Page iii, Item (3) g

In the initial decision for Indian Point Unit 2* the ASLB ruled that "The applicant must monitor the dissolved oxygen in the vicinity of the plant. If the concentration falls to dangerous levels, which is hardly to be expected, the discharge must be aerated or other suitable action taken to satisfy the requirements of the New York State Department of Environmental Conservation." In the light of this decision, it is assured that dissolved oxygen will not be permitted to fall, due to plant operation, to levels dangerous to aquatic life. This should be noted in the staff's conclusion on dissolved oxygen, which as now worded gives the incorrect impression that no action is presently planned to insure that dissolved oxygen will be maintained at safe levels.

5. Page iv, Item (3) i

No reference is made here (Summary and Conclusions) to the program imposed by the Unit #2 Environmental Technical Specification Requirements of determining the lowest residual chlorine that is possible consistent with plant operations. Also we have not chlorinated at the frequencies listed here for several years. The description of the circulating water system (page V-25) contains reference to these current programs and similar statements should be incorporated in "Summary and Conclusions."

6. Page iv, Item (3) j (1)

In addition to studies on the effectiveness of the air bubbler and reduced flow to reduce impingement, the applicant is also undertaking a flume study to investigate fish guidance and avoidance devices which if installed at the Indian Point intakes could reduce fish impingement. This flume study should also be mentioned here.

7. Page v, Item (3) j (2)

There is no sound basis for assuming that all larvae entrained will be killed.

* Docket No. 50-247 (September 25, 1973)

8. Page vi, Item 4b

The staff's assertion that the few additional years required for completion of the proposed ecological study carry significant risk of irreparable environmental damage is unsupported by general theory or by fact.

The Staff also fails to acknowledge methods to mitigate damage while studies are being performed. If operation of the Indian Point power plant caused damage to fish populations which was irreversible through natural processes, then mitigation by stocking, or temporary reduction of fishing with financial compensation to economically damaged parties, could be employed to restore the loss value of the natural resources to the public.

9. Page vii, Item 4c

Staff does not acknowledge data presented in the IP2 hearings. Stresses should not be termed severe if they do not cause mortality. See the following:

Rebuttal Testimony of Gerald J. Lauer, Ph.D., on Effects of Entrainment on *Morone* sp. (striped bass and white perch) eggs and larvae at Indian Point, dated February 5, 1973

Testimony of Gerald J. Lauer on Effects of Operations of Indian Point Units 1 and 2 on Hudson River Biota; October 30, 1972

Rebuttal Testimony of Gerald J. Lauer, Ph.D., on Studies of the Effects of Rapid Pressure Changes on Striped Bass Eggs and Larvae by New York University, dated February 5, 1973

Testimony of Gerald J. Lauer on Effects of Elevated Temperature and Entrainment on Hudson River Biota, April 5, 1972

Rebuttal Testimony of Gerald J. Lauer, Ph.D., on The Temperature Tolerance of Striped Bass Eggs and Larvae Relative to Their Seasonal Occurrence and

Expected Indian Point Plant Discharge Temperatures, dated February 5, 1973

Testimony of Gerald J. Lauer on Effects of Chemical Discharges from Indian Point Units 1 and 2 on Biota and on River Chemistry, April 5, 1972

10. Page vii, Item 4d — Statement is not supported by the analysis.

11. Page vii, Item 4e — There is no sound basis for this statement.

12. Page vii, Item 4f — Reduction of mean probability of entrainment of phytoplankton has inherent value only if it were to be damaged, which NYU studies show will be true only during chlorination. Furthermore, a reduction of phytoplankton is only significant if total populations in the river are reduced. Staff erroneously implies that any reduction is a significant adverse environmental impact. In any event, Staff should state the expected impact of this mortality on total populations in the river.

See the following:

Rebuttal Testimony of Gerald J. Lauer, Ph.D., on Effects of Entrainment on Morone sp. (striped bass and white perch) eggs and larvae at Indian Point, dated February 5, 1973

Testimony of Gerald J. Lauer on Effects of Operations of Indian Point Units 1 and 2 on Hudson River Biota; October 30, 1972

Testimony of Gerald J. Lauer on Effects of Chemical Discharges from Indian Point Units 1 and 2 on Biota and on River Chemistry, April 5, 1972

13. Page ix, Item 8c — Requirement for plan to reduce impact during time prior to installation of cooling towers is inconsistent with Item 4b (see comment above)

which states irreparable damage may take place during studies.

14. Page x, Item 8d — The need for detailed studies is inconsistent with conclusions that studies cannot determine the impact of plant operations.

15. Page xi, Item 8d (5) — The plant does not discharge copper in its operations, although, as a theoretical matter, immeasurable copper discharges may result from corrosion of condenser tubes.

16. Page xi, Item 8d (10) — This requirement is too general to be meaningful, and there is another inconsistency in the following paragraph. It implies that the massive impact predicted might not be detected.

17. Page I-2, Table I-1 —

(A) The maximum ambient temperature in the vicinity of Indian Point, is 79°, not 81°F as postulated by the Staff. A detailed discussion of the maximum ambient temperature in the vicinity of Indian Point, including comments on the Staff's utilization of applicants data is presented in Appendix B-1, Con Edison's comments to the Draft Environment Statement for I.P. 2 (see FES, I.P. 2, Vol II, p. 203).

(B) Freshwater flows in excess of the maximum value stated by the Staff (50,000 cfs) have been regularly reported. See, for example Geise and Barr, "The Hudson River Estuary," State of New York Conservation Department, Water Resources Commission, Bulletin 61, 1967* (Table 2 in the aforementioned document gives mean monthly net fresh water flows at Poughkeepsie (which is upstream of Indian Point) of, for example, almost 68,000 cfs for April 1960.

* Reference 5 in Ch. II of DES.

18. Page I-3, par. 1, I-9, line 4 — Ten supplements, not nine, have been submitted to the Unit No. 3 Environmental Report. Supplement 11 will also be submitted prior to issuance of the Final Environmental Statement.

19. Page I-8 — The discussion on future environmental approvals does not take into account recent changes in New York State law. Effective September 1, 1973, the New York Environmental Conservation Law was amended to eliminate the requirement for an operating permit and to substitute a requirement for an "SPDES" permit. This amendment was intended to make New York law compatible with the federal system adopted under the 1972 Amendments of the Federal Water Pollution Control Act. Until December 31, 1974, an application for a permit is deemed a permit. Accordingly, SPDES permits for Units No. 1 and No. 2 are not required until December 31, 1974.

Furthermore, a certification pursuant to Section 401 of the Federal Water Pollution Control Act was issued by the New York Department of Environmental Conservation for Unit No. 2 on September 24, 1973. An application for similar certification for Unit No. 3 has been filed.

20. Page I-8, Item 3 — The New York State order of April 28, 1972 states that if it were determined at public hearings that the air bubbler system now in use is "not satisfactorily protecting the fish population of the Hudson River, or that the screened lagoon will provide a level of fish protection significantly higher than the air bubbler system", then Con Edison must build the screened lagoon.

21. Page I-9 — Staff should discuss the additional approvals required in connection with its recommendation for the installation of cooling towers.

22. Page II-1, Section A — This discussion should describe the visually affected area around the site, i.e., the region within which the plant structures and emissions can be seen. The size of this region

and the visual impact of the plant varies with light and meteorological conditions and the distance from the plant.

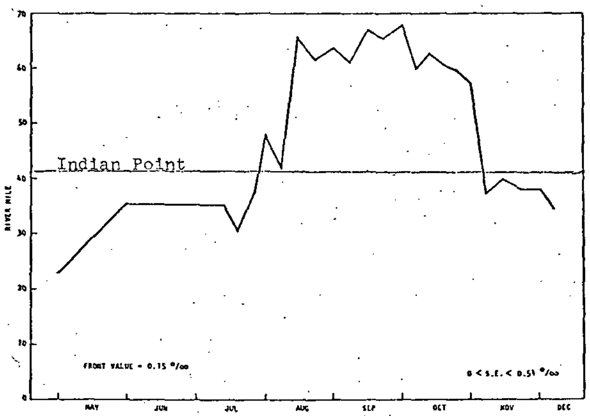
This zone of influence extends from Bear Mountain Bridge south to the Tappan Zee Bridge and to the high topography which creates the Hudson River Valley rim. Natural scenic geologic features include the estuary itself, Prickly Pear Hill, Anthony's Nose, Bear Mountain, Dunderberg Mountain, South Mountain (High Tor) and Hook Mountain, the latter two forming the northern extremity of the Palisade Diabase.

The dominant man-made features include several communities; Buchanan Montrose, Verplanck, West Haverstraw, Stony Point, Tomkins Cove, and Peekskill.

It should be pointed out that the Penn Central Railroad at Croton-on-Hudson has large switching yards and is an important terminus.

The important geographical features in Figure II-1 should be included in the text.

22. Page II-1, par. 3 — The salt front is not neccessarily upstream of Indian Point" much of the year as indicated here or all but three months of the year (March, April, May) as indicated on page B-5. The figure below from Texas Instruments' 1972 Annual Report on Indian Point shows that the salt front is above Indian Point only 3 months of 1972. The remainder of the year it was below Indian Point.



Saltwater Intrusion Length, Indian Point Region, Hudson River, 1972

23. Page II-1, par. 4 — This paragraph is grossly misleading. The entire river south of Albany serves as a spawning and nursery area. The sentence would be more accurate if the words "near Indian Point" were deleted.

24. Page II-6, par. 3 — This paragraph should be rewritten as suggested below:

"The State Archeologist of the New York State Museum and Science Service, State Education Department has noted archeological sites at Montrose Point (shell middens), Georges Island, Oscawana Island, Croton Neck and Kettle Rock Point. None of these sites are impacted by the facility." The reference to relic collectors is sheer speculation.

25. Page II-7, par. 2 — The Staff's statement on the maximum value of the freshwater flow at I.P. (50,000 cfs) is incorrect (see comment 17B above).

26. Page II-13, par. 3 — See comment 17A above for Applicant's analysis of the maximum ambient temperature in the vicinity

of Indian Point. The data presented by the Staff do not acknowledge the effect of plant operation on the measurements and the precision of the instruments used, which were geared for biological activity rather than temperature distribution. See Appendix EE (2), "Supplemental Study of Effect of Submerged Discharge of Indian Point Cooling Water on Hudson River Temperature Distribution, "Qirk, Lawler and Matusky Engineers, May 1972, pages I-3 to I-5, for a detailed discussion (I.P. 3 ER).

27. Page II-17 — It should be pointed out that both the 100 foot and 400 foot meteorological towers are located at sites over 100 feet above sea level.

28. Page II-18, par. 3, line 15 — The Staff rejected Applicant's models on the grounds that instruments were not sufficiently accurate. Wind instruments used on the 100 foot meteorological tower were installed at the 100 foot level and operational from 1 January 1970 to present. Specific sensor criteria for the instrumentation are: threshold of 0.6 MPH and accuracy ±0.15 MPH for the wind speed; wind direction threshold less than 1 MPH and accuracy ±3°. The aforementioned criteria are within the instrument accuracy presented in Regulatory Guide 1.23 (Safety Guide 23). Furthermore, although "more conservative meteorological models" are appropriate for nuclear safety matters, they are not appropriate for a realistic assessment of environmental impact.

29. Page II-26, Section b, par. 1 — Role of phytoplankton as food for zooplankton varies in different bodies of water. In the Hudson River, organic detritus appears to be a more important food source. See Howells, G.P., and Weaver, S. "Study on Phytoplankton at Indian Point", Proceedings of the Second Symposium on Hudson River Ecology. 1969.

30. Page II-28, par. 4

The Staff's statement that macroinvertibrates ability to recover from kills is restricted because they reproduce only once per year, is incorrect. Although some do reproduce only once per year, various individuals may be reproducing at different times throughout the year. Also, Congeria, Balanus, Amnicola, although they naturally incur high seasonal mortalities at Indian Point, nevertheless regenerate and maintain large and healthy populations. For further data the Staff should consult TI's First Annual Report on Indian Point (April 1973)

31. Page II-27

Delete "and euphasiids" from last paragraph. There are no euphasiids in the Hudson.

32. Page II-29, par. d, line 8

The reference to Long Island Sound is misleading. The parties are in agreement that Hudson River striped bass predominate in the western portion of Long Island Sound, but the Staff is well aware that there is a dispute as to their presence in the eastern portion of Long Island Sound. The omission of a reference to this controversy makes this statement misleading.

33. Page III-1, line 18

Insert the word "approximately" before the words "10 feet per second".

34. Page III-1

The Applicant will furnish a more recent photograph of the site.

35. Page III-5, fig III-2

(A) Unit No. 1 has one condenser with two halves, not two condensers as indicated

(B) The de-icing flow for Unit No. 1 is not achieved via a pumped return flow from the discharge canal, as indicated by the Staff, but via a direct flow from the condenser outlet.

(C) The values for Unit No. 3 should be based on the license request power level, not the maximum calculated power. The proper values are:
- MWt: 3025, not 3216
- MWe (net): 965, not 1033

- Condenser Rise: 16.3°F, not 17.5°F
- Canal Rise: 14.8°F, not 15.3°F.

All subsequent calculations and evaluations by the Staff should employ the license request power levels.

36. Page III-6, par. 2

In connection with the parenthetical expression at the end of this paragraph it should be noted that the design of Unit No. 3 has been altered from that of Unit No. 2 for environmental reasons. The fixed screens at Unit No. 2 have been replaced at Unit No. 3 by placing the traveling screens at the river face of the intake structure so that fish cannot be trapped in the forebays as was the case with the Unit No. 2 design before installation of the fixed screens. The air curtains are being tested for possible use with the Unit No. 3 intake.

37. Page III-7, Table III-2.

The columns under "Unit No. 3" and "Total" should be changed to reflect the comments on Figure III-2 above.

38. Page III-10 & Table III-3

The residence time for IP3 at full flow and simultaneous operation of I.P. 1 & 2 is 5.91 minutes. If Unit 3 operates alone at full flow, the transit time is 8.71 minutes.

39. Page IV-3

The discussion of Applicant's upgrading of its transmission facilities is not relevant to the environmental impact of Unit No. 3. The Atomic Energy Commission resolved this matter in Regulatory Guide 4.2 (S. 3.9).

40. Page IV-3 Ninth line from bottom

Change "1952" to"1932"

41. Page IV-4, Item c,. par. 1

Water is recirculated from the discharge side of main pumps to the forebays in front of the pumps. The water is not recirculated from the condenser outlet.

42. Page V-4

Discussion of transmission lines beyond the Buchanan substation is improper under Reg. Guide 4.2 (see comment on IV-3).

43. Page V-5, Section B.2, line 3

The phrase "service nuclear boilers" should be "service boilers".

Section 2 Air Quality section - the sulfur content of the fuel oil used in the package boilers is 0.3%, subject to recent problems of availability. Reference should be made to the Indian Point Unit No. 1 Environmental Report and Benefit Cost Analysis June 1973 (Supplement 1, 8/73, Dckt. 50-3) for an updated document on the superheater stack and associated package boiler installation. There are a total of seven stationary combustion installations including the superheater.

44. Page V-6

We do not object to a comparison of emissions to standards for new stationary sources but we strongly object to omission of the fact that these standards are not applicable to the Indian Point plants. Also, the .055 lbs/10^6 BTU and 28% figures for particulates are inconsistent.

45. Page V-7, Item c.1

All thermal calculations should be revised to reflect the license request values, i.e., three unit heat load of 15.22 x 10^9 BTU/hr, and temperature rise of 14.8°F.

46. Page V-8, par. 2

The statement given on page V-8, which follows,

> "In addition, the limit of 1.5°F during July through September is waived for the estuarine portion of the Hudson River, because of the thermal monitoring studies being carried out in the estuary."

is misleading as written. The actual statement taken from the recommended thermal criteria as determined by the Federal Thermal Task Force in their report of November 1971, is as follows,

> "Because of the studies that have been made on the estuarial portion of the Hudson River the need for limiting the temperature rise here during July through September to 1.5°F is waived and the conditions specified for October through June will be permitted year-round."

47. Page V-9 to V-18

The combination of values of the dispersion coefficient (E) heat transfer coefficient (K) and fresh water flow (Q_f) selected by the Staff are in many cases unrealistic. For example, the Staff selected a K of 90 BTU/sq ft°F with a Q_f of 4000 cfs. Applicant's remarks on this combination of a winter K with a typical summer Q_f are presented in (a) "Additional Testimony of John P. Lawler, Ph.D., Quirk, Lawler and Matusky Engineers on the Cumulative Effects of Bowline, Roseton and Indian Point Generating Station on the Hudson River," March 30, 1972 and (b) "A response by John P. Lawler, Ph.D., Quirk, Lawler and Matusky Engineers on Additional Information Requested by the Staff on the Temperature Distribution Section in our March 30, 1973 Testimony....., "April 20, 1973. Staff apparently refuses to recognize current progress and state of the art in evaluating K, (see Table 2 in (b) above), where values in excess of 200 are presented for summertime conditions. The Staff selection of values less than 10 for a dispersion coefficient is also quite unrealistic for the freshwater flows selected.

48. Page V-9 par. 2

The Staff's remarks "...applicant's difficulties to maintain 10 fps discharge velocity at all times due to leakage around the discharge ports" and inferences from these remarks are incorrect because (a) the leaks have been fixed and (b) the leaks were of such a nature that difficulty in attaining 10 fps was a problem only at low flows (i.e., I.P. 1 alone). One should note that because of the small thermal load of Unit 1, a minimal velocity would provide the required dilution.

49. Page V-12, and V-13, Table V-1

Commenting only on the computational technique employed by the Staff, and not on the validity of the parameters selected, the Staff's employment of the recirculation factor is incorrect. The area average temperatures is not dependent on recirculation, but only on the dispersion coefficient (E), thermal stratification factor (TSF), heat exchange (or transfer) coefficient (K), fresh water flow (Q_r), plant heat rejection rate (H), and river geometry. Employing the nomenclature used by the Staff (FES I.P. 2 p. III-27), the average temperature, T_A is:

$$\bar{T}_A = \frac{H}{\rho c_p Q_r \sqrt{1 + \frac{4KD}{\rho c_p A}(TSF)E/U^2}}$$

Recirculation affects the spatial temperature distributions across the river, but not the area average value.

50. Page V-19 par. 2

The 100,000 gpm necessary for dilution of chemical wastes during outages is not necessarily service water, but water for any use, including condenser cooling water.

51. Page V-19, Section 2.a(1)

First sentence should read: "The standard chemicals utilized in the primary system are lithium hydroxide and boric acid." Hydrazine is used not in the primary, but in the secondary system.

Add "lithium" after "2.2 ppm."

Add "lithium hydroxide" after "lb/day."

52. Page V-20, Table V -2

See Table attached as Exhibit A.

53. Page V-21

Table V-3 serves no purpose and should be deleted.

54. Page V-22

Paragraph on potassium chromate in "Primary System" should be removed and added to section on "Auxiliary Systems" since potassium chromate is not used in the primary system.

55. Page V-22, Section 2

1st par., second sentence should read: In Unit No. 3 the maximum phosphate concentraton will not exceed 80 ppm. At a maximum expected discharge rate of 40 gpm, the expected maximum sustained release is 38 lbs/day from Unit No.2 or 3, and 15 lbs/day for Unit No. 1.

The reference to the blowdown intertie should be deleted. This intertie will not be used for "chemical treatment."

2nd paragraph, second sentence should read: The expected maximum flow rate is 40 gpm, and the expected sustained release is 1 (2) lb/day during normal operation.

3rd paragraph, 1st line: "neither and or morpholine" should be deleted.

2nd line: add "not" before "exceed"

56. Page V-23 1st line:

"maximum" should be "expected" and "200 gpm" should be "40 gpm"

4th line: "12 (24) lb/day" should be "2.4 (4.8) lb/day."

6th line: "either amine" should be deleted

2nd paragraph 3rd line: "excess" should be "spent"

14th line: "clean" should be "treat"

3rd paragraph - line ten: "discharge" should be "use"

The last sentence should be deleted. The blowdown from the flash evaporator containing the spent sulfuric acid (pH 7.0 to 8.5) is discharged directly to the circulating water.

The following sentence should be added. "No bulk amounts of acids or basis shall be instantaneously discharged without prior neutralization."

4th paragraph - The sentence beginning "The sulfuric acid..." should be deleted.

57. Page V-24 — This page should note that the neutralization facility presently under construction will neutralize all acids and bases from the site demineralization facility.

58. Page V-24, 1st paragraph — The sentence beginning, "Thus a total of 1410..." should be deleted. 960 lbs/day of sulfuric acid of this total is not released as sulfuric acid but as a neutralized salt solution.

2nd paragraph — The last sentence should be deleted and the following substituted: "The spent soda-ash solution is neutralized prior to discharge.

3rd paragraph — The following sentence should be added: "Sears biodegradable detergent will also be used."

59. Page V-25, Section 2.a(3) — In lines 6 and 13, "as Cl_2" should be "as available chlorine."

In the last line, change "40°F" to "45°F."

60. Page V-26, section C.2.b — Applicant does not intent to chlorinate effluents from the sewage treatment facility.

61. Page V-26, section C.3 — The sentence "thus about 23% of the tidal water is used by the once through cooling system" is incorrect for it suggests the plant uses 0.23 x 178,000 cfs or 40,000 cfs. Actual plant usage is 4585 cfs.

62. Page V-27, par. 2, line 6 — change "450,000 gpm" to "450,000 gpd."

63. Page V-28 — The DES should note that the thermal discharges will benefit navigation in the winter by reducing ice conditions and will extend the growing season for aquatic biota. If the DES is to represent analysis of all environmental impacts, favorable ones should be noted as well as unfavorable ones.

64. Page V-28, Section C.4 — No one swims in the area of the discharge structure. The reference to this activity should be deleted.

65. Page V-29 to V-37 — The definitions and values for approach and intake velocities are not consistent throughout this discussion and should be made consistent.

66. Page V-29, Item a. impingement, par. 2 — Alterations of the physical structures surrounding the intakes were effective at reducing impingement. Removal of sheet piling and fixed screens eliminated the trapping effect and enlarging the intake openings reduced the intake velocity.

67. Page V-30, par. 1 — Statement concerning fixed screens contradicts statement on V-29 that changes in physical structures surrounding the intakes did not reduce impingement.

Statement that fish count data from 1967 to 1969 were "not included" implies it is available but not supplied. Count data for this time does not exist.

68. Page V-30, par. 2 — The statement that the impingement was simply shifted from the travelling screens to the fixed screens is not justified. Observations and data make it clear that the installation of fixed screens at the mouths of the intake forebays has reduced the impingement problem.

69. Page V-30, par. 3

The meaning of the last sentence is not clear. An example of Staffs' bias is that, after discussing in detail the periods for which accurate impingement data are unavailable, the Staff fails to mention the period subsequent to December 1970 during which time detailed records have been kept of numbers, size and species of all fish collected on the intake screens.

70. Page V-31

Throughout this discussion of fish impingement, the Staff assumes that any plant-induced mortality is an environmental cost. This constitutes an application of the "as low as practicable" philosophy, which has not been made applicable to environmental matters by any law. This mortality does not properly constitute an environmental cost unless there is an impact on total populations in the river, which has not yet been established and cannot be properly assumed.

71. Page V-31

Impingement data since December 1970 should be included.

72. Page V-31, par. 3

Winter water temperatures are commonly at 32°F.

73. Page V-31, par. 4

Statement that reduced intake velocity is <u>only</u> effective method disagrees with statement on p. V-30 that fixed fine screens are effective.

74. Page V-33, par. 2

During reduced flow operation 40% is recirculated and 60% is passed through plant.

75. Page V-31, par. 2

Statement that fish are exposed to velocities up to 2 fps is inconsistent with velocities given on p. V-33.

76. Page V-32, Fig V-4

Change "Intake Current Velocity" to "Average Velocity*." Also, add the following footnote: "*Velocity measurements were made at several locations throughout the intake bays of Unit No. 1 prior to fixed-screen installation and represent average water velocity in the intake bays, not velocity through the screens."

77. Page V-33 to V-34

In addition to the air bubbler and reduced flow, the flume study should also be mentioned. See comment above on p. iv, Item (j).

78. Page V-34, par. 1

Number of species reported (66) is too high. The number should be 44.

79. Page V-35, par. 3

Daily counting actually started in December 1970.

80. Page V-36

It should also be noted in this section on impingement that the plant may be acting as a scavenger in impinging only the less fit members of fish populations. Evidence clearly indicates that fish impinged on the screens have a significantly lower weight per unit length (up to 30%) than fish in the river. See the I.P. 3 Environmental Report, Appendix BB, page 46.

81. Page V-36, par. 3

The last sentence provides further evidence of the one-sided approach taken by the Staff. Applicant's biologists believe that the design improvements in the Unit No. 3 intake should result in less impingement than at Unit No. 2 but here, unlike the Staff's discussion of entrainment, the Staff seeks operating data before making a prediction.

82. Page V-36, par. 4

The Staff appears to have overlooked the fact that the fixed screens at Unit No. 2 have been replaced by traveling screens at Unit No. 3 which will be washed automatically when the head differential exceeds one foot.

83. Page V-36, par. 5

Cause and effect are known. Cause: intake velocity pulls fish back against screen. Effect: fish dies. Subtleties of the process are unknown.

84. Page V-37, section b, par. 1

In order to be accurate after the word "organisms" on line 4 insert "compensatory mechanisms" and at the end of the paragraph add "as related to the river populations of the species."

85. Page V-37, par. 2

"Consumption" of passive organisms is related not only to rate of water used, but to the mortality of organisms withdrawn.

86. Page V-37, par. 3

Plant does not act like large predator even in case of those organisms killed because it does not consume them. Rather it returns them to the river where they are eaten or decomposed, thus recycled through the food chain. This paragraph implies that all entrained organisms are killed. This is a gross exaggeration.

Statement on relation of combined plant flow being equal to volume of river flow in 2.1 days is very misleading.

This discussion of plant predation should be put into perspective by reference to other forms of predation, such as commercial and sport fishing. Biological comparison between plant predation and removal of sport fish by fishermen should be described.

87. Page V-38

In the discussion of Applicant's position, reference should be made to the contention that the post yolk sac larvae gradually develop swimming ability and at 13-16 mm. (approximately 4 weeks old) move to the shoals thus terminating their planktonic downstream movement.

88. Page V-39

The conclusion of the statements of Applicant's position should refer to the fact that Applicant places little confidence in the ability of these early developmental mathematical models to predict biological effects. Applicant contends that the traditional scientific empirical approach of quantifying aquatic data before and after plant startup, while maintaining detailed data on plant operations and all other river variables, is the only scientifically responsible approach. This view of mathematical models is supported by

the Department of the Interior, which in a letter to the AEC Staff dated May 10, 1973, stated as follows: "The combination of fresh water and tidal flows in the vicinity of the plant site is a complex phenomenon which makes modeling and computation of expected thermal effects extremely difficult and open to doubt and manipulation. Only actual measurement of operational temperatures will determine if a different outfall design will be needed; . . .".

89. Pages V-39 to V-46

These pages contain the discussion of the biological model in a way which is contrary to scientific analysis. There is no evidence to support the concept that the predicted percentages of reduction of striped bass are accurate and the most that can be said is that these reductions may occur depending entirely on the validity of the assumptions that went into the Staff model and the ability of the model to reproduce cause and effect over time. The DES does not indicate whether the Staff has applied its model to predict the difference between the base line and the plants in operation at the present time. Applicant's attempt to use the Staff model in this manner showed that the model completely misrepresented the present status of bass populations in the river. Furthermore, at the bottom of page V-42 there is a discussion of the reasons the predicted reductions could be larger. Where is the corresponding discussion of the factors that could make the predicted reductions smaller?

90. Pages V-39 to V-40

The assumptions used in developing equation (1) are incorrect. The assumption of uniform concentration of organisms through the plant river segment and the failure to allow for intake avoidance by entrainable organis result in unrealistically high probabilities of entrainment (P_t). Also, the method used by the Staff in equation (2) to calculate the effective downstream transport flow (Q_{TR}) is incorrect and yields values of this variable which are unrealistically low. When substituted into equation (1) to calculate the probability of entrainment these values of Q_{TR} yield even higher and more unrealistic values of P_T than indicated in the above comment. The reason equation (2) yields unrealistic values of Q_{TR} is that it fails to account for vertical mixing caused by density differences and tidal turbulence. A detailed criticism of the use of this equation by the Staff can be found in Con Edisons' comments on the Staff's Indian Point Unit 2 DES. (See I.P. 2 FES, Volume II, pages 239-263)

91. Page V-40, par. 1

The relationship of the assumption to reality and the sensitivity of the results to the assumption should at least be set forth in a footnote, together with a range of results reflecting other assumptions.

92. Page V-40 end of par. 3

Very doubtful if any population is maintained solely by local reproduction as implied.

93. Page V-41, fig. V-5

The probability of entrainment (P_T) presented in this figure is unrealistically high for the reasons indicated in the above comment.

94. Page V-42, par. 2

American eel is not likely to be affected because it is relatively unavailable to entrainment and hardy enough to survive entrainment in any case.

American shad not likely to be much affected because shad spawn far up river.

The Indian Point plants do not entrain or impinge a significant number of American shad.

95. Page V-42, par. 3

The data provided in our October 1973 Report "1973 Hudson River Program, Fisheries Summary Data, May-July", supplemented by our December 1973 Report to be released shortly "1973

Hudson River Program, Fisheries Summary Data, August-November", provides far more accurate and reliable data and should be used in any analysis of river populations of young of the year striped bass.

96. Page V-43

Are these plots based on 50% or 100% assumption mortality of entrained organisms? How would it appear if 50% were assumed? Do these also assume no compensation? The presentation of a chart like this, without a clear identification of assumptions, is misleading.

97. Page V-44, par. 2-3 and Figures V-7 and V-8

The predicted reductions in juveniles presented here by the Staff are the result of a math model which, because of several serious flaws, gives unrealistically high estimates of plant entrainment impact. A detailed description of these flaws is presented in the comments below on Appendix B of the DES.

98. Page V-47, Table V-4 and Page V-51

Most of acclimation temperatures quoted are far below summer ambient temperatures at Indian Point; therefore, upper critical temperatures are also low and not relevant to conditon described in top paragraph on Page V-51.

As for tomcod, the small sizes of those occur during winter and late spring, in which case upper critical temperature is far higher than plume temperature that would occur at Indian Point.

There is a "curious" absence of any of the abundant New York University data on summertime temperature tolerance for Hudson River species in this table.

99. Page V-49

Statement that "larval development also requires narrow ranges of temperature" is taken out of context. In stating this, de Sylva was referring to marine species which are much more stenothermal than estuarine species .

100. Page V-51 par 1

Thermal range of metabolic insensitivity undefined. Here Staff says effects are difficult to detect. In section on primary producers Staff says effects would be readily detectable.

Fish and larger invertebrates could prefer or avoid plume to cause changes in composition, but not microcrustaceans or algae. In any case no algae data are referenced in Table V-4.

101. Page V-51, par. 3

No mention of NYU Temperature Tolerance data on earlier life stages submitted for Indian Point Unit 2. See the following:

Rebuttal Testimony of Gerald J. Lauer, Ph.D., on The Temperature Tolerance of Striped Bass Eggs and Larvae Relative to Their Seasonal Occurrence and Expected Indian Point Plant Discharge Temperature dated February 5, 1973.

Duration of expos[illegible] several hours is speculative as indicated.

102. Page V-51, par 1.

Assumption that detrimental effect would be positively correlated with extent and volume of 4° and 6° isotherms indicates that those temperatures increases are detrimental.

This is an unfounded assumption. There is more foundation for concluding that growth, reproduction and species diversity would be increased in those areas.

103. Page V-51, par. 3

The temperature history of the Hudson River indicates 90° will be reached in the Indian Point discharge the second week in July (see Figure 13 of Feb. 5, 1973, testimony of John Lawler "Expected Water Temperature at Indian Point During Entrainment Period").

104. Page V-52, par. 2

The statement "the probability of being exposed to a ΔT of 4°F or greater in moving past Indian Point is 0.37" and its accompanying calculation is incorrect.

105. Page V-52, par. 4

No basis exists for saying this. Spawning location may have and probably does have little to do with temperature.

106. Page 52, par. 4

Raney testified (TR. 5843 and 5983 ff) that behavior of spawners would not be altered by a thermal plume. Merriman reports similar experience.

107. Page V-52, par. 5

Thermal attraction will lead fish to the discharge not the intake. If recirculation causes an increase in temperature at the intake of 1 - 2°F and the discharge produces an increase in temperature of 15°F, there is no question but that the fish will be attracted to the discharge rather than the intake.

108. Page V-53, par. 1

In its discussion of fish in the discharge canal, the Staff has ignored the fact that the 10 ft/sec velocities will normally preclude fish from entering the discharge canal.

109. Page V-53, par. 1

If indeed the plant induces spawning near the plant (and the evidence at other plants is to the contrary) the entrainment losses would thereby be reduced based on the AEC model for they would move downstream sooner where they then become free of plant entrainment.

110. Page V-53, par. 3

The growth rates would be enhanced rather than decreased. At no time will a significant portion of the Hudson River exceed the preferred temperature.

111. Page V-54

Rejection of Dr. Lauer's studies is unwarranted and further evidence of the bias in the DES. The criticism that the pressure studies did not include turbulence and shear is erroneous. Dr. Lauer's pressure tests were conducted in a static pressure chamber.

But he also performed a comparison of intake and discharge mortalities on passage through the plant, which necessarily included the synergistic effects of pressure and the other relevant variables. But, most importantly, what does the Staff substitute for Dr. Lauer's studies? Sheer speculation. The Staff has absolutely no data to support its discussion on this page, which is no more than a theoretical possibility.

112. Page V-54, par. 5

No data supports statement that more organisms will be withdrawn with bubbler screen.

113. Page V-55, Item 3 & V-56

The statement on D.O. levels ranging "from low summer values of 3 ppm to high winter values of 11 ppm" appears to be based on a few data points in a report of Raytheon Company.

Since the Staff has previously agreed that the Raytheon data are probably erroneous (see FES I.P. 2 Volume I, page V-13), Applicant fails to understand why the Staff continues to refer to these data, particularly without reference to the evidence of inaccuracies in the data.

The first T.I. Annual Report, p. II-19 (April 1973) shows mean D.O. levels varying from 5 to 13 ppm. with the variation from station to station showing little relation to plant location, and in many instances being less than the mean variation from surface to bottom.

114. Page V-55

Summary not consistent with preceeding. In any case, NYU's no ΔT operation intake-discharge studies relate directly to this speculation and indicated mortality somewhere between 7 and 39%. Similar range found at ΔT up to 11°F.

1973 data from no ΔT operation show latent effects for larvae collected from discharge no greater than for those collected from intake.

115. Page V-56, par. 1 & 3

Increased metabolism e.g. photosynthesis also, tends to increase D.O. during the day. Net effect could be slight elevation of D.O. in day, slight reduction in D.O. at night in plume.

116. Page V-55, par. 3

An objective report should reflect that the applicant and other power companies on the river are continuing to collect data on the synergistic effects of passage through condensers and better information will be available by 1976.

117. Page V-58, par. 3

Analyses are spurious. D.O. is so variable from place to place that one can pick out data from any two points and have one be lower than the other. There were also many occasions when D.O. in plume was same or higher than outside plume.

118. Page V-54, par. 2

There are no data to support statement of certain damage to gas bladder due to pressure change.

119. Page V-58, par. 2

The first sentence of this paragraph illustrates how the Staff consistently rejects field data collected by the Applicant when it does not support the Staff's speculations. In the Indian Point 2 proceeding, Applicant submitted ample data to show that the impact of plant operations on D.O. is very small. The Staff also ignores the fact that the D.O. of the river at Indian Point has undoubtedly been affected by the BOD of the Standard Brands Company and Peekskill sewer discharges upstream of the plant/

120. Page V-60, par. 1

The evidence is all to the contrary wit[h] respect to growth rates and D.O.

121. Page V-61

The absence of any discussion of the chlorination frequency studies by the Applicant and the % of time chlorination will be used biases the report.

122. Page V-62, par. 2

Organisms were held for 4 days(96 hours

123. Page V-62, par. 4

Clarify the first sentence in item (a). As presently worded, it is unclear.

124. Page V-63, par. 1

Inhibition in plume was at about the level expected based on a dilution of discharged water at sampling point. This doesn't indicate damage was taking place in plume.

125. Page V-63, par. 4

Although the sensitivity of the amperometric technique is superior to that of the ortho-tolidine or Black-Whittle method of analysis, for the concentrations which were found to result in mortality to test organisms, the sensitivity of the latter technique was sufficient.

126. Page V-64, par. 1

Last sentence is sheer speculation.

127. Page V-65, par. 1

The evidence to date at Indian Point supports a contrary conclusion of no deleterious effect of chlorine in the plume.

128. Page V-70, line 6

Should read "1983".

129. Page V-71, line 4

Insert after "years" "by commercial fishing".

130. Page V-72, par. 2

The Staff ignored the potential for extended growing periods of certain organisms caused by the thermal plume and the beneficial consequences it offers. It is further evidence of bias to talk about inhibition of growth during certain portions of the year without also mentioning the stimulation of growth during greater portions of the year.

131. Page V-63, par. 6

Whether or not two of species were not among most common is irrelevant.

132. Page V-65, line 9

On page V-65 the Regulatory Staff asserts "....most of the toxic chlorine components will be in the thermal plume, which will be spread out on the surface.", that is, the thermal discharge from Indian Point (or any other power plant) induces thermal stratification in the Hudson, with the warm water (i.e., the thermal plume) on the surface. Therefore, the thermal stratification factor (TSF), defined as the surface average excess temperature divided by

the area average excess temperature is greater (in fact much greater) than one. The foregoing is inconsistent with the Staff's handling of the degree of stratification of the thermal plume in its analysis of the thermal discharge from Indian Point. The Staff asserts (page V-9) that their parametric studies involved "...varying the values of input parameters over a reasonable range." Yet in the Staff's assignment of TSF's, the value of unity was selected most often (Table A-4, page A-12, -13, out of 47 cases, 29 (61%) has a TSF of unity; and in Table A-6, page A-21, out of 8 cases, 6 (75%) had a value of unity.) A TSF of unity is indicative of a well mixed effluent, without a surface plume. The Applicant has presented field data indicating the existence of TSF's greater than unity - in fact TSF values of about 20 were observed approximately one half mile downstream of the Danskammer power plant (Re-direct-Rebuttal Testimony of John P. Lawler, Ph.D., Quirk, Lawler and Matusky Engineers, on the Thermal Effects of Indian Point Cooling Water on the Hudson River, February 5, 1973).

133. Page V-65, line 3

With regards to the statement "the probability....would also be lessened by chlorination schedules that coincide with peak tidal flows . . . ," the Staff implies that the chlorine will be diluted, not only with the freshwater flow, but also the tidal flow. This is in direct contradiction to Table V-2, p. V-20, where the Staff calculated the chlorine concentration in the Hudson River by assuming the chlorine diluted was only with the freshwater flow.

134. Page V-65

The Staff indicates that the Applicant is conducting a series of bioassays on the exposure of biota to metals. This should be deleted since no such study is being conducted. It has been adequately demonstrated by past investigations that there is no threat to biota from metal discharges at Indian Point. (See IP 3 Environmental Report, Appendix Z).

135. Page V-71, par. 4

Phytoplankton productivity in the Hudson is so low that they probably are much less important than detritus as food. See Howells & Weaver, "Study on Phytoplankton at Indian Point", Proceedings of 2nd Symposium on Hudson River Ecology (1969)

136. Page V-71, par. 5

First sentence fails to acknowledge Lauer data which shows a net increase in assimilative capacity. See:
Testimony of Gerald J. Lauer on Effects of Elevated Temperature and Entrainment on Hudson River Biota, April 5, 1972

137. Page V-71, last par.

Why does the Staff refer to other power plants when Lauer has presented extensive data from Indian Point? Unless the data is obtained at Indian Point, it is essentially irrelevant. The Staff appears to accept Con Edison data only when it shows environmental damage.

138. Page V-72, par. 2

Estimation of complete "reproductive kill" is unwarranted because data show complete kill does not occur.

139. Page V-72, par. 3

Dominance by blue-greens in discharge canals occur at temperature near 90°F and above.

140. Page V-73, par. 1

Much data directly from Indian Point shows that inhibition will not occur at maximum plume temperatures.

141. Page V-73, par. 2

Speculative. Data from site indicate that neither of these types of damage will occur, so neither will secondary effects listed.

142. Page V-73, par.3

Data which Lauer presented supports neither the position in the prior paragraph or in this paragraph.

143. Page V-74, par. 1

The York River results are different with respect to the temperature associated with change than reported by Lauer but not in <u>conflict.</u> Conflict would exist only if someone else's data from Indian Point was different than Lauer's. Data from

Hudson is certainly more relevant to Hudson than data from York. Also, quite a number of other references report data more in agreement with Hudson River data than with York River data.

142. Page V-74, par. 2

Would it not be more fair to say that these "changes can be easily detected by the sampling program the Applicant proposes"? As written the implication is that the sampling program is not "proper".

143. Page V-75, par. 2

Bottom temperatures are not expected to exceed 90°F. So why include the implication that they will?

144. Page V-76 to V-77

Recent Texas Instruments' studies indicate that Neomysis is probably not very important in aquatic community dynamics near Indian Point. This should be noted here.

145. Page V-76, par. 1

Statement on Neomysis is true but Neomysis is not a microzooplankton form.

146. Page V-76, par. 2

Each <u>Neomysis</u> female can reproduce only <u>once</u> but the population probably produces three generations per year, only one of which occurs when <u>Neomysis</u> is present as far north as Indian Point. <u>Gammarus</u> produces two or more generations/year/female, and there are almost always gravid females present during spring, summer and fall

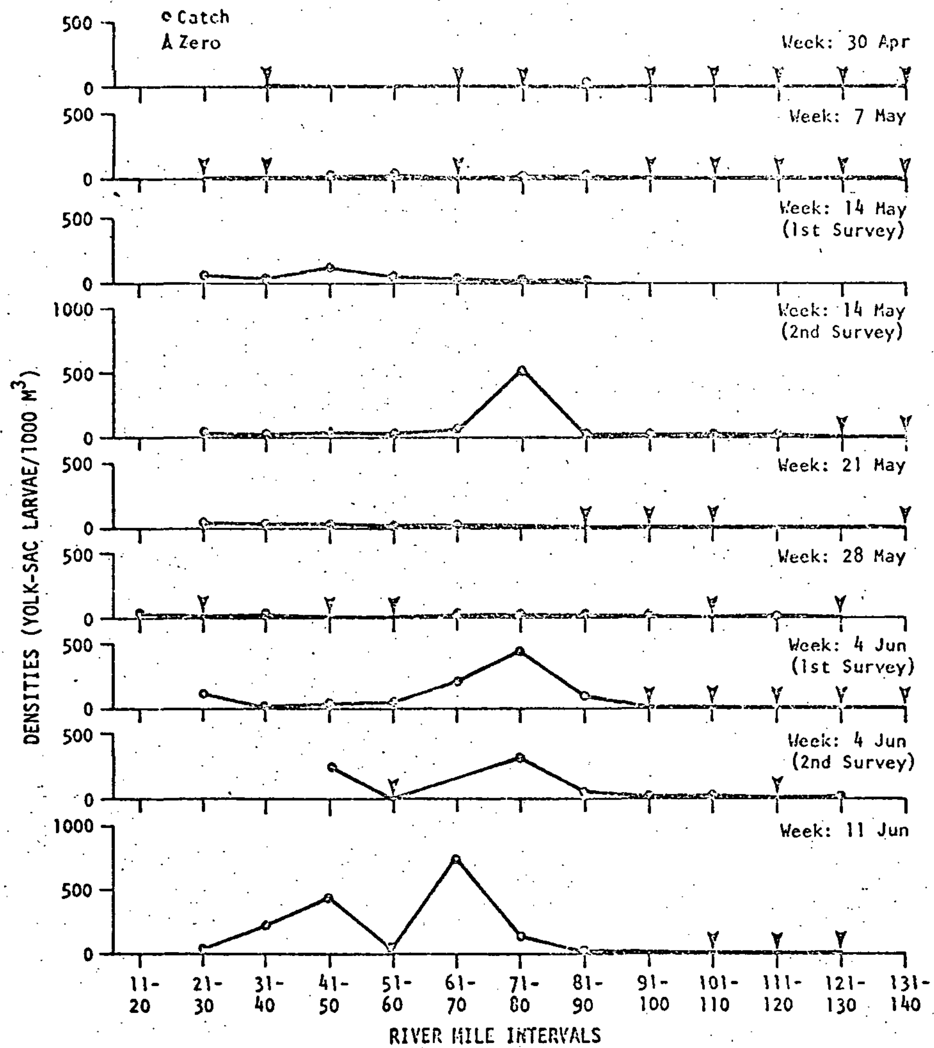
There is no basis for saying they move to get to Indian Point from downstream and then stay there. Rather the Neomysis are probably being continually sloshed back and forth and intermixed longitudinally along the river and adjacent coastal waters by the tidal currents and mixing, at and below the salt front.

147. Page V-77, par. 1

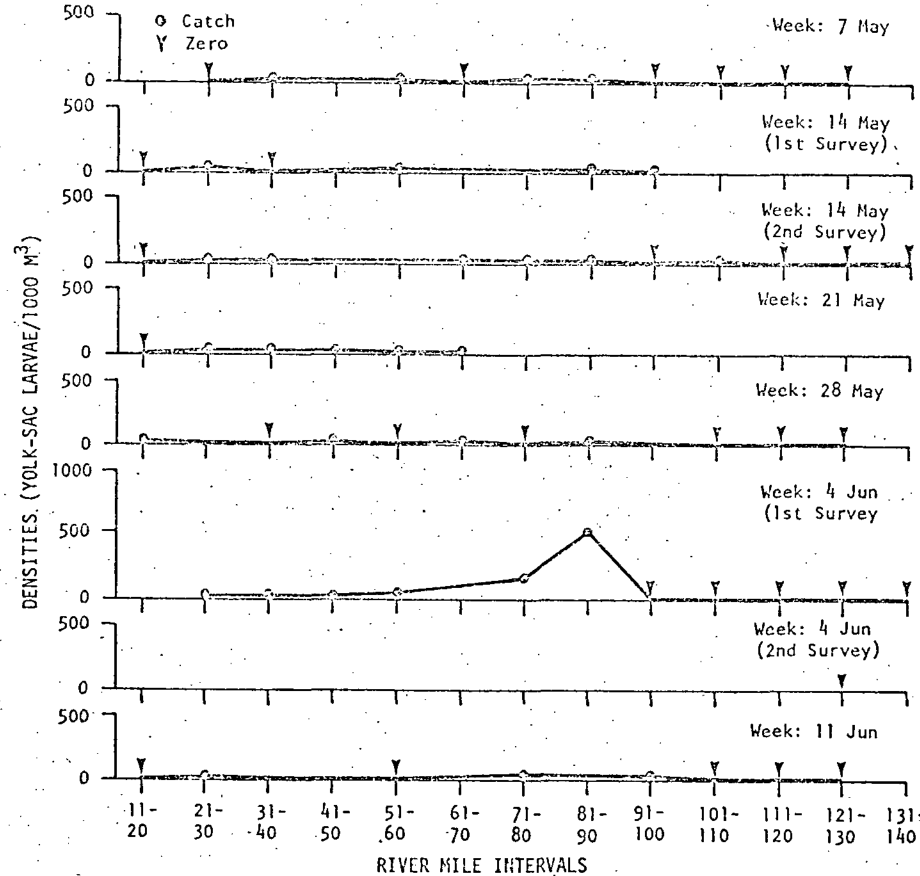
Conclusion completely overlooks the abundant data that <u>Gammarus</u>, not <u>Neomysis</u>, are the principal food item and thus the effect on neomysis (none of which are removed from the food chain in any case) will probably have no identifiable deleterious effect on the recruitment from the nursery.

148. Page V-77, par. 2	Maintenance in zone of preferred salinity is speculative. Neomysis may just avoid fresh water zone or die and settle out if carried into it. The species occurs at least to Montauk Point to the east and to Sandy Hook to the south, so it lives in much higher salinity in most of its regional range than is present at Indian Point.
149. Page V-77, par. 1 and 4	"Unpublished 1972 NYU data indicate that juvenile Neomysis are distributed throughout the salt water portion of the estuary, thus disproving the Staff's suggestion that the Indian Point region may be a nursery area for juvenile Neomysis.
150. Page V-78, par. 3	It is only fair to add at least that "the Applicant maintains that reductions in annual recruitment greater than 25% caused by the plant operation will be detected in the course of the Applicant's study and in time to take corrective action before the change becomes irreversible".
151. Page V-78	In fairness there should be added the conclusion that "in no case will the effect on neomysis be irreversible".
152. Page V-79, par. 1	There is insufficient evidence to support the supposition that longitudinal distribution is controlled by temperature. Other influences such as salinity and hydrology are probably more important. Also there is no basis to suppose that the presence of the thermal plume from Indian Point will cause a greater proportion of spawning in the vicinity of Indian Point.
153. Page V-79	Evidence clearly indicates that the progression from planktonic movement to independent swimming starts at the post yoke sac stage and by 13 to 16 mm (about 4 weeks of age) the larvae are more independent than planktonic and have also acquired an avoidance capability, and exhibit a shoreward and to a lesser extent downstream migration.

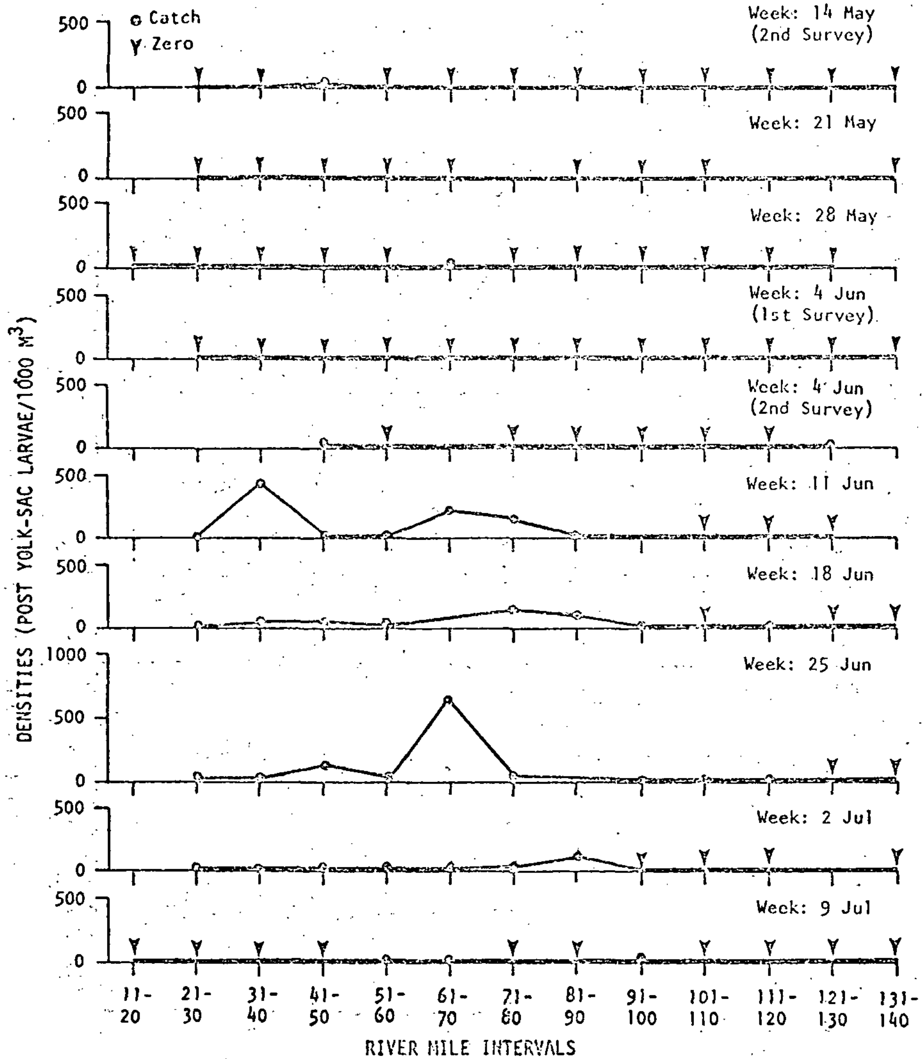
154. page V-17, par. 2.	The statement than 70 to 90% of the surviving juveniles had migrated past Indian Point is not correct. The data presented in Table B-11 only indicates that 70 to 90% were distributed below Indian Point. This does not mean that all of these 70 to 90% migrated past the plant. Some and possibly many of them were spawned below the plant and therefore never passed it.
155. Page V-79, par. 2, last sentence	Our analysis of 1973 data shows that all spawning does not take place above Indian Point.
156. Page V-79 to V-82	Staff's position on downstream migration of young striped bass in relation to entrainment by Indian Point power plant as developed in V-79 to V-82 is based upon data of very poor scientific quality compared to data now available from Applicant's ecological study. These newly available data will be further supplemented by additional studies to be carried out during 1974. Analyses of 1973 studies are not yet complete but preliminary indications are that previously held notions about striped bass abundance, spawning areas, movement of young, and distribution of nursery areas are seriously in error, and that the more accurate view which will be available through 1973 and 1974 studies will not support Staff's predictions of extremely high losses due to entrainment. Furthermore, Applicant's research program is expecte to yield empirical estimates of fraction of young striped bass population entrained, which can be presented free of the assumptions included in the models used in Indian Point #2 hearings
157. Page V-80	Attached are updated charts showing spatial and temporal distribution of striped bass eggs and larvae in 1973. These should be substituted for the charts on page V-80.



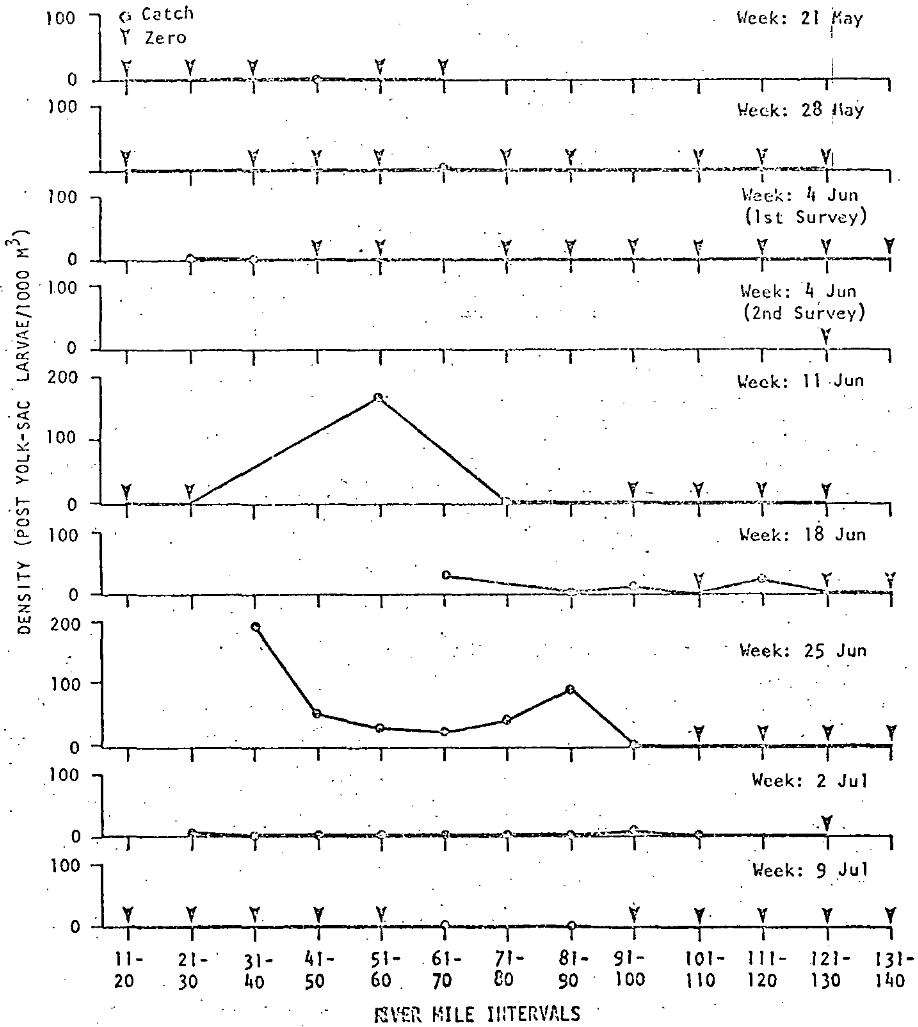
Densities for Striped-Bass Yolk-Sac Larvae (No. /1000 M^3) Collected by Epibenthic Sled in 10-Mi Intervals, Hudson River Estuary, RM 11-140, April-June 1973



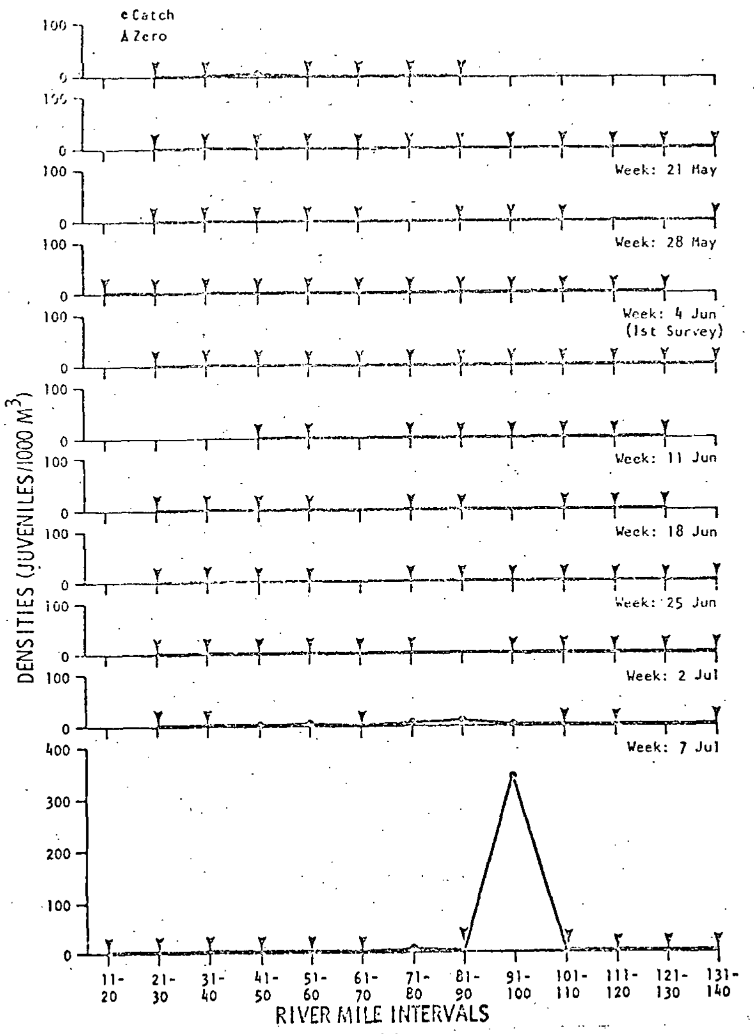
Densities for Striped-Bass Yolk-Sac Larvae (No. /1000 M^3) Collected by Tucker Trawl in 10-Mi Intervals, Hudson River Estuary, RM 11-140, May-June 1973



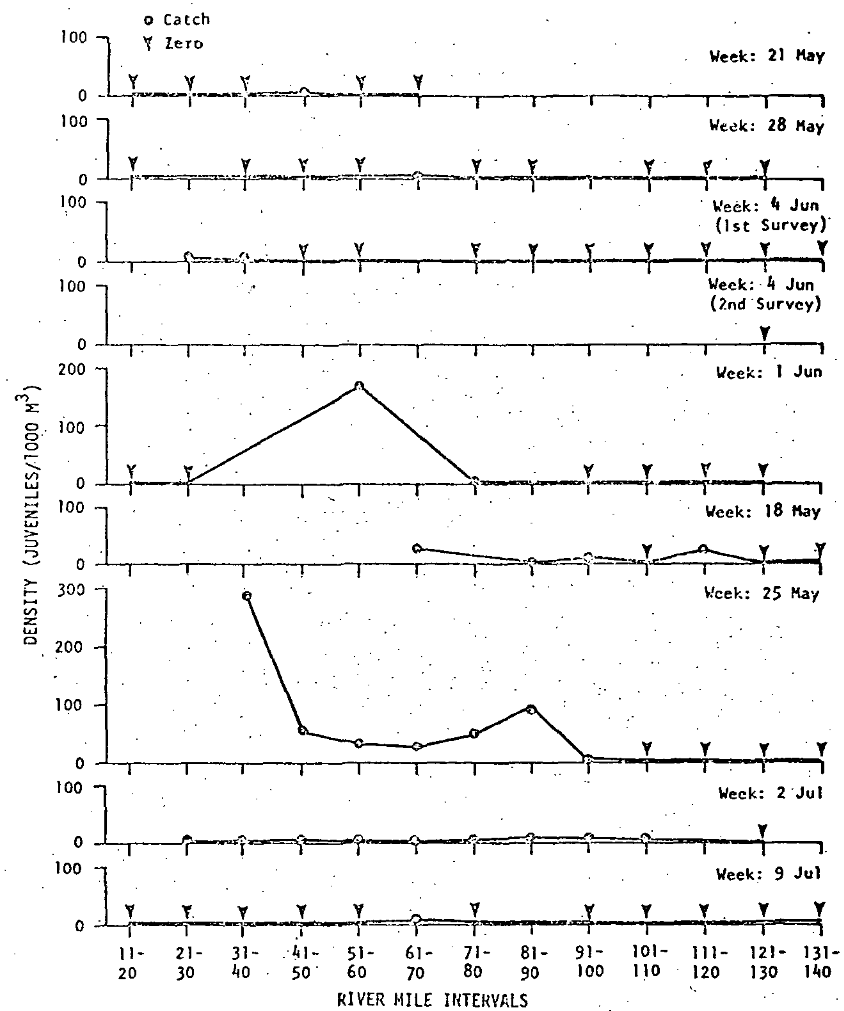
Densities for Striped-Bass Post Yolk-Sac Larvae (No. /1000 M^3) Collected by Epibenthic Sled in 10-Mi Intervals, Hudson River Estuary, RM 11-140, May-July 1973



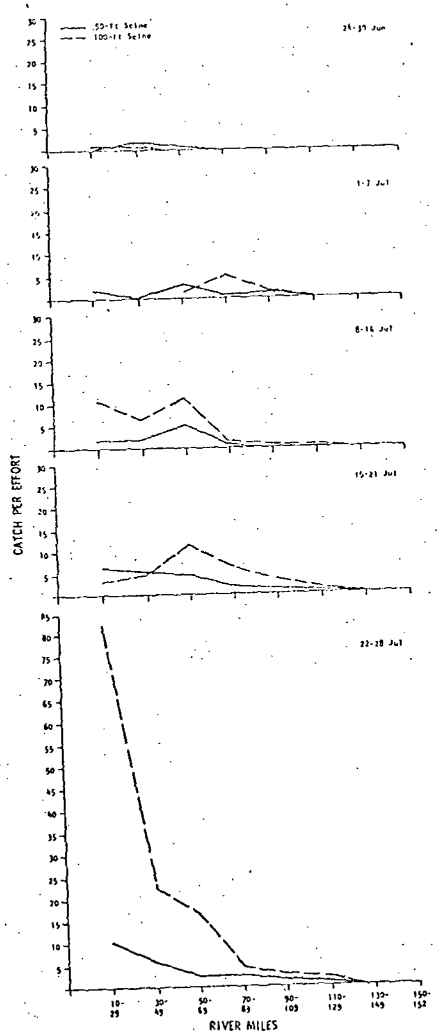
Densities for Striped-Bass Post Yolk-Sac Larvae (No. /1000 M^3) Collected by Tucker Trawl in 10-Mi Intervals, Hudson River Estuary, RM 11-140, May-July 1973



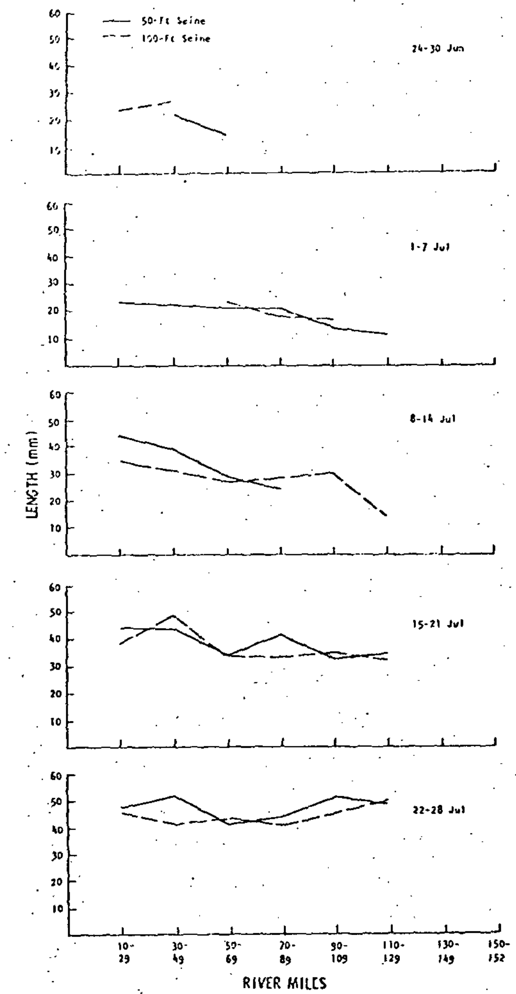
Densities for Striped-Bass Juveniles (No. /1000 M^3) Collected by Epibenthic Sled in 10-Mi Intervals, Hudson River Estuary, RM 11-140, July 1973



Densities for Striped-Bass Juveniles (No. /1000 M^3) Collected by Tucker Trawl in 10-Mi Intervals, Hudson River Estuary, RM 11-140, May-July 1973



Catch per Effort for Young-of-the-Year Striped Bass Captured by 50-Ft and 100-Ft Beach Seines in 20-Mi Intervals, Hudson River, Weekly, 24 June-28 July 1973



Average Total Lengths (mm) of Young-of-the-Year Striped Bass Captured by 50-Ft and 100-Ft Beach Seines, RM 10-152, Hudson River, Weekly, 24 June-28 July 1973

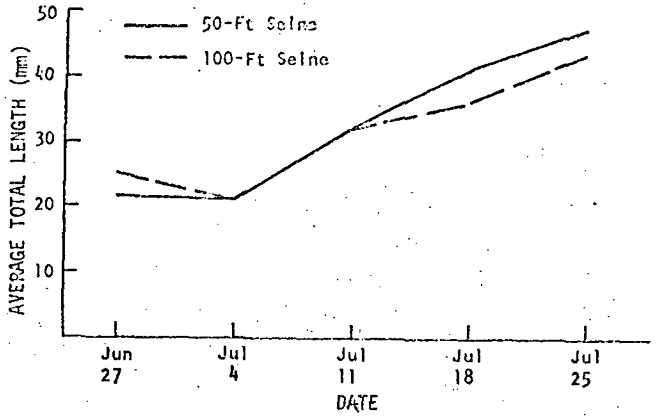
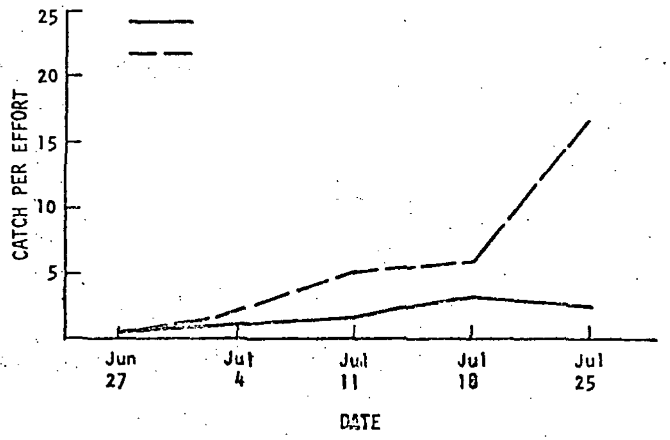
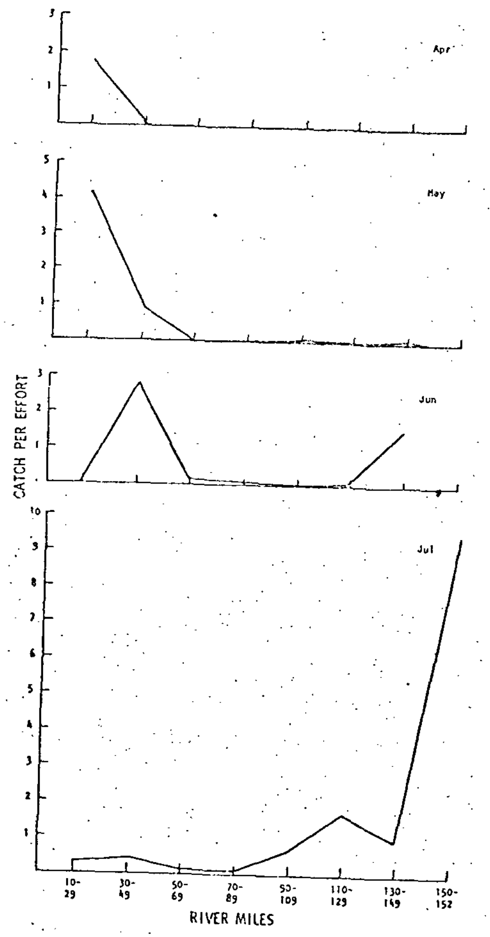


Figure IV-13. Average Total Lengths (mm) of Young-of-the-Year Striped Bass Captured by 50-Ft and 100-Ft Beach Seines in 20-Mi Intervals, Hudson River, Weekly, 24 June-28 July 1973



Catch per Effort for Young-of-the-Year Striped Bass Captured by 50-Ft and 100-Ft Beach Seines in 20-Mi Intervals, Hudson River, Weekly, 24 June-28 July 1973



Catch per Effort for Yearling Striped Bass Captured by 100-Ft Beach Seine, RM 10-152, Hudson River, April-July 1973

158. Page V-81, par. 1

Add "but in no case is the change expected to be irreversible by 1983".

159. Page V-81, par. 2

Although the Applicant has little confidence in the ability of a math model to replicate biologic cycles in the river, it is preparing a third generation model which will reflect variations in abundance and life stage on a real time basis.

160. Page V-82, par. 2

Striped bass are known to be cannibalistic, a form of predation which is generally density dependent.

161. Page V-82, par. 2

The Staff's statement that the major predator on striped bass is man ignores the fact that during its early life stages the striped bass is exposed to many predatory fish whose impact on the striped bass population size can far exceed the impact of man's fishing.

162. Page V-83, par. 3

There are many influences besides food that effect population density, some density dependent such as cannibalism and interspecific predation and predation and competition for food, and some density independent such as storms, run-off, and pollution and fishing intensity which can be either. The widely observed year class fluctuation of striped bass, which has been apparent for 40 years, has yet to be related to a specific cause.

163. Page V-83, par. 3, last line

The fecundity is known to increase naturally as populations decrease. Thus speculating to the contrary withou a full discussion of the alternative would indicate bias in the analysis.

164. Page V-83 & V-84

A definition of a "stable population size" would help particularly in view of the known year class fluctuations of 400% in the Hudson and 300% in the Mid Atlantic.

165. Page V-83

All of the discussion on reproduction strategy leads inescapably to a conclusion that short term effects (less than 10 years) would not be expected to be irreversible.

166. Page V-85, par. 2

The Applicant did supply an estimate of 5% to 10% contribution of the Hudson to the Mid Atlantic (Raney Tr. 5965 - 5973 and 5985 - 5988) Presently planned meristic and electro pheresis studies are expected to provide definitive data that will confirm this hypothesis.

167. Page V-86

The Staff's conclusion that the Hudson is the major contributor to the Mid-Atlantic striped bass fishery because 93% of the variability in recruitment can be attributed to the presence of mature fish in the Hudson is improper. This only demonstrates that a correlation exists and not that the Hudson is the major contributor. An analysis was presented by the Applicant in the Indian Point Unit 2 hearings which demonstrated a similar correlation with the Chesapeake.

A third analysis between Mid-Atlantic and combined Hudson/Chesapeake landings showed an even higher correlation than the above two. Also, under cross examination in this hearing the Staff admitted 1) That this method of analysis could not be used to prove a hypothesis but only to show that one cannot be rejected; and 2) That the variations in Mid-Atlantic and Hudson landings could very well both be the results of a third factor such as climate or fishing effort, rather than cause and effect themselves. This should be noted here in the DES.

168. Page V-83, par. 2

The first sentence of par. 2, page V-83 is misleading on two counts. First, regulation of a prey population by factors such as predation or competition with another species does not, indeed cannot by definition, take place independent of the density of the prey population. Regardless of whether the process is intra specific or inter specific, regulation of a population involves feedback from its own density. Second, a population which is regulated by inter specific factors <u>can</u> compensate for changes in survivorship of other individuals in the population (taken to mean individuals other than those upon which the interspecific factor referred to impinges). Unless the population has been driven to such a low level of abundance that every potential compensatory process was operative, additional mortality imposed on, say, the juveniles, might reduce population density to a level where one of the following occurrs: (a) lower juvenile density triggers compensatory response in juvenile stage, (b) lower juvenile density results in lower adult density and population stability at the new, lower, average density due to compensatory response of the fishery; (c) lower juvenile density results in lower adult density and population stabilized at the new, lower, average density due to compensatory response other than the fishery-possibly an increase in survival when some natural predator switched from less abundant striped bass to other food resources.

169. Page V-83 to V-84

The last par. of V-83 and first par. of V-84 repeat the misleading dissociation of prey population density from regulation by predation cited in the first part of the preceeding comment here. If predation is regulating a population (i.e. if it is a compensatory process) then it involves feedback from prey population density and it produces effects similar (possibly identical) to those of intraspecific regulation. Applicant agrees that predation need not be a regulatory process - that it can be density independent, or even inversely density dependent (depensatory; creates positive feedback).

170. Page V-86 to V-92

Staff analyses on pages V-86 through V-92 are seriously wrong methodological and logically and the conclusions reached are utterly without substance.

171. Page V-86

The Staff's failure to even mention here the many studies that reach a contrary conclusion which are discussed in Appendix F is reflection of bias.

172. Page V-91, par. 3

The Staff's bias is again illustrated by their continued reference to an alleged decline in populations of white perch. Populations fluctuate naturally and, by selecting a temporary downward fluctuation, the Staff projects a continuing decline. Furthermore, the theory that impingement at Unit No. 1 could have caused the decline in 1965-69 is obviously false because impingement problems recurred in late 1969 and 1970. It would appear obvious to an unbiased writer that the reduced impingement in the intervening years was caused by improvements in the intake structure design.

173. Page V-91, par. 3

Not true that NYU data indicated decline in white perch between 1965-1969. The data were too variable to indicate anything by professional interpretation, as already debated in Unit 2 hearings.

174. Page V-95

Contrary to Staff position in paragraphs 1 and 2, page V-95, that impacts on fish populations of the drastic proportions predicted by Staff and intervenors can be readily detected through changes in fish population parameters measured in the ongoing ecological study. Had lower impacts been predicted by Staff, the Applicant's field studies might not have been sensitive enough to detect them. However, the position taken by Staff has been that impacts on fish populations will be serious because they will be massive. This position is inconsistent with the view that the ecological studies underway cannot detect the postulated serious change.

175. Page V-92, figure V-15

No consideration is given to the method of haul, the season, the net size, or mesh size, which must be included in order to avoid possible bias. For example, if beach seines in 1969 were taken in areas or times of low concentrations as compared to 1967, they would necessarily have a lower catch-per-unit-effort. The white perch must be considered a migratory species in its first year.

176. Page V-94

The Applicant holds that the fish species in the Hudson having significant social value are limited to striped bass and shad. Other aquatic species are significant to the extent they are a vital link in the food chain of one of these two species. The evidence that shad are not impinged and that young of the year are spawned and reared past the first life stage of passively floating planktonic larvae is clear evidence of the validity of the Applicant's conclusion.

177. Page V-94, par. 2

More than 1700 megawatts of once through cooling have been added to the lower Hudson since 1949. If that is minor, then by definition the addition of Indian Point 2 and 3 must be minor.

178. Page V-95, par. 1

We are not trying to determine any irreversible damage in two years. We do intend to determine if the operation of the plant will reduce annual recruitment by the amounts speculated by the Staff.
We are committed to take the appropriate mitigating measure (including the alternative of the construction of cooling towers) should such losses be identified. Thus the last sentence is irrelevant and misleading.

179. Page V-97

The "general concurrence" in paragraph (3) is not clear. The preceeding paragraph on the position of HRFA contains several points, some substantive and some unsupported attacks on the honesty and integrity of Con Edison and its consultants. The Final Environmental Statement should clarify the concurrence, and the Staff should disassociate itself from this attack.

180. Page V-97

The staff again states that the Applicant must "conclusively demonstrate no unacceptable adverse impact on the fisheries. This standard is not only contrary to law, but contrary to scientific method which depends on statistical significance of results rather than conclusive demonstration. Thus, by adopting this standard, the staff has placed upon applicant a burden which is not only illegal but which cannot be achieved through scientific procedures. The Staff certainly cannot "conclusively demonstrate" its prediction of environmental damage.

181. Page V-98

Objectives 2, 3, 4 in part, and 5 in part, are being pursued by NYU, not T.I. as indicated.

182. Page V-100, par. 3

The Applicant does not intend to use the striped bass transport model as the basis for the conclusions to be drawn from the study. The conclusions will be based on the data, not on the mathematical model.

183. Page V-102

It is simply not true that no baseline of prior environmental measurements exists to be used as a control for new measurements made concurrent with start up of Indian Point Units 2 and 3. Significant studies have been carried out since the mid 1960's. These are well known to Staff who have used them to formulate their present position. Applicant has outlined in detail the continuity for comparative purposes which exists between these earlier studies and the present ecological studies.

184. Page V-103, par. 3

Staff's allegation that "the applicant has formulated his hypothesis in a way that allows the applicant to derive benefit from poor experimental design or careless execution of the required sampling" is untrue and completely contradictory to statistical theory and scientific method. The choice used in the form of statement of null hypothesis:

a) is consistent with universally accepted scientific procedures;
b) does not preclude Applicant, Staff or intervenors from establishing and testing different hypotheses with data from past and ongoing ecological studies.

c) has not led to experimental or sampling designs in the research program which are importantly different from those which would have been employed had the hypotheses been stated in a different way;

d) confers absolutely no benefit on the applicant from deliberate or accidental carelessness in conducting the research programs;

e) does not in any way preclude use of the "interval estimation" approach to statistical analysis of research data, which approach applicant intends to use along with the "hypothesis testing" approach in order to provide the most complete and understandable analysis of research findings attainable.

Poor experimental design or careless execution of sampling would work to great disadvantage of the Applicant. Greater sample size would be required to reach satisfactory levels of precision in the data, thereby increasing the cost of research. More important, anything which increases the sampling variability of research data widens the confidence interval around estimates and thereby admits of a larger probability of severe environmental impact even if the point estimates indicate moderate or no impact.

185. Page V-104, par. 1

The first sentence is grossly erroneous and is another indication of bias. The Applicant has never proposed "research as an alternative to closed cycle cooling systems".

186. Page V-105, par. 1

The estimate of impingement was conditioned heavily. Experience at Indian Point 2 since making a projection on Indian Point 1 statistics indicates impingement rates at 1/10th of the Indian Point 1 extrapolations.

187. Page V-105, last par.

Probability of entrainment should not be equated to mortality.

188. Page V-106

There are considerable data from studies at the site on many of these points and experience says the Staff is wrong or over-exaggerates. Valid cost-benefit analysis would require evaluation of the most probable level of environmental effects, rather than the maximum possible approach that the Staff has taken.

189. Page V-108

The last sentence makes a factual prediction which is not supported by the preceeding analysis, since it was largely in terms of potential adverse impacts. Also, the Staff fails to state how long it would take to create "irreparable damage".

190. Page V-111, fig. V-17

The figure is not totally correct. The corrected version is attached as Exhibit B.

191. Page V-113

The Staff estimates steam generator blowdown to be 10 gpm. Blowdown rates are, however, expected to be about 5 gpm per steam generator for a total continuous blowdown rate of 20 gpm.

192. Page V-117 to V-122

There appears to be an inconsistency concerning monitoring of gaseous releases. At the bottom of p. V-117 the Staff says that all paths except turbine hall ventilation air will be monitored. On p. V-122 they indicate that the Indian Point Unit No. 1 Blowdown Flash Tank vent releases will not be monitored. This path will be monitored indirectly for I-131 by sampling and analyzing the liquid blowdown upstream and downstream of the flash tank.

In addition, the releases from the Indian Point Unit No. 3 Blowdown-Flash Tank vent will not be monitored. The maximum releases from this path will be so low (less than 0.04 Ci/yr) that monitoring is not considered necessary.

193. Page V-122, item 6 — Delete "through the plant vent".

194. Page V-122, item 7 — The sentence starting with "after treatment..." should be changed to read "prior to treatment..."

195. Page VI-6 — The Staff states that accidental criticality for new fuel shipments is "impossible for all meaningful purposes." It is, therefore, illogical to discuss the hypothetical results of the impossible accident.

196. Page VII-1 to VII-5 — This discussion of adverse environmental effects which cannot be avoided is limited to the plant as presently designed. Since the AEC Staff is recommending the construction of natural draft cooling towers, the adverse effects of these towers should be discussed in at least equivalent detail.

197. Page VII-2, par. 2 — The present version should be deleted and the following substituted: "The visual impact from some historical landmarks on the west bank of the Hudson will be different viewing the nuclear facilities than the amusement park previously located at Indian Point. The architectural style, building massing, organized site development, as well as the appearance of building materials are esthetically superior to most other industrial or commercial facilities situated along the estuary."

198. Page VII-4, item b — The concept of relating the water withdrawal rate of the plant to the freshwater flow is misleading. It implies that the plant withdraws only fresh water, and makes no allowance for the tidal flows past the plant.

199. Page VII-5, par. 2, line 3 — To be consistent with the analysis, this should read "effects which <u>might</u> occur <u>would be</u> to the aquatic environment **".

200. Page VII-5, par. 2 — More recent data suggest the 3 million will be substantially reduced.

201. Page VII-5, par. 3 — Chlorination will also be limited to selected river temperatures and in frequency.

202. Page VII-7, par. 2 — Long term should be defined. Nothing has been presented to indicate that operation of once through cooling through 1983 can have these effects.

203. Page VII-6 — The sentence starting with "The staff will require ..." should be changed to read: "The staff will require that, subject to feasibility studies, the total residual chlorine concentration at the point of discharge into the Hudson River shall not exceed 0.1 ppm."

204. Page VII-7 — In the first paragraph, the Staff includes American shad among the species most likely to be affected by the plant. Extensive studies have shown that American shad is not significantly affected by either impingement or entrainment by the Indian Point plants.

205. Page VII-7, par. 2 — The fact that phytoplankton in Hudson are light-limited, combined with relatively short exposure time to elevated temperature above 3 to 4 °F and experience from other plants, indicates that effects on phytoplankton will be slight.

206. Page VII-7, par. 3 — Entire paragraph is speculation not based on facts.

207. Page VII-7, par. 4 — A similar relationship exists by this kind of analysis between Atlantic and Chesapeake landings.

208. Page VII-8, par. 1 — At issue in this case is the definition of a few years. The Staff has provided no analysis to support the view that from 1975 to 1983 is more than a few years.

209. Page VII-8 — Among the additional adverse impacts due to the operation of wet natural - draft cooling towers, land use effects, noise and economic impact should be added.

210. Page VII-8, Par. 2 — If mortality of entrained striped bass 50% instead of 100%, then by staff's own analyses the present once through system starts to approach the 15% loss the staff projects for the closed cycle system. See p. XI-34.

Adverse effects on other biota are only assumed by Staff and are not supported by data.

211. Page VIII-1, Item A, Par. 2 — "national park area" should be "natural park area."

212. Page VIII-3, Par. 1 — The statement "Further quantification of long-term effects seems irrelevant to the basic objective of preventing significant damage to the fishery resources of the Hudson River" is inconsistent with the requirement that decisions be made by a balancing of costs and benefits, which have been quantified whenever possible.

213. IX - General Comments — Since the Staff is proposing the construction of cooling towers at Indian Point, this chapter should include a discussion of irreversible and irretrievable commitments of resources resulting from that recommendation. Such a discussion should properly include not only the land and materials required for the towers but also the irretrievable scenic losses and the possible losses caused by the emission of air pollutants from the towers.

214. Page XI-1, par. B2 — Classifying as irreversible, biospecies destroyed indicates a lack of understanding of the definition of aquatic biosystems.

215. Page X-1, par. B2 — Add "initially" before "40% of the Roseton Station Capacity".

216. Page X-19 — Table X-7, the schedule of capacity additions and retirements, including dates of initial service or shutdown, is properly listed. However, the projected capacity, load and reserve as a result of these changes improperly shows capacity which is to be installed or retired after a given summer capability period but before the end of the year as being either added or removed before that summer capability period rather than by the next summer period. The effect of this error is to increase the capacity apparently available in most of the summer capability periods.

In addition, the following items in the table should be changed, as winter rather than summer ratings were given:

Gas Turbines (location undecided)
Spring 1976 550 MW

Gas Turbines (location undecided)
Spring 1977 220 MW

217. Page X-26 — The Draft states that Con Edison has recently announced plans to build five 1100 MW baseload units in the 1980's. At the present time Con Edison has not announced specific plans for these plants, but rather, has included provision in its 20 year generation expansion program for such units to maintain reserve levels consistent with our long range load forecast. If and when firm plans are made for any of these units, they will be specified in future changes to our 20 year generation expansion program.

218. XI-1 General Comments — The Benefit/Cost Analysis performed by the AEC Staff does not consider carrying charges in the determination of generating costs and incremental generating costs with cooling towers installed. Accordingly, their analysis does not reflect the true revenue requirements which will be incurred by Con Edison if a cooling tower were installed. Moreover, the AEC Staff analysis does not consider the cost of replacement capacity and energy during plant downtime to allow cut-in of the cooling tower. The effect of these omissions is to understate the cost of the cooling tower for Indian Point No. 3.

219. Page XI-14, line 12 & line 21 — Change "periodically" to "continuously" and "400" to "500" feet high.

220. Page XI-14 — The adverse salt drift effects are expected to attack the leaves by percolation and root absorption.

221. Page XI-4

Energy conservation suggests shutting these old plants down as soon as possibl because of their high heat rate and high atmospheric discharge rate per kw of power generated.

222 Page XI-6

Since the Staff concludes that it is not appropriate to consider alternative types of plants, it is not appropriate to include the discussion of alternative plants which follows that statement.

223 Page XI-7 to XI-9.

Costs estimates for coal and oil fired units are not representative of Con Edison's costs in New York City. For example, Astoria 6, an 800 MWe, oil-fired unit may cost Con Edison $310/Kwe.

224. Page XI-14 to XI-15

AEC Staff fails to describe and assess environmental effects of alternate cooling systems to the same degree that the AEC Staff assesses the damage caused by once-through cooling systems, see comments which follow.

225. Page XI-15

On page XI-15, the Staff referred to a recent article (Reference 16 of Section XI) on the construction and design time requirement for a natural-draft cooling tower. The Staff misinterpreted the content of this report, and erroneously implies that construction of the system is complete. According to Ecodyne Cooling Products division, the designer and builder of the 350-foot Ecokel natural draft tower, the erection of the hyperbolic shell structure was indeed completed just over a year after the start of foundation work on May 16, 1972. (Site preparation including any excavation, land fill, etc. must be completed prior to foundation construction.) However, in order to complete the installation of all other components, such as water distribution systems, cooling fill and supporting columns, drift eliminator, etc., the total time requirement would be about two and a half years. As of November 16, 1973, the

construction work was still going on and will not be completed by the end of 1974.

This tower was originally designed for Miami Fort Station No. 7, a 500 MWe fossil plant. But the design was modified to handle the additional heat load from Unit No. 8, the other 500 MWe fossil plant. The dimensions of the hyperbolic shell itself remains intact, but the size of the internal cooling "fill" section has been doubled to accommodate the higher heat load. From the thermodynamic point of view, since the cooling air flow rate could not possibly be doubled without increasing the tower diameter, the tower "approach" must be increased for closed-cycle operation. This would increase the turbine back pressure, which in turn would increase the turbine derating.

Therefore, comparing the present single tower design to a hypothetical two-tower system for the two 500 MWe units, the former system will cause higher turbine derating during the entire service life of the cooling tower. The additional incremental generating cost due to higher derating might not be compensated by the lower initial construction cost.

226. Page XI-16

The statement that wet towers have minimal impact cannot be supported by data and should be deleted.

The discussion of dry cooling towers fails to mention that such towers cannot operate under all conditions with the existing turbine generator.

227. Page XI-18

The AEC Staff does not lack land or location requirements. They toured the site and have access to detailed plot plans.

228. Page XI-19

The Staff states that a natural draft tower would extend more than 350 feet above surrounding vegetation. It would be more accurate to state "more than 500 feet".

The statement "...noise levels outside the immediate perimeter of the towers usually do not exceed background levels" is unfounded. The estimate of 50 dB (A) at 2500 feet can be interpolated to 80 dB (A) at 80 feet. This estimate is in substantial agreement with actual field data, taken by Ostergaard Associates, for Con Edison. These preliminary data range from 83-99 dB (A) at the tower rim to 75-80 dB (A) at 80 feet, to an average of 54 dB (A) at 1000 feet. It is certainly reasonable to suggest that natural draft cooling tower noise emissions will exceed background (sound) levels.

Concerning the statement "...the applicant's information suggests that sound levels attributable to the towers will be exceeded by those generated by vehicular traffic along Broadway, which exceed 60 dB (A) more than 50% of the time...," the applicant agrees that the noise primarily generated by traffic along Broadway exceeds 60 dB (A) more than 50% of the time.

However, this statement is valid for only the increment of time during which community (traffic) sound levels were measured. These measurements along Broadway were taken during daytime and were, at best one hour in duration. It is more appropriate to compare cooling tower noise emissions to the (background) sound levels that exist more than 90% (L_{90}) of this time, especially during the quieter nighttime hours. Data taken near Broadway during nighttime (ER, IP-3 Section 22, page 4.2-2, 4.2-5: Point 6) indicate background sound levels (L_{90}) below 40 dB (A). Additionally, this nighttime data indicates that community noise exceeded a level of only 40 dB (A) more than 50% of the time.

The additive effect of the operation of natural-draft cooling towers was not estimated. It can be reasonably anticipated that approximately 53 dB (A) (average) at 2500 feet will result from the operation of two natural-draft

towers of similar size, for both Units 2 and 3

The directional aspects of noise from large complexes of mechanical draft towers must not be overestimated, as cell units are placed mostly in series and the cased surface area is relatively small. The louvered faces of such complexes, both for Unit No. 2 and 3, would substantially face the nearby community. The approximate sound level, at 5000 feet, from the operation of two complexes would be 63 dB (A).

As stated in the DES "...mechanical-draft towers for Unit No. 3 will produce a sound level of 50 dB (A) at a distance of 5000 feet...". Estimated sound levels of 50 dB (A) at 5000 feet can be interpolated to 66 dB (A) at the Broadway property line. This suggests that some of the 745 residents will be exposed to sound levels as high as 66 dB (A), which according to the proposed HUD criteria are "clearly unacceptable".

The applicant recognizes the potential detrimental sound impact due to the operation and construction of either natural-draft or mechanical-draft cooling towers. A study undertaken by an independent acoustical consultant will examine the existing day and nighttime community sound levels and estimate the intrusion and subsequent environmental costs caused by the operation and construction of these alternate cooling systems.

The results of salt deposition studies mentioned for the Forked River plant are not applicable to Indian Point because of the different types of flora existing in and near the Indian Point site.

230. Page XI-21 Line 3-7

Reference is made to the fact that water containing 640 to 1280 ppm of total salts is suitable for supplemental irrigation of plants having low salt tolerance. The conclusion drawn from this point, that drift deposition from cooling towers is unlikely to cause vegetative damage, is faulty. The amount of vegetative damage due to salt to a particular plant is different depending upon whether the salt is taken in through the roots or impact on the leaf directly. The reference in question deals only with vegetative damage by means of root uptake and not with direct leaf impaction.

231. Page XI-21 Lines 9-14

Reference is made to the Forked River Nuclear Station Unit 1 Natural Draft Salt Water Cooling Tower study entitled Assessment of Environmental Effects, which "suggests that average nearground concentrations of drift salts are a factor of 40 to 100 below levels known to affect the general vigor and distribution of plants (i.e., 0.23 to 0.1 ug/m^3)." The species of plants used to make this assumption are species indigenous to the Forked River area which is in an area in close proximity to a large salt aerosol source (i.e., the Atlantic Ocean). Those indigenous species in order to survive must be salt resistant. The Indian Point area is not as close to such a salt aerosol source and the vegetative species indigenous to the natural ecosystem have not had to be as salt resistant to survive. Therefore, conclusions drawn from the Forked River Study concerning plant susceptibility may not hold ture for the Indian Point site.

It should also be noted that on page 39 of the Forked River Study the statement is made, " Experiments indicated there was also variable response of individual plants within the same species." This particular

statement shows that plant response is not clearly defined, and preliminary results of our Boyce Thompson study are showing that the relative susceptibilities of plants to salt aerosols are more complex than previously assumed.

Existing data on plant susceptibility very often does not account for changes in temperature, relative humidity, degree of light and size of the salt particle. All of these factors are being shown to be important parameters in the determination of plant susceptibility.

The effects of salt spray on vegetation indigenous to the Indian Point area can only be known by empirical methods given the poor reproducibility of existing and past data. Empirical results in this area are now being performed by the Boyce Thompson Institute for Con Edison and it would be premature to make conclusions without this specific empirical data.

232. Page XI-22 Lines 32-34

It is stated that, "In practice, it becomes quite difficult to separate vegetation damage related to foliar deposition from that caused by uptake of salts from soil solution." This is an erroneous statement as a controlled experiment has been designed and is being carried out by Boyce Thompson for Con Edison to estimate the risk of vegetative injury related to only foliar deposition of a salt aerosol of cooling tower origin.

233. Page XI-29

The figure "319,000 gpm" should be "318,000 gpm".

234. Page XI-32, par. 1

Probability of entrainment cannot be assumed equivalent to loss. All phytoplankton and zooplankton entrained into closed cycle cooling systems will be killed compared to essentially no phytoplankton and variable percentages of zooplankton in once-through, except during chlorination when high mortality is expected.

235. Page XI-26, par. 1

If the effects of other water users are to be combined in determining a need to mitigate damage, then alternate mitigating measures by all users including fishermen should be considered in any NEPA balancing of alternatives and in the selection of the alternative that maximizes public benefit at minimum public cost.

236. Page XI-31, Table XI-6

This table erroneously equates plant mortality with environmental costs when the effect on the populations of socially significant species should be a measure of the costs, or to be more precise, of the reduction in income from commercial fishing and the loss of recreation days.

237. Page XI-31

It is erroneous in a cost-benefit analysis to indicate impingement losses as an environmental cost without any relationship to total fish populations of the river. If impingement at the plant has no impact on the total fish populations of the river, as may well be the case, then the environmental cost of impingement is zero.

238. Page XI-32, par. 2

Projection for all other fish species is unfounded since many species are not subject to entrainment.

239. Page XI-34 to XI-37

It is not clear that the portions of these tables and figures designated "50% mortality" only assume 50% mortality for the plants with open-cycle cooling. The plants with closed-cycle cooling should of course compute 100% mortality in all cases.

240. Pages XI-34 to XI-37

Although these charts and tables indicate results of the base design at 60% flow, alternative A is analyzed only at full flow. If alternative A were adopted, Con Edison would operate Units Nos. 1 and 3 with reduced flow during the cold portions of the year. Accordingly, alternative A should be reanalyzed with reduced flow or a reduced flow analysis should be added to alternative A in these charts and tables.

241. Page XI-35, Table XI-8

Table should be revised to reflect 50% mortality for once-through cooling and 100% for closed-cycle in all cases. The comparable figures should similarly be modified.

242. Page XI-38

The assumption by the Staff that biological damage is proportional to the volume of water within a specified isotherm (i.e. 4°F and 6°F isotherms), is improper because it fails to consider:

1) that the critical isotherm will probably vary for different species at different life stages and seasons of the year.
2) that the time of exposure to increased temperature greatly affects the occurrence of biological damage.
3) that the distribution of organisms in the river is non-uniform.
4) that some organisms can use their motive ability to avoid entering the plume.

The Staff's assumption that there will be a reduction in D.O. in the plume is probably not valid since the aeration effect of water turbulence along with oxygen production from phytoplankton should offset any oxygen consumed by increased metabolism of oxygen consumers.

243. Page XI-39 and XI-40 Table XI-10 and XI-11

Table XI-10 gives, for the base design at 100%, a volume of 66,000 ft^3 of water inside the 4°F excess temperature isotherm. If this excess isotherm was concentrated at the plane of discharge (where the cross sectional area is approximately 160,000 ft^2, the width of this isotherm is approximately (66,000/160,000) 0.41 ft. Or, if one uses the width of the discharge structure* (250 ft)

* This is apparently how the staff determined its number of 66,600 ft^3 (see page A-10, Table A-3)

and assumes all the heat is concentrated in this region, the corresponding cross-sectional area is (66,600/250) 270 ft^2, which is (270/160,000) = 0.16% of the River cross sectional area. This does not even approach the values presented by the staff in table A-4.

Table XI-11 presents, for the distance along the river where the excess temperature exceeds 4°F, a value of 15 miles (base case, 100% flow). If one combines this value with the volume presented in Table XI-10, 66,600 ft^3 (see above), one gets an average width of the 4°F isotherm of (66,600/15x5, 280) 0.85 ft. This suggests an extremely thin ribbon for the 4°F excess isotherm which would not contravene the state criteria.

244. Page XI-41

The Staff suggested that the blowdown could be held up to allow sunlight to decompose excess residual chlorine prior to discharge to the river (page XI-41). This is not a practical method for Indian Point.

245. Page XI-45

The Staff's figure of 15,000,000 juveniles which would have to be replaced by a hatchery is not consistent with table XI-8 which presents the results of the Staff's entrainment model for Indian Point Units 1, 2, and 3. This table shows a <u>maximum</u> reduction in juveniles caused by Indian Point of 7,500,000 (13,500,000 baseline population minus 6,000,000 if plants are operated). Average population reductions shown in this table are 5,500,000 fish (assuming 100% entrainment mortality) and 3,700,000 fish (assuming 50% entrainment mortality). Not only does the 15,000,000 figure cited by the Staff far exceed these figures, it even exceeds the 13,900,000 maximum baseline population predicted by the Staff's model if there were no plants operating.

Also, unpublished verbal communication from the 21 state and federal rearing facilities using striped bass furnished by Monck's Corner indicates that in 1973 a composite survival of 9% from egg to fingerling size was

obtained. In light of this the 1.4% survival estimated by the Staff is too low.

246. Page XI-46, par. 1

We commend the Staff for this conclusion and urge it be a basis for permitting the Applicant to complete and report upon its study before imposing the irreversible burden of closed-cycle cooling on our customers.

247. Page XI-46, par. (VI) 2, last sentence

Here the Staff again mistakenly deals in the priceless value of one food source and recreational experience contrary to NEPA and Federal Policy as set forth in Senate Document 97.

248. Page XI-46

The Staff states that the hatchery program would be a means to mitigate damage done to the striped bass fishery during interim plant operation. If this is acceptable as a mitigation measure, it would seem that operation with the once-through cooling system could be allowed until sufficient data is obtained to reach better environmental decisions.

249. Page XI-47, last par.

We agree with the Department of Interior (see comment on p. V-39) concerning the doubtful results of mathematical models relating to thermal plumes and suggest that the doubts increase geometrically as uncertainties of life systems are added. One must thus conclude that the probability of the results of a biomodel at this stage of development can be accepted with confidence only suggests that confidence is misplaced.

250. Page XI-49

The Staff has taken information on costs for a single tower at Unit No. 2 from the Environmental Report for Unit No. 2 instead of the more recent analysis presented in the testimony of Carl L. Newman dated April 9, 1973, in the Unit No. 2 licensing proceeding.

251. Page XI-50, lines 3-7.

The Staff should indicate what steps would be appropriate to minimize drift losses and subsequent salt deposition.

252. Page XI-50

The 400-foot meteorological tower is fully operational at this time.

253. Page XI-51

The flume study should also be mentioned here.

254. Page XI-51, Item E., Par. 1

The channel walls at Unit 3 do not have openings at the bottom to allow lateral movement of fish. The channel walls do not extend beyond the travelling screens. Lateral freedom is provided by placing the travelling screens at the river's edge and by placing the bar racks on pillars which do not obstruct the flow.

255. Page XI-51, Par. 2

The 0.5 ft/sec. approach velocity is for the area directly in front of the travelling screens, not the trash bar racks.

Present plans call for reduction of flow rate by construction of a recirculation loop as was done at Indian Point 2, rather than by two-speed pumps.

256. Page XI-51, Par. 4

The velocities for the common intake structure are designed as 0.5 ft/sec. in summer and 0.3 ft/sec. in winter and would be "less" only if one of the units were down.

257. Page XI-52, Par. 2

Staff states that no method of fish protection was effective except for the air bubble curtain. This is in disagreement with a previous statement that reduced flow was reducing fish impingement.

258. Page XI-52

Con Edison now estimates the cost of installing the common intake structure at $18 million.

259. Page XI-56

Computation of "regional product" substantially underestimates the product. The calculation is based on the number of households in Applicant's service area. This ignores the fact that Con Edison's service area is probably responsible for a large part

of the regional income of surrounding communities. If environmental costs are considered to include impacts on the striped bass population of the New England Coast and the Mid-Atlantic, certainly the calculation of benefits from the plant should include consideration of impact on the surrounding communities. Also, no valid reason appears for omitting the income multiplier referred to in the last sentence of this section. And finally, the prorating of the regional product to Unit No. 3 was based on percent of future generating capacity (MW) instead of future generation(MWHRS). The result of correcting all these errors would be a number considerably higher than $2.1 billion.

260. Page XI-57

The employment is incorrect for the same reasons the regional product is wrong (see above comment on Page XI-56).

Kerosene should be noted as being 0.05% sulfur, not 0.5% sulfur.

As stated, a reduction in atmospheric emissions will improve air quality. However, with the latest cooling tower design, the 83 MW(e) derating would have to be made up using fossil-fueled plants.

261. Page XI-58

Since the AEC Staff is recommending installation of wet natural draft cooling towers, this table should include a statement of the environmental damage from salt drift.

262. Page XI-59

The calculations for generating costs are grossly underestimated. The major omission is that of cost of capital. The Staff apparently assumes that money to construct cooling towers will be made available to Con Edison without charge. This is highly erroneous. In Con Edison's testimony in the Indian Point 2 proceeding, a composite cost of capital of 8-3/4 percent was used in order to comply with AEC guidelines then in existence, but Con Edison's actual costs are higher, recently estimated at 9.375 percent. This figure is undergoing upward revision to reflect recent increases in the cost of capital.

In addition, the calculation is erroneous for the following reasons:

a. The Staff omitted the cost of replacement power for plant down-time during final "cut-in" of the cooling tower. The Staff assumes the cut-in could be accomplished without downtime. This assumption has no foundation in fact.

b. The Staff amortized the cost of the cooling tower system over the 30-year life of the plant. This does not take into account the fact that the plant will probably operate for approximately five years without a cooling tower system. Accordingly, the cooling tower system should be depreciated over 25 years.

c. The Staff admittedly failed to include taxes for no apparent reason. Taxes are real expenses and recognized as such by all accounting authorities.

263.	Page XI-67	The present value and annualized generating costs are wrong for the above reasons.
264.	Page XI-67, Item (1)	Staff should provide method for estimating numbers and weight of fish impinged with various alternatives.
265.	Page XI-69	The AEC Staff does not evaluate the damaging devaluation which will result to neighboring property from alternative cooling system requirements.
266.	Page XI-70	The Staff should state why 1981 or 1983 would not be suitable as alternatives to 1978 as target dates for operation of cooling towers at Indian Point, especially since during interim operation the applicant would take all practicable steps to minimize any adverse impact of the plant.
267.	Page XI-73, item d (2)	Delete "and trash racks." No fish are impinged on trash racks.

APPENDIX A

(1)	Appendix A	Staff's analyses of thermal impact for the facility should be based on the license requested for Unit 3, not the plant's maximum calculated capacity.
(2)	Page A-11, Item (3)	See comment concerning pages V-9 to V-18 for remarks on the Staff's selection of parameters for model.
(3)	Page A-18, 19	Comments on the Staff's analyses have been previously presented by Applicant. ("Additional Testimony of John P. Lawler, Ph. D., on the cummulative Effects of Bowline, Roseton and Indian Point Generating Stations on the Hudson River," March 30, 1973, and "A response by John P. Lawler, Ph. D., on Additional Information Requested by the staff on the Temperature Section in our March 30, 1973, Testimony...," April 20, 1973.). Reiterating the salient points:

a. The instantaneous water velocity profile presented by the staff

$$U(t) = U_f + U_{max}\sin(\frac{t}{T_d})$$

where:

U_f = freshwater velocity
$U(t)$ = instantaneous water velocity
U_{max} = maximum tidal velocity
T_d = tidal period
t = time

is incorrect, for it ignores the phase lag along the river, i.e., the time of maximum velocity is different at, for example, Bowline and Roseton* plants.

b. The Staff's analyses ignores the presence of thermal stratification (i.e., plume buoyancy) in its model, by employing a thermal stratification factor of unity.

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*In its simplest case, the time of ebb and flood varies along the river

APPENDIX B

(1) Pages B-11 to B-40

Results of the 1973 Texas Instruments' riverwide ichthyoplankton and beach seining programs should be included in this section. See comment concerning pages V-79 to V-81.

(2) Pages B-41 to B-55

The model presented in this section by the AEC Staff is similar to that presented by the staff in the Indian Point Unit 2 hearings. Prominent flaws in this model which result in an unrealistic overestimate of plant entrainment effect on striped bass include:

1) the improper use of daily average tidal flows and larval vertical distributions without including terms to represent deviations from these averages within the 24 hour period. This generates a continuous circulation belt of larval organisms passing Indian Point.

2) the use of segment averaged concentration of larvae in the Indian Point river segment for withdrawal concentrations rather than the upper layer concentrations.

3) the absence of a compensatory mechanism to control population growth and decline.

4) the inability of the model to predict the impact of plant operation on adult populations of striped bass.

These flaws are described in detail in the testimony of Dr. John P. Lawler in the Indian Point Unit 2 Hearings.*

*February 5, 1973 testimony of John P. Lawler, Ph. D. on the Mathematical Model used by the Staff to Estimate the Effect of Indian Point Units 1 and 2 Entrainment on Hudson River Striped Bass. (Docket No. 50-247)

February 20, 1973 testimony of John P. Lawler, Ph. D. on the Mathematical Model used by the Staff to Estimate the Effect of Indian Point Units 1 and 2 Entrainment on Hudson River Striped Bass. (Docket No. 50-247)

(3) Page B-49

The egg release function with temperature (Fig. B-14) appears to be a hypothesis which is not substantiated with calculations or comparison with 1966 or 1967 [illegible] spawn distributions.

(4) Page B-51

The additional mortality encountered when early stages transfer from one age group to the next (Fig. B-15) also appears to be an unsubstantiated hypothesis.

APPENDIX E

(1) The tables should be relabelled with the standard meteorological notation as supplied in the ER. The listed tables will tend to confuse analysis and interpretation.

Calms should be stated. The extremely low frequencies reported are significant to the meteorology of the site.

APPENDIX F

(1) Page F-1

The Staff commences this discussion with the statement that the contribution from the Hudson to the Mid-Atlantic fishery is 80%. The following pages do not support such a specific figure. The first five pages discuss studies entirely consistent with Applicant's position. Commencing in the middle of page F-6, there is a theoretical attack on these analyses which, at most, establishes that the source of Mid-Atlantic striped bass is presently unknown. The figure of 80% is not substantiated.

(2) Pages F-3 to F-9

A substantial portion of the discussion involves the interpretation of tagged recoveries. This entire discussion assumes that the percentage of tag returns are equal to percentage contribution. This is only true if the exploitation rate (not discussed) is the same for all populations.

(3) Page F-4

In the 7th line from the bottom, the word "lighter" should read "higher".

(4) Page F-6

The 2nd line should read "...South Beach between 1961 and 1963, may have been of Hudson origin. As indicated earlier, however, most striped..."

(5) Page F-6

The assumption that a bass captured in the winter would spawn in that area is not only unsupported by any data but is contradicted by several observations. In the Indian Point 2 hearings, Dr. Raney described the wintering of striped bass in the Connecticut River where it is well known they do not spawn. See also Vladykov & Wallace, 1952. Accordingly, the discussion following this assumption is erroneous.

(6) Page F-6

The logic of the last paragraph which makes four recaptures in the Hudson greater than seven recaptures in the Chesapeake is spurious, particularly when one considers the above comment on intensity of fishing rates. Furthermore, it is unlikely that the four fish recaptured in the Hudson were potential spawners since only eleven of the 103 tagged fish were large enough to be mature.

(7) Pages F-7 to F-8

The refutation of the well-accepted Merriman position on the origin of striped bass is still unconvincing. First, it is highly likely that two-year-old fish, although generally non-migratory, will migrate in years of large year classes because of overcrowding. Furthermore, the statement on page F-8, "It is apparent from tagging data in the Chesapeake area that two-year-old fish are not migrating out of the bay to any significant extent" is simply not true. The study referred to shows that a small percentage of Chesapeake Bay stock could be a very large number of fish in view of the substantially greater spawning areas in the tributaries to Chesapeake Bay compared to the spawning areas in the Hudson River. The Staff also fails to mention the basis for Merriman's conclusions, which the Staff acknowledges are generally accepted.

1) Page G-3, last par. 1.3

"The following weather conditions..." This statement is misleading in as much at it implies the weather conditions are representative or typical of what one may expect at the site. The purpose of the weather conditions is for general illustrative representation and should be stated as such in the assumptive manner.

2) Page G-5, par. 2

In reference to "plume rise", specific mention of plume definition is required. Plume rise is generally considered the centerline value; however, vertical and lateral dimensions must also be specified.

3) Page G-5, par. 5, last sentence

Comments on the plume penetration local inversions should either be clarified or described in a manner so the possibility of plume trapping by an elevated inversion is also qualitatively described.

4) Page G-5, par. 1, 1.5

"...suspended in the form of fog", Any suspended moisture that condenses aloft is meteorologically classified as a cloud. Fog is a cloud, based at the ground.

5) Page G-7, par. 2, line 6

The obvious qualifications on using wet-bulb temperature from Poughkeepsie and applying it to the Peekskill area should be explained along with the assumptions made in utilizing the data. The proximity of Peekskill to the Hudson River compared to the inland Poughkeepsie station should be stated. Also, low level meteorological wind sensors and vertical temperature measurements were used to predict plume dispersion at elevations of several thousand feet. Therefore, the accuracy of this procedure must be stated, especially when considering that the wind sensors were in the valley micrometeorological regime.

6) Page G-8

Only the drift and salt deposition were considered in the analyses, not the effect of airborne salt concentrations causing an increase in ambient salt. This effect can subject the vegetation to a higher salt concentration and is a different process than deposition.

(7) Page G-14

Reference should be made to the company onsite research effort to obtain data required for a realistic assessment of cooling tower plume behavior. A 400 foot AGL meteorological tower was erected to collect wind, temperature and humidity data characteristic of the area. Extensive ambient salt concentration and deposition measurements are also collected. Additionally, the company is funding research on a cooling tower plume dispersion model and a cooling tower field observation program.

Table V-2. Maximum sustained discharges of chemicals to the Hudson River from the Indian Point Plant (Units Nos. 1,2, and 3)

	Sustained release (lb/day)			Total Concentration in discharge canal (ppm)[a]	Increase in concentration in Hudson River (ppm)[b]	Applicant's proposed limits for discharge canal (ppm)[c]
	Unit No. 1	Unit No. 2	Unit No. 3			
Sodium phosphate (as PO_4)	15	38	38	0.084	0.0047	1.5
Hydrazine	24[m]	1	1	0.0017	0.00009	0.1
Cyclohexylamine	2.5	2.4	2.4	0.004	0.0002	0.1
Lithium hydroxide (as Li)[d]	0.66	0.66	0.66	0.006	0.00037	0.01
Boric acid (as B)[d]	600	600	600	1.5[d]	0.083	9.0
Potassium chromate (as Cr)		30	30	0.05[k]	0.003[k]	0.05
Sodium hydroxide	156[o]	12[e]	12[e]	0.24[d]	0.013	
Sulfuric acid	450[n]			9.0	0.5	
Soda ash (as Na_2CO_3)	1,000[g]					5
Detergent[h]	3[i]			0.03	0.002	1
Copper (See Text)						
Zinc (See Text)						
Residual chlorine	73[j]	215[j]	215[j]	0.5[p]	0.026[q]	0.5
Chlorine reaction products	73[j]	215[j]	215[j]	0.5[p]	0.026[q]	

Notes to Table V-2

[a]Based on 100,000 gpm flow in discharge canal.

[b]Based on 4,000 cfs (1.8×10^6 gpm) freshwater flow in Hudson River.

[c]ER, IP-3, p.10-8.

[d]Released only in case of evaporator breakdown of Unit #2 and Unit #3.

[e]Release at this rate for 2 hr/day once every four to seven days.

[f]A maximum of 20 lb/hr of concentrated sulfuric acid is used in the flash evaporation of river water for makeup water. The resultant blowdown has a pH of 7.0 to 8.5. No acid is discharged.

[g]Release at this rate for 12 hr two to four times a year. Reaction products neutralized prior to discharge.

[h]Colgate Low Foam detergent consisting of 26.5% sodium phosphate, 28% sodium sulfate, 10% sodium carbonate, 6% silicates, 15.5% benzene sulfate, 10% unspecified nonionics, and ~4% water, or Sears Biodegradable detergent.

[i]Release at this rate for 2 hr/day.

[j]See Text.

[k]Based on continuous system leakage and discharge of 25 gpm and an evaporator breakdown. All planned releases will be collected and processed prior to release.

[m]Released once/year.

[n]Released at this rate for 1 hr, once/day. A system is to be installed to neutralize this waste.

[o]120 lbs released once/day for hr. 36 lbs/day sustained release.

[p]Effluent chlorine conc. given as 0.5 mg/l, considers only dilution by other side of Unit 3.

[q]River concentration of 0.026 mg/l considers only river dilution, no river chlorine demand. Demand reactions are considered in Section 2.a(3).

EXHIBIT B

V-111

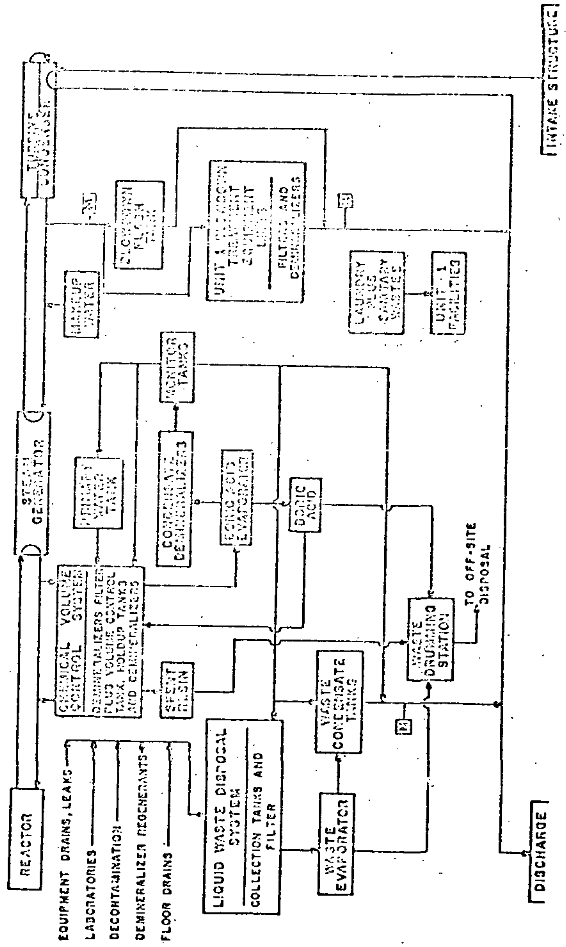

Fig. V-17 Liquid radioactive waste treatment systems for Indian Point Unit No. 3.

FEDERATED CONSERVATIONISTS OF WESTCHESTER COUNTY, INC.
Dedicated to environmental planning and education for the preservation of our natural resources.
Box 1306, Marymount College, Tarrytown, New York 10591 (914) 631-8336

December 7, 1973

U.S. Atomic Energy Commission
Attention: Deputy Director for Reactor Projects
Directorate of Licensing
Washington, D.C. 20545

This letter is to comment on the Draft Environmental Statement for Indian Point No. 3 (A.E.C. Docket No. 50-286).

Federated Conservationists of Westchester County, Inc. is a coordinating group of 59 organizations in Westchester County concerned with environmental problems in the county, including the nuclear generating facilities at Indian Point and the Hudson itself.

As indicative of the breadth of our interest in these problems, attached hereto and made a part of this comment is the Statement of Policy of the organization, dated March 10, 1971, with reference to the proposed licensing of Indian Point No. 2.

Leaving to experts more particular comment with regard to the Draft Environmental Statement, we commend the AEC for its recommended installation of cooling towers. We believe any delay in the erection of the cooling towers should be rejected as an impermissible relaxation of the utility's responsibility to the Hudson. In the meantime, until cooling towers are installed, the utility should be required to avoid maximum operational strain on the fish life in the river. Other aspects of study to minimize fish kills in the pre-cooling tower period, a clearer cost-benefit analysis, and a coordinated study of the Indian Point-Storm King impact is essential.

We renew our suggestion, both to the AEC and Consolidated Edison itself, that it get effective independent outside help to assist it in solving its environmental problems; those who are expert in producing power at the least cost are not necessarily the best people to determine questions of meeting necessary standards of air and water quality, of aggressively pressing for alternatives in terms of transmission, generation, and storage of electricity, or of relating the utility's responsibility to environmental goals. Just as a utility has accountants to go over its

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books, and independent certification of its accounts, it would do well to have independent environmental experts undertake its compliance programs, and to subject its operations to a periodic environmental audit by outside and independent environmental experts.

This is particularly crucial now that we are, as predicted, moving into a period of energy shortages in all areas; the energy crisis must not be the occasion for public utilities to allow problems of management and planning to obscure the importance of environmental controls. Rather, it should be taken as a challenge to continue to produce energy at the most efficient and economical rate and, at the same time, to redouble and make more effective efforts to find environmental solutions in all phases of operation, from generation through storage and transmission to the consumer.

Mrs. David C. Donaldson, President
Federated Conservationists
of Westchester County, Inc.

FEDERATED CONSERVATIONISTS OF WESTCHESTER COUNTY, INC.
Dedicated to environmental planning and education for the preservation of our natural resources.
20 Soundview Avenue, White Plains, New York 10606 (914) 761-3493

March 10, 1971

Statement of Policy
by the
Federated Conservationists of Westchester County, Inc.

With reference to the Proposed
Licensing of a Nuclear Generating
Station at Indian Point, New York
(Indian Point No. 2)

We are aware of the need for power in the New York metropolitan area, and of the technological incapacity of Consolidated Edison to meet these needs. And yet, the power emergency is as much an emergency in terms of corporate and political leadership as it is in terms of electrical power, a default in leadership that does not yet relate its responsibilities to the growing need for environmental conservation and protection.

It is against this background that we address ourselves to the burden of full environmental responsibility resting on those who would build nuclear plants.

To the extent that its rules accord with recognition of its full environmental responsibility,and its actions are consistent with this responsibility in these matters, the Atomic Energy Commission will properly acquit itself of its duty. To the extent that it does any less, it is subject to legitimate environmental criticism and subject to such changes in its organization, powers, and procedures as Congress may eventually determine to be necessary to bring the Commission's functions and operation into harmony with the environment.

This responsibility, in short, rests both upon Consolidated Edison Company and the Atomic Energy Commission, since they are so closely related in the planning and construction of the proposed facility, that they assume the full burden of proof that the proposed plant will not damage the environment or adversely affect the public health and safety. In the absence of having met such burden, the plant should not be licensed for operation until this burden is met. Indeed, until this burden is met, we are moved on a broader basis to urge that a moratorium be imposed on all new nuclear plants.

The particular areas of environmental impact with regard to which we would like to have more information to establish the proposed plant's compliance with environmental standards are:-

1- Taken in conjunction with existing and proposed utilities' construction in the area, to what extent will this proposed use of the waters of the Hudson add a thermal increment to those waters; and can the utility and the Atomic Energy Commission establish by a fair preponderance of the evidence that such thermal increment will have no adverse effect on the ecological balance of the River, or adversely affect its marine life?

2- To what extent, taken together with existing and proposed construction, will the proposed installation add radioactive elements, in the low level range, to our air and water; and can the utility and the Atomic Energy Commission, in connection with their proposed plant, establish that the cumulative effect of such low level radioactive waste will have no adverse effect upon the chain of life, or upon the mutation rate, or in terms of cancer?

3- To what extent will the proposed installation, taken by itself, create a danger of nuclear excursion through malfunction of the unit, or through sabotage resulting from breach of security, or unfriendly act; and can the utility and the Atomic Energy Commission guarantee that the installation will cause no danger to life or property of those living in the New York metropolitan region?

Would the utility, in the absence of Government insurance against catastrophe, be prepared to construct and operate the proposed plant and to secure conventional insurance at rates to be set by underwriters on the basis of their independent evaluation of the risks involved?

4- To what extent will the proposed construction result in possible contamination of neighboring areas running into the next century through long-lived radioactive elements in the installation housing; and what provisions, after termination of the use of the plant, are there for removing the installation housing to prevent possible contamination of ground water levels?

5- To what extent is the utility prepared to adjust its plans to natural, scenic and esthetic considerations, and to protect the natural values and scenic beauty of the Hudson and of Westchester by screening or undergrounding its plants, and by undergrounding the overhead transmission lines that now disfigure the county, the Hudson Valley and the region?

6- To what extent is the utility and the Atomic Energy Commission prepared to guarantee that the transportation of radioactive elements from and to this and other installations existing and proposed for the Hudson and Long Island Sound regions will not adversely affect the health and safety of the people ot Westchester and of the New York metropolitan region?

We ask the assistance of independent scientists, particularly those in the biological field, to review and advise us, the utility and the Atomic Energy Commission with regard to these problems, and to assist our planning officials to proceed wisely and carefully with the major problem of reconciling planning to meet our reasonable energy needs with the requirements of protecting the environment.

Marilyn C. Bowler
President
Federated Conservationists of Westchester County, Inc.

ROCKLAND COUNTY Conservation ASSOCIATION, INC.

Ruth C. Hardy, Corresponding Secretary
Pomona Country Club, Spring Valley, N.Y. 10977

December 11, 1973

50-286

To: United States Atomic Energy Commission
Att: Deputy Director for Reactor Projects,
Directorate of Licensing
Washington, D. C. 20545

Re: Draft Environmental Statement by the Directorate of Licensing, U. S. Atomic Energy Commission related to the operation of Indian Point Nuclear Generating plant, Unit # 3

From: Rockland County Conservation Association, Inc.
Statement prepared by Mrs. Robert W. Pugh, First Vice-President
231 McNamara Road, Spring Valley, N. Y. 10977

The construction of atomic energy plants and especially those at Indian Point have always been of major concern to the Rockland County Conservation Association, situated as they are just a few miles to the northeast of our county. Our association is a member of the National Intervenors and support its activities and favor a moratorium in the building of atomic fission plants. We believe that the dangers of nuclear plants are irreversible and a legacy that we should be ashamed to foist on future generations.

It now appears that Indian Plant # 2 might be put into operation. The stand taken by the Atomic Energy Commission that it must have cooling towers is to be commended - inadequate as that precaution might be.

We know from first hand experience about the fish kills at Indian Point, and that especially high kill of the winter of 1969-70 when fish attracted to the thermal discharge from Plant # 1 were sucked into the intake screens resulting in literally a cres of dead fish. The sea gulls mercifully removed the holocaust. Mr. Lawler, of the Engineering firm of Quirk, Lawler and Matuske, attributed the fish kill to human fraility - the fact that the intake screens had become clogged - He was our speaker at one of our Quarterly meetings.

If human fraility could result in this serious fish kill for a plant of 265 MWe (I'P. # 1) we shudder to think of what could happen to a plant of 873 MWe (I.P. # 3) should human fraility again be a factor. Consolidated Edison has illustrated in the operation of Indian Point # 1 that to date it has no completely successful means of eliminating fish kills.

Thermal polution depends on dilution to minimize its effect - a factor that will become increasingly difficult as plants increase along the river. No definitive study has ever been made of the metabolic changes and chain reaction which will result in the raising of the temperature of the Hudson. A prolonged summer heat spell resulting in increased energy consumption and peak performances of all plants along the river; accompanied by a lack

8916

ROCKLAND COUNTY Conservation ASSOCIATION, INC.

Ruth C. Hardy, Corresponding Secretary
Pomona Country Club, Spring Valley, N.Y. 10977

of rainfall minimizing tidal action, could raise river temperatures to such heights as to result in permanent damage to all forms of aquatic life. At the top of the biological chain are the fish - a priceless food and recreational resource. Existing information on the Hudson River is inadequate to predict accurately the long term impact on all aquatic organisms and the ecological consequences.

We urge that the Atomic Energy Commission take a stronger stand on Indian Point # 3 and mandate a closed-cycle cooling system from the beginning of its operation. In fact we favor cooling systems on all existing plants.

The agencies requested to comment on the Draft Environmental Statement do not include any totally private agency financed by independent means whose sole concern shall be to analyze scientifically the long term impact to all forms of biological life by the operation of power plants along the Hudson River. We believe that the Atomic Energy Commission should take the leadership in legislation that would tax all power companies their proportionateshare to finance such on-going studies. We know from experience that Utilities should not be given the sole responsibility of monitoring the environmental impact of their operations.

ENVIRONMENTAL DEFENSE FUND

162 OLD TOWN ROAD, EAST SETAUKET, N.Y. 11733/516 751-5191

50-286

RECEIVED DEC 13 1973 U.S. ATOMIC ENERGY COMMISSION Regulatory Mail Section

December 10, 1973

U.S. Atomic Energy Commission
Deputy Director for Reactor Projects
Directorate of Licensing
Washington, D. C. 20545

RE: Draft Environmental Statement for Indian Point Unit No. 3
[AEC Docket Number 50-286]

Dear Sirs:

Having participated actively in an examination of the environmental impacts of Indian Point Unit No. 2, the Environmental Defense Fund reiterates its position in that licensing proceeding (AEC Docket No. 50-247). The issue before the staff regarding Indian Point Unit No. 3 is perfectly parallel to that delineated in the licensing of Indian Point Unit No. 2.

EDF calls the attention of the staff to a recent publication by John Clark and Willard Brownell entitled "Electric Power Plants in the Coastal Zone: Environmental Issues," American Littoral Society Special Publication No. 7, October 1973 (published December 8, 1973). This publication summarizes and tabulates the impact of electric power generation in the U.S. coastal zones.

The Indian Point nuclear units offer a spectacular example of inadequate site selection procedures; unless the operator of these units is compelled to generate electric power in a fashion most compatible with the highly sensitive local aquatic environment, site selection by utility managers will continue to be made without judicious foresight. The importance of the Indian Point Units in this matter cannot be overstated. The rapidly profilerating nuclear sector of the electric power generating industry engenders cooling water demands that are growing somewhat more rapidly than the aggragate demand for electric power. As Clark and Brownell point out: "The potential for environmental damage from a massive entrainment and death of these organisms -- fishes, plankton, and larvael stages of shellfish -- is of such a magnitude as to require sweeping change in policy governing design and location of power plants in the coastal zones." Unless the costs of such damage are internalized swiftly a "sweeping change" will materialize slowly, if at all.

EDF urges the speedy retrofitting of Indian Point Unit No. 3 with closed-cycle cooling towers. Such an order has already

8873

been issued for Indian Point Unit No. 2. The interim operation of these two units should be conducted in such a fashion as to minimize adverse impacts on the Hudson River fisheries. Furthermore, as set forth on page XI-50 of the DES, the use of a mechanical condensor - tube cleaning system is urged so as to greatly reduce the need for biocides. Given the coterminous nature of the discharge canal at Indian Point, all three units should be compelled to switch to mechanical cleaning of condensors.

In the matter of Nine Mile Point Nuclear Station Unit No. 2 (Docket No. 50-410), the full Commission has ordered the Staff to consider a redesign of rate structure as a possible alternative to the need for construction of new capacity. EDF believes that this is applicable in Docket 50-286. The utility in question, Consolidated Edison Company of New York, has a formidable array of problems centered about the ability to obtain new generation capacity, a markedly unfavorable system load factor, extremely high capacity costs, and a severe attrition of earnings situation. All of these problems could be minimized by moving to a rate design based on marginal cost pricing. Such a pricing structure would impose premium charges for on-peak consumption of electric power and thus far more closely approach a truly efficient rate design in which each consumer of electric power pays a price that is truly representative of the costs of service. Such a rate design depends on the availability of moderately priced time-of-day demand meters that can be easily installed. EDF is satisfied that the requisite technology is at hand and that peak demand pricing can become a reality in less time than is required for completion of a modern nuclear generating station. In view of this utilities' announced plans for further nuclear capacity additions, it is important to scrutinize this alternative as soon as possible.

It is entirely erroneous to assume in the cost description of base design in the proposed alternative cooling systems (Table XI-15, page XI-63ff) that the base design occasions no evaporative loss. In point of fact, the once-through cooling systems of these three power plants will occasion consumptive use of water approaching that required by alternatives B or C. Staff is referred to "Economics of Thermal Pollution Control" by George O.G. Löf and John C. Ward, Resources for the Future Reprint No. 91, January 1971. These authors state: Under conditions which obtain at Indian Point "... the principle mechanism for restoring the river temperature to its natural level is by evaporation with resultant cooling. This is effectively the same process that occurs in a cooling tower in a recirculation cooling system, so from the overall water evaporation standpoint, there is not a large difference in the extent of evaporation on-site with cooling tower use or off-site where once-through cooling is practiced. The off-site evaporation loss is slightly less as a result of the fact that some of the heat transfer is by radiation, particularly if large river surfaces are exposed and flow is relatively slow."

It is not at all clear that the staff examined recent developments in cooling tower design which have led to the availability of "wet-dry" tower. These devices occasion substantially less consumptive use of water during periods of cold weather when they may be operated in an essentially "dry" mode.

In closing, EDF congratulates the staff for the environmentally sound position taken in Docket No. 50-247. EDF believes this is an excellent precedent for the licensing of Indian Point Unit No. 3 in Docket No. 50-286. EDF urges that the operation of Indian Point Unit No. 1, 2 and 3 be considered synchronously in any orders pertaining to interim or long term operations at Indian Point. EDF also recommends that at the earliest possible date the experiences gleaned by the staff in consideration of operations at Indian Point be applied to analogous situations throughout the United States.

Respectfully submitted,

Ernst R. Habicht Jr.

Ernst R. Habicht, Jr., Ph.D.
Staff Scientist

ERH:vp

North Brookhaven Sport Fishermen's Club Inc.

P. O. BOX 514
ROCKY POINT, N. Y. 11778

December 6, 1973

Director of Regulations
Atomic Energy Commission
Washington, D.C.

Dear Sir,

The Sport Fishermen of Long Island have been watching the progress of Con Edison's plans for the Hudson with great concern.

We are relieved and at the same time dismayed about the AEC ruling on Indian Point concerning cooling towers. Con Edison has been ordered to build the towers to protect the Striped Bass and other species of fish that live and spawn in the river from irreparable damage. Great! We congratulate the AEC on this ruling. But, why wait for five years. If it is left to the Utility company, it is evident that they will stall and delay, use whatever tactics they can to put off the target date of 1978 to install the towers. Con Edison does not have any concern whatso ever for the fisheries in the river(if they did, Storm King, which will make further inroads on the fisheries would not be contemplated).

We urge you to have Con Edison(and other companies such as Long Island Lighting Co.) abandon the concept of once-through cooling and start immediate construction on cooling towers for all power plants. Do not give in to these companies, who will most certainly use the energy crisis as a weapon to attack those who feel we can have electricity without destroying rivers, lakes and estuaries.

12/18/73
7:35 pm
6468

Sincerely,

Daniel Marchand - President

Great South Beach Mobile Sportfishermen
of BROOKHAVEN TOWN
ORGANIZED 1961
POST OFFICE BOX-66 • PATCHOGUE, N.Y. 11772

December 9, 1973

RECEIVED DEC 13 1973

.rector
Division of Radiological and Environmental Protection
Atomic Energy Commission
1717 H Street, N.W.
Washington, D.C. 20545

RE: Indian Point III, Environmental Statement

Dear Sir:

We are a practical sport fishing organization composed of individuals interested in the well-being of man and the environment.

We recognize the need for more power, and we also recognize the ease with which the needs of man and his environment may both be fulfilled.

Indian Point No. 1 is known to damage fish, Indian Point No. 2 had its operation curtailed by the New York State Environmental Conservation Department, Indian Point No. 3 is about the same size as Indian Point No. 2, and is also located where irreparable environmental damage of catastrophic proportions can occur.

We must strongly urge that cooling towers be utilized and functioning before any operation of Indian Point No. 3 commences.

Sincerely,
H. Fletcher Bedell, Jr.
H. Fletcher Bedell, Jr.
Director and Conservation
Chairman

CC: President, United Mobile Sport Fisherman
25 Treat Road
Wethersfield, Conn. 06109

9021

WEST BRANCH CONSERVATION ASSOCIATION 100 SOUTH MOUNTAIN ROAD
NEW CITY NEW YORK 10956 914 634-9700

December 14, 1973

RECEIVED DEC 13 1973

U. S. Atomic Energy Commission
Washington D.C. 20545
Attn: Deputy Director of Reactor Projects
Directorate of Licensing

Re: Comment on Draft Environmental Statement for Indian Point #3, AEC Docket No. 50-286

Gentlemen:

I am writing as Vice-President of the West Branch Conservation Association. The purpose of our organization is the protection and enhancement of the environment. We are located in Rockland County, N.Y. which has over 30 miles of Hudson River shoreline and lies due west of Indian Point. Our interest in the protection of the Hudson River and its biological community is obvious.

We concur in the findings of the obvious physical destruction of fish at the present and future river water intakes and the thermal pollution of the river. However, we feel the situation is more complicated and serious than the "Statement" explores. As an example, the interaction of the thermal discharge with the newly introduced effluent from various sewage disposal plants or the proposed diversion of 500 to 1,000 million gallons per day from the river by the Hyde Park project. Also not considered are the additional thermal discharges to the river from industrial plants such as I.B.M. at poughkeepsie in the order of 2.5×10^8 BTU/hr at peak summer loads.

Considering the facts brought out in the "Statement" the additional possibilities delineated above and the limited knowledge of the biological functioning of the river, we feel it would be suicidal to allow additional massive thermal discharge into the river. We therefore endorse the concept of mandating the installation of cooling towers.

The use of cooling towers for electric generating plants is certainly not novel or untried and has been extensively used in Europe, particularly in England.

An added advantage of closed circuit cooling not brought out in the "Statement" is the possibility of corrosion control which can markedly reduce corrosion and fouling of the piping and condensers which would be a monetary offset against the added cost of the cooling towers.

Very truly yours,
Walter L. Fleisher Jr.
Walter L. Fleisher, Jr.
Vice-President

WLF/z

50-3
50-286
50-247

Connecticut Coastal Anglers Association

GROTON, CONNECTICUT

Director of Regulation
United States Atomic Energy Commission
Washington, D. C.

Dear Sir;

In regard to the Con-Ed application for license to operate power plants on the Hudson River, further study and investigation of the environmental impact of such construction and operation would seem imperative.

The cumulative effects - 20% to 60% reduction of striped bass larvae migrating past this area per year - of current power plant operation dictates that cooling towers should be installed not by the target date of 1978, but as soon as possible. Further, the impact on this major spawning and nursery ground by proposed projects such as Storm King Mountain must be considered.

The fishery spawned by the Hudson River is an invaluable sport and commercial asset. Therefore, urgent legislative and corporate action is necessary to conserve this natural resource.

Cordially,

Frank B. Holmgren
Secretary

9092

KENNETH E. BAY · 27 MAPLE AVENUE · HASTINGS-ON-HUDSON · NEW YORK · 10706
PHONE 914-478-0565

RECEIVED DEC 10 1973

December 7, 1973

U S Atomic Energy Commission
Washington, D. C. 20545

Atteþion: Deputy Director for Reactor Projects
Directorate of Licensing

Subject: Draft Environmental Statement for Indian Point #3
Con Edison Co., of NY.
AEC Docket #50-286

Gentlemen:

I write as an interested fisherman, a resident on the banks of the Hudson River as well as a user of the energy generated by Con Edison Co., of NY, for many years, interested in all areas of our environment.

I was greatly heartened by the decision requiring cooling towers to be installed at Indian Point #2, which will serve to continue the progress of pollution abatement slowly showing itself in the Hudson River.

I trust that this decision will not be negated by a lesser requirement to result from your deliberations over the projectdd plant at Indian Point #3.

I also urge you to extend this thinking to the Storm King Project which would similarly have a drastic and mortal effect on the aquatic and marine life of the Hudson estuary.

Sincerely,

Kenneth E. Bay

cc. Con Edison Co.
HRFA/SOS

12/12/73

Re Hudson River Indian Point Nuclear Plant

Mrs. Harold Cooper
4483 Douglas Avenue
Riverdale, New York 10471

I would like to support the environmental impact ~~Statement~~ concerning the Indian Point nuclear plant operations. The cooling towers should be built before the 1978 deadline proposed or it will be too late to reverse the destruction caused by the plant.

Mrs Harold Cooper

DR- 6474

November 30,1973

Gentlemen;

In my opinion the dangers to the environment which might take place with the activation of Con Ed power plant I.P.3 concern possible radioactivity to plants and humans, the wholesale murder of thousands of fish (especially striped bass) and the marring of the landscape.It seems inconcieveable to me at just the moment when things are looking hopeful for the restitution of the Hudson River that such a plant, with its inherent dangers, should be activated.

As a musician, I have worked with the various ecological organizations along the Hudson by raising funds and lending my talents to the constant effort to defend this region. Unless far more stringent measures are taken to reduce or eliminate the threat to the envoronment that I.P.3 poses I, as a member of this region, citizen of this country and lover of this land, will do all I can to stop it.

We must find environmentally compatible ways of creating energy for the sake of future generations before the chemestry of the planet is permenantly boggled.

Sincerely,

Don McLean

Don McLean

421 SYLVAN AVE.
RIVERDALE, N.Y. 10471
December 8, 1973

DIRECTOR OF REGULATIONS
UNITED STATES ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

Dear Sir:

I wish to express my support for your conclusions as stated in the Final Environmental Statement related to operation of Indian Point Nuclear Generating Plant Unit #2 by Consolidated Edison Company of New York (Docket # 50-247), which orders the building of "closed circuit" cooling towers by 1978.

However, I respectfully urge that the 1978 deadline be moved up to a much earlier date because all the available evidence in your statement indicates a very high percentage of striped bass (and other fish) eggs and larvae would be destroyed by that time.

Very truly yours,

[signature]

JOHN NICHOLAI JR.

Rec'd Off. of Dir. ... 12/10/73 ...

DR-6466

December 9, 1973

U.S. Atomic Energy Commission
Att: Deputy Director for Reactor Projects
Directorate of Licensing
Washington, D.C. 20545

Dear Sir:

I've just received and read the Draft Environmental Statement for I.P. 3, AEC Docket No. 50-286 and wish to make the following comments.

I have fished for striped bass for 35 years around Long Island and the Hudson River in New York. And now my twelve year old son has taken up the sport and become my fishing buddy. We, like so many other Long Island residents, are "hooked" on striped bass.

However, the threats posed by Consolidated Edison's nuclear power plants on the Hudson River have me greatly concerned. The Impact Statement related to proposed operation of Unit No. 3 makes it abundantly clear that this plant, as well as unit No. 2, should never be permitted to go into operation, even for an interim period, until the cooling towers are completed and approved. The Hudson River nursery is far too important to the mid-Atlantic striped bass fishery to allow Consolidated Edison to gamble with so valuable a public-owned recreation and food resource.

I urgently request that my views be given full and studied consideration by the Licensing Board.

Thank you for permitting me to present my view and concern.

Very truly yours,

[signature]

Robert J. Rance
57 Glengariff Road
Massapequa Park, N.Y.
11762

Rec'd Off. of Dir.
Date 12/14/73
Time 2:36 PM

Dennis Zaccardi
88 Romaine Ave.
Jersey City, N.J.

December 8, 1973.

Director Of Regulations of
the U.S. Atomic Energy Comm.
Washington, D.C.

Gentlemen,

As a member of the Salt Water Anglers of Bergen County and as a contributor to the Hudson River Fishermen's Assoc. and the Striped Bass Fund, I am pleased to learn that the AEC will require Con Edison's Indian Point III Atomic Power to have operational Cooling Towers by 1978. However, I am dissapointed by the fact that Indian Plants I & II are still operating without Cooling Towers and that Con Edison is resisting the construction of Cooling Towers for these plants.

On behalf of the Atomic Energy Commission, Dr. G. Philip Goodyear testified at the Licence hearings for Indian Point I that 80% of the Striped Bass along the Atlantic Coast had originated in the Hudson River. He also testified that between 30 & 50% of the Striped Bass Eggs and Larvae would be killed by entrainment and also that large numbers of older Striped Bass are likely to be killed by impingement on the screens on the water inlets. This is why a closed cycle cooling system is absolutely necessary right now.

On behalf of my fellow fishermen and non-fisherman alike, I demand that the AEC require Con Ed to begin immediate construction of Cooling Towers for Indian Point Plants I & II.

It is true that we are now faced with an Energy Crisis, however the protection of our fisheries is imperative if we want to avoid a food crisis. After all, poor planning was the cause of our energy crisis; it would be foolish to make that same mistake again with our Fisheries.

You might say that the Striped Bass is not a very important food fish, however there are numerous species which spawn and/or live in the Hudson which are important food fishes. Besides, we have a moral obligation to preserve fishing as a sport for our children and our children's children.

To further clarify my position, I have enclosed an article of mine which appeared in the Spectrum of the Institute of Electrical & Electronic Engineers.

Very Truly Yours,

Dennis Zaccardi

Dennis Zaccardi

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-ination as to age by companies with or more employees. If anyone tells you you are "overqualified" (an unacceptable excuse), file a complaint with the U.S. Department of Labor. Meantime, send a stamped, self-addressed envelope to the er (5 [illegible] 56 East Acoma Drive, Phoenix, Ariz. 85032), who is trying to organize a self-help group for over-50 engineers. The very least we can see that the companies doing contract or subcontract work the U.S. Government obey the law.

All persons of all colors, religions, and es grow old. While young, they will be taxed to support their over-50 engineer brethren. So we all are directly concerned.

There is no excuse for a qualified engineer to lie down and play dead because of a passing fad that says "over 50 is over the hill."

B. B. Deien
Phoenix, Ariz.

...ward uniform registration

In January Forum (pp. 16–18), George Paris offered three plans "in order to ...in uniform national professional registration in the U.S."

The following plan patterned after the Actuarial Examinations is offered as an alternative. In the Society of Actuaries, admission to membership is by examination. There are ten examinations. A person who completes the first five examinations is designated a Fellow.

Under the proposed plan, the first five examinations would be given nationwide and be conducted by the NSPE; included would be mathematical sciences and engineering fundamentals. Upon successful completion of the first five examinations, a person would become a member of one of the specialized societies: for example, IEEE, ASME, etc. The remaining five exams would be prepared and supervised by the specialized societies. In the IEEE, the last two exams could be given by the individual Professional Group or Society selected by the candidate.

If the examinations were given twice a year, the minimum time required to become a Fellow would be five years, presumably it would take longer, perhaps ten years, and maybe 15 years if extensive academic experience were necessary for the specialized tests.

Anthony J. Zygmont
Villanova University
Villanova, Pa.

...wer crisis

Who is James J. Andover—a PR man for the Edison Electric Institute? (See "About That Power Crisis," Mar., pp. 72–73.) Why are statements from this electric utility information treated with apparent objectivity, whereas opponents of rapid (read "insufficient safeguards") construction of nuclear plants are considered "doomcasters"? The title statement itself is inflammatory: "... the U.S. may find itself headed for a super-blackout." (Who is casting doom here?) The tactics of sensationalism are carried further by concluding with Teller's "I like people more and fish less." Such an ecological travesty deserves no serious response.

The astute reader will not be misled by this sham; nevertheless, such insidious bias properly belongs in an editorial section of *Spectrum*. The article should not have been treated as a wholly factual presentation.

R. L. Couch
Huntsville, Ala.

I wish to comment on "About That Power Crisis" (Mar., pp. 72–73). I was particularly annoyed by the quote from Edward Teller: "I like people more and fish less."

It's truly unfortunate that many of our most learned scientists are *extremely* shortsighted. What Dr. Teller fails to realize is that man can live without electricity *but fish cannot live in hot polluted water.* Besides, there is no reason why both fish and man cannot live in harmony. The technology exists for closed-cycle cooling systems but the utility companies are so profit motivated that they refuse to invest any of their capital expenditures in a better environment. To quote Sandy Greene, who is affiliated with the Striped Bass Fund, "172 out of 286 projected new *large power plants plan closed water systems* .... Why are the remaining 114, including Indian Point, not installing such a system?"

Another factor that is often completely ignored is the fact that fish on the U.S. Atlantic Coast are a tremendous source of food, as evidenced by the huge catches made by foreign trawlers off our continental shelf. As the population of the *world increases, so does its need for food,* and agriculture has been pressed to expand to meet this need. If we start to upset the ecological system of our estuaries, we no longer will need to worry about all the foreign trawlers that are fishing off our shores, because the trawlers will no longer be there *once the fish are gone.*

In testimony at the hearing relating to Consolidated Edison's Indian Point Two nuclear power plant on the Hudson on behalf of the Atomic Energy Commission, C. Philip Goodyear stated that 60 percent of all the striped bass on the East Coast originate in the Hudson River. Dr. Goodyear also testified that between 30 and 50 percent of the striped bass eggs and larvae would be killed if Indian Point Two is allowed to operate without a closed cooling system.

Also, I am still quite skeptical as to the safety of atomic power plants. A friend who lives in Forked River, N.J., about a mile from the atomic plant on Oyster Creek, reports that there have been several fish kills there. At least three major kills during the *year were due to sudden* drops in the water temperature of Oyster Creek as a result of shutoffs of the reactor for maintenance—yet Central Power and Light denies responsibility. What is especially frightening is the fact that several of the other fish kills occurred for no apparent reason.

To summarize, I feel that all due precaution should be taken in the construction of atomic plants, that such plants should be built in isolated areas away from population centers, and, finally, that they should utilize closed-cycle cooling systems.

Dennis E. Zaccardi
Jersey City, N.J.

More on BART

As a taxpayer in Contra Costa County, Calif., and thus a part owner of the Bay Area Rapid Transit District (BARTD), I am interested in seeing that all related information is presented to *Spectrum* readers. Attention is called to important facts that should be considered when comparing BART with other recent transit systems placed in service, and when looking at *present BART performance.* Some of these facts have been included in *Spectrum*'s series on BART. Others, I believe, have not.

First, BARTD and its PBTB consulting engineers set out to make good on the promise that the public would have the best rapid-transit system modern technology could provide.

Second, the BART system with its four *original branch lines requires* train switching in the Oakland–Berkeley section. This requirement is more sophisticated than other recent systems, such as Toronto. Other recent operating installations have been point-to-point systems, requiring no switching. Automatic train control on the BART system required the use of new approaches over point-to-point systems.

My third, and most important, point is that it had been an early decision by the District and PBTB that the *first ten production cars were to be made available for six months of thorough testing before revenue service was started.* Manufacturers could not possibly conduct adequate tests in their factory, and because of the unique gauge and third-rail voltage of the BART system, they could not even conduct tests of production cars on other properties.

The public clamored for service, even though they had helped delay purchase and construction by a six-month taxpayers' suit in Contra Costa County. That and other delays, all of them related [illegible] the *Spectrum* series, meant that the Oakland–Fremont line was opened without