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Evaluation of Impingement Losses of White Perch at the Indian Point Nuclear Station and Other Hudson River Power Plants

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ENVIRONMENTAL SCIENCES DIVISION
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Prepared for the
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Task: Methods to Assess Impacts on Hudson River White Perch

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ABSTRACT

W. VAN WINKLE, L. W. BARNTHOUSE, B. L. KIRK, and D. S. VAUGHAN. 1980. Evaluation of impingement losses of white perch at the Indian Point Nuclear Station and other Hudson River power plants. ORNL/NUREG/TM-361 and NUREG/CR-1100. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 152 pp.

This report evaluates two independent lines of evidence concerning impingement losses of white perch at the power plants on the Hudson River. Based on regression analyses of impingement rate as an index of year-class strength versus year over the period 1972 through 1977, it is concluded that there is little evidence of a statistically significant downward trend. However, an analysis of minimum detectable differences in impingement rates indicates that a long time series of year-class strength would be required to detect even substantial reductions (e.g., 50%). Second, based on our estimates of percent reduction in year-class strength due to impingement (> 20% for the 1974 year class and > 15% for the 1975 year class), it is concluded that the level of impingement impact is not acceptable _a priori_ from the point of view of managing the white perch population. Our methodologies and results are compared with those of the utilities, and the bases for the substantial difference in estimate of impingement are discussed. Appendices are included on survival of impinged white perch, impingement rate as an index of population abundance, and ability to detect decreases in population abundance.

SUMMARY

This report presents two independent lines of evidence evaluating impingement losses of white perch at the power plants on the Hudson River, based on data provided by the utilities and their consultants. The first line of evidence involves analyzing the variation in impingement rate among years over the period 1972 through 1977. The second line of evidence involves estimating the conditional mortality rate (or equivalently, the percent reduction in year-class strength in the absence of compensation) due to impingement for the 1974 and 1975 year classes.

Impingement rate provides one index of year-class strength on a relative scale. As such, it reflects the effect of entrainment and impingement losses during the preceding months, as well as the effect of any compensatory mechanisms which might alter survival during the preceding months. Regression analyses of impingement rates of young-of-the-year white perch among years suggest that there has been no linear change in the size of the white perch population during the period 1972 through 1977. In particular, there is little evidence of a statistically significant downward trend. However, given the large variability in impingement rates used in these regressions, the time series are relatively short (i.e., 5 - 6 years), and thus, the statistical power of the test for a trend is not high. Based on a systematic analysis of minimum detectable differences in annual impingement rates and the number of years required to detect a specified reduction in this index of year-class strength, it is concluded that long time series of year-class strength would be

required to detect even substantial reductions (e.g., 50%). In addition, based on an analysis comparing data on impingement rate and beach-seine catch per unit effort (CPUE), the relative accuracy of impingement rates as estimates of relative year-class strength is called into question. A final point relating to the use of impingement rate as an index of year-class strength is that a systematic decrease in year-class strength due to impingement mortality would only start to manifest itself with the 1977 (or 1978) and subsequent year classes. This delay is due to the age of sexual maturity for females, the multiple age-class composition of the spawning population of females, and the appreciable increase in impingement mortality starting in 1973 and 1974.

Our estimates of percent reduction in year-class strength due to impingement indicate that the level of impingement impact was probably greater than 20% for the 1974 year class and was probably greater than 15% for the 1975 year class. These estimates do not include consideration of entrainment, so the total power plant conditional mortality rate is obviously greater than the values presented in this report for impingement only. Given the information currently available, it is our judgment that this level of impingement impact is not acceptable *a priori* from the point of view of managing the white perch population.

In terms of the comparability of assumptions and values for input parameters used in the utilities' methodology and in ORNL's methodology for estimating percent reduction, the utilities' estimate of percent reduction due to impingement for the 1974 year class of 11.3% is best compared to ORNL's estimate of 25.5%. Five "decision points" accounting for this more-than-a-factor-of-two difference are discussed. The utilities' choice at <u>every one</u> of these five decision points affects the results in the same direction, namely, to lower the estimate of percent reduction. ORNL's choice at each of these five decision points is scientifically more sound and defensible.

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I. INTRODUCTION

Oak Ridge National Laboratory (ORNL) performed a preliminary evaluation of impingement losses of white perch at the Indian Point Nuclear Station and other Hudson River power plants in preparing the Final Environmental Statement for Indian Point 3 (USNRC 1975). In that evaluation we stated:

> "A 1973 field-tagging study by a consultant for the applicant indicates that the September-October population estimates to be used for planning purposes should be 23 million white perch for the entire Hudson River. This population estimate includes all age groups and not just young-of-the-year, but the young-of-the-year account for the majority of the white perch impinged. This population estimate is tentative, it may vary by an order of magnitude from year to year, and it is based on 1973 data (whereas the impingement estimates are based on 1971-1972 data); nevertheless, the staff feels that impingement may have a significant impact on the white perch population. For example, the projected total impingement loss at all plants with once-through cooling at the three Indian Point Units is 4.1 million white perch per year. If the assumptions are made that these are all young-of-the-year and that 80% of the total white perch population of 23 million are young-of-the-year, then 20% to 25% of these young-of-the-year white perch will be impinged." (p. V-61)

In response to the above concern, the Office of Nuclear Regulatory Research, U. S. Nuclear Regulatory Commission, funded research at ORNL starting in May 1978 with the following objectives: (1) to determine the significance of impingement losses on the white perch population at the Indian Point Nuclear Station (all units); (2) to collect, compile, and analyze data and information on white perch impingement losses in the Hudson River; (3) to estimate the impingement exploitation rate by power stations and the conditional rate of mortality due to impingement for the Hudson River white perch population; and (4) to document in a final report the results of the analysis and to make a determination whether the impingement losses are having a potentially adverse impact on the population of white perch in the Hudson River.

This topical report is organized as follows: Section II deals with the white perch impingement data *per se*, including a description of the data base and analyses of variation in the impingement rate among years, months, and power plants. Section III deals with white perch population data, including estimates of population size and monthly natural mortality rates. Section IV integrates the results from Sections II and III to estimate the conditional mortality rate and exploitation rate due to impingement, using the ORNL empirical impingement model. Section V is a discussion of our results in light of the utilities' results, and it concludes with consideration of whether impingement of white perch at Hudson River power plants is a problem.

Appendices B, C, and D address three special analyses that were performed as part of this evaluation of impingement losses of white perch. Survival of impinged white perch is covered in Appendix B, impingement rate as an index of population abundance is evaluated in Appendix C, and a preliminary analysis of the ability to detect decreases in population abundance based on impingement rate data is presented in Appendix D.

II. WHITE PERCH IMPINGEMENT DATA

In this section, we first present a brief description of the data base on the number of white perch impinged (collected) and on the impingement rates at each power plant. Then, we present the results of our analyses of these impingement rates, focusing on the pattern of variation among years, months, and power plants. Our analysis of the variation in impingement rate of young-of-the-year white perch among years addresses the question of whether there has been a statistically significant and systematic trend in the size of year classes during the period 1972 through 1977. Our analysis of the variation in impingement rate among months focuses on how these variations depend on location of the power plant and age of the white perch. Finally, our analysis of the variation in impingement rate among power plants focuses on identifying which power plants have the highest and lowest impingement rates and how the rankings of power plants depend on the age of the white perch impinged.

A. Description of the data base

We have compiled data on the number impinged and the impingement rate for white perch by month for all years for which data were obtainable from the utilities for each of the following power plants (moving downriver): Albany; Danskammer; Roseton; Indian Point Units 1, 2, and 3; Lovett; Bowline; and Astoria. These data are presented in Appendix A, Tables A-1 through A-9. Collection rate is defined as the number of impinged white perch counted (Indian Point) or estimated (all other power plants) to be impinged at the intake per unit intake flow.

Except for Indian Point, where collection rates were adjusted upward to correct for less than 100% collection efficiency, collection rate is assumed to be approximately equivalent to impingement rate, which is defined as the number of white perch killed at the intake per unit intake flow. A detailed analysis of factors that influence impingement estimates at Hudson River power plants is given in Barnthouse (1979), including adjustment factors. A detailed discussion of survival of impinged white perch is presented in Appendix B of this report. We designated May 31 through June 1 (a one-day interval) as the dividing line between 12-month-old young-of-the-year and 13-month-old yearlings.

B. Variation in impingement rate among years

Impingement-rate data are available on a monthly basis for a period of 4 to 6 years for Bowline, Lovett, Indian Point 2, Roseton, and Danskammer. We treated impingement rate, which is equivalent to a catch per unit effort (CPUE), as an approximate index of population size. For a CPUE index to serve as an accurate index of population size, there must be some assurance that actual variations in effort are measured. We believe that data on power plant intake flow (= effort) satisfy this condition, because the uncertainty associated with estimates of intake flow is relatively small. An analysis of impingement rate as an index of population abundance is presented in Appendix C. Given this assumption, we examined the time series of impingement rates over years for trends in population size. The regression model used was Y = a + bX, where Y is the impingement rate for young-of-the-year white perch (RATEO in Appendix), X is year, a is the Y-axis intercept, and b is the slope. A slope (b) significantly greater than 0.0 ($P \leq 0.10$) suggests an increasing trend over years in population size, while a slope significantly less than 0.0 suggests a decreasing trend in population size. A slope not significantly different from 0.0 indicates that, although year-class strength may have varied, there was no systematic trend in year-class strength over the period 1972 (or 1973) through 1977. The regression analysis was performed for each of the above five power plants and for all five power plants combined for each month separately. The reason for performing individual regressions for each power plant and month was to examine the possibility that there might be consistent patterns of variation at a power plant for certain months which were masked by averaging over power plants or over months. The regression analysis was also performed using the mean annual impingement rate, which was calculated as the average of the twelve monthly impingement rates for each year. In all, 78 regressions were performed. Because the twelve monthly impingement rates are used to calculate the mean annual impingement rate for each year, however, this set of regressions cannot be treated rigorously as a set of 78 statistically independent regressions.

The results of these regression analyses are presented in Table 1. Of the 78 regressions, the slope (b) differs significantly ($P \leq 0.10$) from 0.0 in only eight cases. Of these eight cases, the slope is significantly greater than 0.0 seven times and less than 0.0 only once (Lovett, in March). In our judgment the mean annual impingement rates for each of the five power plants and for all five plants combined are

Table 1. Summary of results from regression analyses to examine the time series of impingement rates for trends in the Hudson River young-of-the-year white perch population[a]

Month	N	r^2	b	P	N	r^2	b	P	N	r^2	b	P
	Bowline				Lovett				Indian Point 2			
January	5	0.06	-84.5	0.68	5	0.60	208	0.12	5	5810	0.16	
February	5	0.17	-95.1	0.49	5	0.27	95.7	0.37	5	0.44	11539	0.22
March	5	0.21	-80.6	0.44	4	0.88	-29.8	0.06*	5	0.12	-565	0.57
April	5	0.11	-75.7	0.58	5	0.11	-39.5	0.59	5	0.02	349	0.82
May	5	0.53	-24.0	0.16	5	0.37	-23.1	0.27	4	0.21	-462	0.54
June	5	0.00	0.00	-	5	0.00	0.00	-	5	0.00	0.00	-
July	5	0.05	-1.00	0.71	5	0.00	-0.02	0.99	4	0.63	8.49	0.21
August	5	0.26	13.2	0.38	5	0.25	-8.09	0.39	4	0.14	93.2	0.63
September	5	0.03	0.52	0.79	5	0.02	-0.65	0.82	5	0.04	28.5	0.75
October	5	0.26	7.42	0.39	5	0.35	33.3	0.29	5	0.81	534	0.04*
November	5	0.16	65.2	0.51	5	0.71	93.6	0.07*	5	0.59	1795	0.13
December	5	0.06	81.1	0.70	5	0.15	45.8	0.52	4	0.63	5625	0.20
Annual	5	0.05	-16.1	0.72	4	0.67	29.9	0.18	4	0.74	2335	0.14
	Roseton				Danskammer				All five plants			
January	4	0.83	4.65	0.09*	6	0.25	2.23	0.31	5	0.52	1149	0.17
February	4	0.24	4.05	0.51	6	0.27	2.26	0.29	5	0.42	2261	0.24
March	4	0.88	12.7	0.06*	6	0.54	13.0	0.10*	5	0.21	-216	0.44
April	4	0.21	55.7	0.54	6	0.48	121	0.13	5	0.01	33.5	0.90
May	4	0.37	77.1	0.39	6	0.08	36.0	0.58	5	0.21	-96.9	0.43
June	4	0.00	0.00	-	6	0.00	0.00	-	5	0.00	0.00	-
July	5	0.01	0.033	0.85	6	0.44	-2.82	0.15	5	0.00	-0.247	0.91
August	5	0.26	17.8	0.38	6	0.36	-14.8	0.21	5	0.06	13.4	0.68
September	5	0.42	-59.8	0.23	6	0.19	-8.83	0.39	5	0.06	-7.05	0.70
October	5	0.34	-80.8	0.30	6	0.10	25.2	0.54	5	0.84	108	0.03*
November	5	0.04	23.7	0.76	6	0.26	109	0.30	5	0.79	419	0.04*
December	5	0.01	-1.67	0.87	6	0.03	-4.01	0.73	5	0.05	255	0.73
Annual	4	0.49	14.8	0.30	6	0.40	23.2	0.18	4	0.45	402	0.33

[a]The regression model used was $Y = a + bX$, where Y is impingement rate for young-of-the-year white perch and X is year. N is the number of data points (i.e., number of years); r^2 is the coefficient of determination (i.e., the fraction of variability in Y values accounted for by X); b is the slope of the straight line; and P is the probability of obtaining a slope this steep (either positive or negative) if the true slope is 0.0. P values ≤ 0.10 are indicated by an asterisk (*).

likely to be more reliable indices of population size than the individual monthly impingement rates. Monthly impingement rates are more subject to variation from year to year due to temperature or salinity differences and, consequently, to differences in the spatial distribution of young-of-the-year white perch in the Hudson River, rather than due to real differences in year-class strength. None of the slopes for the six "annual" regressions differs significantly from zero. Thus, the impingement rate data from these five power plants suggest that there has been no linear change in the size of the white perch population during the period 1973 through 1977 (1972 through 1977 for Danskammer).

Because of the age of sexual maturity for females and the multiple age-class composition of the spawning population of females, and because impingement mortality increased appreciably starting in 1973 and 1974, a systematic decrease in year-class strength due to impingement mortality would only start to manifest itself with the 1977 (or 1978) and subsequent year classes. Female white perch collected in the Indian Point region in May 1973 indicated 24% sexual maturity at age 2, 96% at age 3, 92% at age 4, and 100% at age 5 and older (Texas Instruments, 1975a, p. VII-22). The large increases in power plant intake flow started during 1973 through 1975 (Christensen et al. 1976, Fig. 5). Thus, the year classes spawned during these years were spawned by year classes that were not themselves subjected to the increased levels of impingement mortality. Assuming a median age of reproduction of four years, only beginning in 1977 or 1978 would the compounding effect of entrainment and impingement mortality have an opportunity to manifest itself in reducing year-class strength.

The variability in the impingement rate data already available can be used as a guideline to estimate how much of a reduction in population size (and for how many years) would be required to detect the reduction statistically (i.e., statistical power of the test). This analysis is presented in Appendix D. However, assuming that a statistically significant decrease did occur, independent evidence indicating the same result would be required to demonstrate conclusively that such a decrease was related to "overfishing" by the power plants.

C. Variation in impingement rate among months

Variations in mean impingement rate among months are highlighted in Table 2 for young-of-the-year white perch and in Table 3 for yearling and older white perch. The pattern among months depends quite noticeably on location. In particular, at the downriver plants (Astoria, Bowline, Lovett, and Indian Point), impingement rates of white perch of all ages are highest during the months of December, January, and February, with the months of November, March, and April also being quite high on occasion. In contrast, at the upriver plants (Roseton, Danskammer, and Albany), impingement rates of white perch of all ages indicate two peaks, one in April and May and a second during September through November. Impingement rates of yearling and older white perch tend to be relatively high at a number of the power plants in June (Table 3), which in part is an artifact due to designating May 31 to June 1 (a one-day interval) as the dividing line between 12-month-old young-of-the-year and 13-month-old yearlings.

Table 2. Variation in mean impingement rate of young-of-the-year white perch among months and among power plants[a]

Plant	Location[b]	Number of years of data	June	July	August	September	October	November	December	January	February	March	April	May	Annual
Astoria[c]	East River	1							6.9 (1)		4.6 (2)		3.1 (3)		1.8 (9)
Bowline	37.5	5							767.1 (1)	553.6 (3)		332.9 (4)	577.9 (2)		248.0 (4)
Lovett	42	5						394.8 (2)	273.9 (4)	558.0 (1)			315.7 (3)		177.2 (5)
Indian Point Unit 1	43	2-4							3415.3 (2)	2542.9 (4)	4196.6 (1)		3219.2 (3)		1563.7 (2)
Indian Point Unit 2	43	4-6							7942.4 (3)	12610.4 (2)	18101.3 (1)		5822.8 (4)		4565.6 (1)
Indian Point Unit 3	43	1-3						1286.7 (3)	646.0 (4)	1836.2 (2)	2973.2 (1)				666.5 (3)
Roseton	65.4	4-5					246.8 (2)	286.5 (1)					149.6 (4)	233.5 (3)	97.5 (7)
Danskammer	66	6					413.0 (2)	482.9 (1)					304.0 (4)	305.9 (3)	153.2 (6)
Albany[d]	140	2				20.8 (2)	7.7 (3)						7.7 (4)	26.3 (1)	6.24 (8)

[a]Based on analysis of RATEO values in Tables A-1 and A-9 in Appendix A. The top number of each pair of numbers in the table is the mean impingement rate (number of fish collected per million cubic meters). The bottom number of each pair (in parentheses) is the ranking for that mean impingement rate, with one (1) denoting the highest rate. The mean monthly impingement rates are averages over all years for which estimates for that month were available; these mean monthly rates were ranked from 1 to 12 for each power plant, but only entries for the four highest months are given in this table. The mean annual impingement rate for each power plant is the average of the 12 mean monthly rates; these mean annual rates were ranked from 1 to 9 over power plants.

[b]River mile (RM) on the Hudson River, with RM 0 at the Battery.

[c]All ages combined at Astoria.

[d]Based on RATEO values in Table A-1 in Appendix A only for the period April 1974 through March 1976.

Table 3. Variation in mean impingement rate of yearling and older white perch among months and among power plants[a]

Plant	Location[b]	Number of years of data	June	July	August	September	October	November	December	January	February	March	April	May	Annual
Bowline	37.5	5								175.3 (1)	87.9 (3)	61.0 (4)	123.1 (2)		46.1 (6)
Lovett	4[illegible]	5	70.6 (1)					14.3 (3)		35.6 (2)		13.2 (4)			15.2 (8)
Indian Point Unit 1	43	2-4	117.9 (4)						127.5 (3)	162.3 (2)			184.2 (1)		84.6 (4)
Indian Point Unit 2	43	4-6							420.0 (3)	804.9 (1)	515.3 (2)	413.3 (2)	413.6 (4)		231.9 (1)
Indian Point Unit 3	43	1-3	65.4 (3)						45.3 (4)	117.2 (1)	78.6 (2)				34.4 (7)
Roseton	65.4	4-5	55.7 (3)					50.5 (4)					164.5 (1)	155.4 (2)	48.0 (5)
Danskammer	66	6	312.9 (1)	164.9 (4)									273.4 (2)	208.7 (3)	101.4 (2)
Albany[c]	140	2 (4)	164.1 (2)	212.0	(1)	218.2 (3)	211.1								90.9 (3)

[a]Based on analysis of RATE1 values in Tables A-1 and A-9 in Appendix A. The top number of each pair of numbers in the table is the mean impingement rate (number of fish collected per million cubic meters). The bottom number of each pair (in parentheses) is the ranking for that mean impingement rate, with one (1) denoting the highest rate. The mean monthly impingement rates are averages over all years for which estimates for that month were available; these mean monthly rates were ranked from 1 to 12 for each power plant, but only entries for the four highest months are given in this table. The mean annual impingement rate for each power plant is the average of the 12 mean monthly rates; these mean annual rates were ranked from 1 to 8 over power plants.

[b]River mile (RM) on the Hudson River, with RM 0 at the Battery.

[c]Based on RATE1 values in Table A-1 in Appendix A only for the period April 1974 through March 1976.

D. Variation in impingement rate among power plants

Variation among power plants in the mean annual impingement rate is surprisingly great (Tables 2 and 3, last column). Although data are available for only one year at Astoria, and there is no way to estimate from the data reported the impingement rates for young-of-the-year and older white perch separately, it is evident that relatively few white perch are impinged at Astoria. At the other geographical extreme, it is evident that impingement of young-of-the-year white perch is relatively low at Albany compared to the other plants (Table 2), but Albany ranks third out of eight power plants with respect to the impingement of yearling and older white perch (Table 3). In fact, at Albany the impingement of yearling and older white perch is appreciably higher in absolute numbers than for young-of-the-year white perch.

For Bowline, Lovett, Indian Point, Roseton, and Danskammer, impingement of young-of-the-year white perch is higher in absolute numbers than impingement of older white perch. The values for Indian Point Unit 2 are appreciably higher than those for any other plant (see Table 2). Although the values for Indian Point Unit 1 are also high, impingement of fish at Unit 1 is not currently of major concern, because the unit is not generating electricity at this time. The circulating pumps are generally only operated for experimental purposes (e.g., testing of fine-mesh screens). Impingement of young-of-the-year white perch is higher at Bowline and Lovett than at Roseton and Danskammer (Table 2), but the rankings are reversed for impingement of yearling and older white perch (Table 3).

III. WHITE PERCH ABUNDANCE AND MORTALITY

A. Abundance

No estimates were made of the absolute abundance of yearling and older white perch in the Hudson, and none of the existing data are adequate for this purpose. However, two independent estimates of the abundance of young-of-the-year white perch are available. The first, or combined gear estimate, is derived from a combination of data from the Texas Instruments' (TI) longitudinal ichthyoplankton survey, fall shoals survey, and riverwide beach seine survey. Descriptions of these surveys can be found in the Multiplant Report (TI 1975b) and the Final Research Report (FRR) (McFadden 1977).

The second estimate is derived from a mark/recapture program conducted by Texas Instruments. Descriptions of the methods used in data collection and analysis can be found in the Multiplant Report and the FRR. Mark/recapture estimates of white perch young-of-the-year abundance in October 1974 and in October 1975 are presented in a supplement to the FRR (McFadden and Lawler 1977). A comparison of the two sets of abundance estimates reveals substantial discrepancies for both years (Table 4). The mark/recapture estimates are far larger than the corresponding combined gear estimates, 14 times as high in 1974 and 6 times as high in 1975. We believe that the mark/recapture estimates are the more reliable of the two sets for the reasons discussed below.

The combined gear estimates undoubtedly underestimate the true abundance of young-of-the-year white perch, because Texas Instruments made no corrections for gear efficiency (FRR, Sections 7.9.1.2, 7.9.1.3, and 7.9.1.4). In effect, they assumed that all of the gears

Table 4. Estimates of young-of-the-year white perch abundance in the Hudson River[a]

	October 1974	October 1975
Combined gear estimate[b]	1.5×10^6	5.0×10^6
Mark/recapture estimate[c]	21×10^6	30×10^6

[a]Regions included in the combined gear estimates were KM 38-98 (RM 24-61) in 1974 and KM 22-122 (RM 14-76) in 1975. The region included in the mark/recapture estimates was KM 19-243 (RM 12-152) during both years.

[b]Based on extrapolation from beach seine and epibenthic sled data. Value for 1974 is mean of five weekly estimates. Value for 1975 is mean of three biweekly estimates.

[c]Based on young-of-the-year white perch released in the fall and recaptured the following spring.

(beach seine, epibenthic sled, and Tucker trawl) catch 100% of the fish in their path. In reality, no gear captures 100% of the organisms in its path. Even the smallest larval fishes possess a limited ability to evade capture. Recent tests conducted by Texas Instruments (1978) indicate that the efficiency of the 100-ft (30.5-m) beach seine at catching young-of-the-year white perch probably ranges between 7 and 25%. The epibenthic sled and Tucker trawl were designed primarily as ichthyoplankton gear. Since the majority of young-of-the-year white perch are well in excess of 50 mm in length by early August, the efficiency of these gears during the period of interest here (August-December) is probably very low. Although no attempts have been made to quantify the efficiency of the epibenthic sled and Tucker trawl, Kjelson and Johnson (1978) recently reported that the 6.1-m Otter trawl, which, because of its larger size, is probably more efficient than either of the above gears at catching young-of-the-year fish, is only about 30 to 50% efficient.

An additional source of error in the combined gear estimates for young-of-the-year white perch is the design of the sampling program itself. As described in the Multiplant Report (Section III), the longitudinal river survey, fall shoals survey, and the riverwide beach seine survey are all designed for optimal sampling of striped bass. A common result of this design is the collection of large numbers of samples in regions that contain low densities of white perch, and the collection of few samples in regions containing high densities of white perch. For example, during the period August 19-22, 1974, 34 epibenthic sled tows were conducted in the Tappan Zee region. No white perch were caught. Virtually all of the white perch collected during this period (58 out of 64) came from five tows collected from the shoal stratum of the Cornwall region.

By comparison, the mark/recapture estimates seem to be more free of major biases. Population estimates calculated from mark/recapture data are subject to several sorts of biases (Ricker 1975). Three that seem potentially important in this application, although probably only as minor biases, are: differential mortality of marked and unmarked fish, nonhomogeneous distribution of marked and unmarked fish, and the natural occurrence of "marked" fish.

If marked fish suffer more mortality than unmarked fish, either from the stress imposed by handling and marking or because marked fish are more vulnerable to predators or disease than are unmarked fish, then an overestimate of the true population size can result. Texas Instruments (TI) addressed this problem with experiments conducted in 1973 (described in the Multiplant Report, TI 1975b) and derived correction factors to account for short-term (14-day) handling mortality of marked white perch. The possibility that long-term survival of marked white perch under natural conditions may be lower than that of unmarked fish was not evaluated by TI.

The Peterson method of estimating population size from mark/recapture data, the method chosen by TI, requires that marked fish mix completely with the unmarked population prior to recapture. If this mixing does not occur, a bias can be introduced into the results.

In particular, if sampling during the recapture period is concentrated in regions where marked fish are relatively abundant in comparison to their true proportion in the population, then the true population size will be underestimated. In the Multiplant Report, TI cited insufficient mixing as a reason for discarding estimates of the number of young-of-the-year white perch in the Hudson in the fall of 1973. In this case, fish were both marked and recaptured in the fall. Insufficient mixing is probably not a problem with the fall 1974 and 1975 estimates, because fish were released in the fall and recaptured during the following spring. From the distributional data presented in McFadden (1977, Section 6.1) and from the seasonal patterns of impingement discussed in Section II of this report, it is evident that young-of-the-year white perch migrate downstream to Haverstraw Bay and the Tappan Zee in the late fall and overwinter there before returning upstream in the spring. These migrations would appear to provide ample opportunity for mixing.

Texas Instruments uses finclips to mark young-of-the-year white perch and striped bass. Natural loss of fins is not uncommon, and the mistaking of fish that have lost fins for marked fish can cause underestimates of population size. Texas Instruments discovered several such "fin anomalies." According to the Multiplant Report, in 1974 it was discovered that about 0.3% of unmarked young-of-the-year white perch were missing one or both pelvic fins. This finding necessitated the recalculation (by excluding fish marked with single or double pelvic finclips) of mark/recapture estimates for the 1973 year class. Mark/recapture estimates of the August-September 1975 abundance of young-of-the-year white perch (presented in the FRR, Exhibit UT-4) were discarded (McFadden and Lawler 1977, Exhibit UT-3) after it was discovered that a mark type (anal finclip) used in the August-September 1975 release also occurs among unmarked fish. To this date no fin anomalies have been noted that involve any of the finclip types (six marks were used; five of these were double finclips) used in the October-November 1974 and October 1975 releases. We currently believe that the Peterson mark/recapture estimates of young-of-the-year white perch abundance in October of 1974 and 1975 are the best available estimates of the abundance of the 1974 and 1975 year classes. These estimates are used in the direct impact assessment contained in Section IV.

B. Mortality

Dew (1978) used the catch-curve method to calculate an average annual mortality rate for young-of-the-year and older white perch (Table 5). His results are derived from bottom trawl data collected in the vicinity of the Bowline Point Generating Station between 1971 and 1976. We believe, however, that young-of-the-year fish should not have been used in this analysis, because their mortality is probably higher than that of yearling and older fish. We also believe that Dew's method of analysis was not the most appropriate application of the catch-curve methodology. Dew estimated the annual fractional mortality separately for each age class, grouping together all fish of age 5 and older. He then averaged the individual estimates (value for A of 0.53 in Table 5). Robson and Chapman (1961) described an entirely different

Table 5. Catch-curve estimates of white perch mortality based on bottom trawl data from the Bowline Point vicinity, 1971-1976

	Annual fractional mortality (A)	Annual instantaneous mortality rate[a] (Z)
Original values[b] (ages 0 through 5+)	0.5349	0.7655
Recalculated values[c] (ages 1 through 5+)	0.4854	0.6644

[a] $Z = -\ln(1-A)$.

[b] Calculated by Dew, C. B. 1978. Age, growth, and mortality of Hudson River white perch (Morone americana) and the use of these parameters in evaluating the exploitation rate represented by impingement at power plant intakes. Paper presented at the Northeast Fish and Wildlife Conference, Greenbriar, West Virginia, February 28, 1978.

[c] Recalculated by excluding age 0 fish and using the method of Robson, D. S., and D. G. Chapman. 1961. Catch curves and mortality rates. Trans. Am. Fish. Soc. 90:181-189.

method of calculating average annual mortality when all fish older than a certain age are grouped together. As Robson and Chapman's method has been proven to be unbiased under the assumptions of the catch-curve method, and since its statistical properties are known, we believe that it is preferable to Dew's method. Therefore, we reworked Dew's analysis, excluding young-of-the-year white perch and using the method of Robson and Chapman (1961), to calculate an annual mortality rate for yearling and older white perch of approximately 50% (value for A of 0.49 in Table 5). This value is undoubtedly in error to some extent, since the catch-curve method is sensitive to fluctuations in year-class strength (Robson and Chapman, 1961). However, it is in good agreement with values obtained by Wallace (1971) for age I-IV white perch in the Delaware River: 54% for males and 58% for females. We believe at this time that 50% is a reasonable estimate, and this value is used in our direct impact assessment.

None of the available data appear adequate for deriving reliable estimates of total mortality in impingeable young-of-the-year white perch. Using the method employed by TI to estimate mortality in young-of-the-year striped bass, we attempted to calculate a mortality rate using TI's weekly combined gear estimates of young-of-the-year white perch abundance. The method involves regressing the natural logarithm of the population estimate against time (in days) from the end of July to mid-December. The slope of the regression line is an estimate of the daily instantaneous mortality rate. Using this method we obtained no useful results, because there was no discernible decline in the combined gear estimates between early August and mid-December.

We performed a similar analysis using data from only a single gear, the epibenthic sled, and a single sampling program, the fall shoals survey, in the hope of eliminating variation due to pooling different gears and different sampling programs. Although the epibenthic sled samples during the fall shoals survey seemed like the best single source of data from which to derive estimates of total mortality, this analysis was even less successful: population estimates based on epibenthic sled data alone increased between August and December, both in 1974 and in 1975.

We, therefore, used a range of values for young-of-the-year mortality in our direct impact assessment. As a high estimate we used the value of 80% assumed by McFadden and Lawler (1977, Exhibit UT-3). Given the absence of a seasonal decline in the combined gear and epibenthic sled abundance estimates, this value may be too high. Alternatively, we assumed that the mortality among impingeable young-of-the-year is identical to that among yearling and older fish, i.e., that the annual fractional mortality of young-of-the-year white perch is about 50%. Because of their smaller size, young-of-the-year should be more vulnerable to predators than are older white perch; hence, this value may be too low.

IV. ESTIMATION OF CONDITIONAL MORTALITY RATE AND EXPLOITATION RATE DUE TO IMPINGEMENT

The empirical model of impingement impact used to estimate the conditional mortality rate and exploitation rate due to impingement for the Hudson River white perch population is described in Barnthouse et al. (1979). The model requires (1) estimates of the initial number of young-of-the-year in the Hudson River white perch population at the time they first become vulnerable to impingement, (2) estimates of the rate of either total or natural mortality during the period of vulnerability to impingement, and (3) monthly estimates of the number of white perch impinged by year class.

For the purpose of comparing alternative assumptions about the age of impinged fish, it is desirable to formulate the model in terms of natural rather than total mortality, even though in practice only total mortality can be directly estimated from field data. This is not a major problem, however, because it is possible to calculate the conditional natural mortality rate, given the total mortality rate and the impingement exploitation rate (Barnthouse et al. 1979). In addition, when natural mortality is high relative to impingement mortality, total mortality and natural mortality are nearly numerically identical. For example, the natural conditional mortality rate calculated by Barnthouse et al. (1979) for impingeable young-of-the-year striped bass was 0.79, only slightly smaller than the total mortality rate of 0.8. Similarly, we believe that it is reasonable to use the same value (0.5) as an approximation of both the natural conditional mortality rate and total mortality rate in yearling and older white perch.

The estimates of initial population size and natural mortality rates are given in Table 6, and the bases for these estimates are discussed in Section III. Monthly estimates of the number of white perch impinged by year class are given in Table 7. These estimates include white perch impinged at all the power plants discussed in Section II and in Appendix A, except Astoria. Although impingement data are not available for the Albany power plant except for the period April 1974 through March 1976, Albany was operating continuously during the period June 1974 through December 1977, which is the period considered in this report in estimating conditional mortality rates and exploitation rates due to impingement for the 1974 and 1975 year classes. Consequently, the number of young-of-the-year and older white perch collected at Albany was approximated for each month from April 1976 to December 1977, as described in Table A-1 of Appendix A.

The value of a sexually immature fish to a population increases with its age, because its probability of surviving to sexual maturity increases. For this reason the impact to the population of killing a sexually immature fish increases with its age. If, as the utilities assume, the total mortality of juvenile white perch between July of year 0 and July of year 1 is 80%, then a single yearling impinged in July is worth five juveniles impinged 12 months earlier. If mortality between year 1 and year 2 is 50%, then each 2-year-old white perch is worth two yearlings or ten young-of-the-year. Even though the number of yearling and older white perch impinged each year constitutes only about 10% of the total white perch impingement, the impact of killing these fish is quite substantial.

Table 6. Initial population sizes and mortality estimates used in the empirical model of impingement impact to estimate the conditional mortality rate and exploitation rate due to impingement for the Hudson River white perch population

Initial population size[a]		Natural mortality[b]	Year class 1974	Year class 1975
$P_{October\ 1}$[c] (x 10^6)	LB		12	21
	BE		21	30
	UB		39	45
$P_{July\ 16}$[d] (x 10^6)	LB	Low	13.9	24.3
		High	16.8	29.4
	BE	Low	24.3	34.7
		High	29.4	41.9
	UB	Low	45.1	52.0
		High	54.5	62.9

[a]BE denotes the best estimate of initial population size. LB and UB denote the lower and upper bounds, respectively, of the 95% confidence interval about the best estimate.

[b]Low natural mortality: $r_n = 0.001899$ per day for the entire period of vulnerability to impingement. This instantaneous natural mortality rate corresponds to an annual (i.e., 365 days) conditional mortality rate of 0.5 due to all causes of mortality other than impingement.

High natural mortality: $r_n = 0.004409$ per day from July 16 as young-of-the-year to May 31 of the following year just as they become yearlings. This instantaneous natural mortality rate corresponds to an annual (i.e., 365 days) conditional mortality rate of 0.8 due to all causes other than impingement. $r_n = 0.001899$ per day from June 1 as yearlings until the end of the period of vulnerability.

[c]$P_{October\ 1}$ denotes the size of the Hudson River young-of-the-year white perch population on October 1, as estimated by Texas Instruments using mark-recapture techniques [p. 2-VII-2, as modified by errata in McFadden, J. T., and J. P. Lawler (eds.)]. 1977. Supplement I to Influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on striped bass and other fish populations. Consolidated Edison Company of New York, Inc. (Exhibit UT-3). Errata correcting the estimates of the size of the Hudson River young-of-the-year white perch population on October 1, originally given on p. 2-VII-2 of this reference, are contained in Utilities' Exhibits UT-3E-2 and UT-3E-5 which were submitted in December 1977 during the EPA, Region II, adjudicatory hearing in the matter of National Pollutant Discharge Elimination System Permits for Bowline, Indian Point, and Roseton Generating Stations.

[d]$P_{July\ 16}$ denotes the size of the Hudson River young-of-the-year white perch population on July 16. It is calculated using the equation

$$P_{July\ 16} = P_{October\ 1}/\exp(-76\ r_n) ,$$

where values for $P_{October\ 1}$ and r_n are given elsewhere in this table and 76 is the number of days between July 16 and October 1.

Table 7. Monthly estimates of the number of white perch impinged at all the Hudson River power plants combined for the 1974 and 1975 year classes[a]

		Year class			
		1974		1975	
		Number of years of vulnerability		Number of years of vulnerability	
Age (years)	Month	2	3	2	3
0	6	0		0	
	7	3,486		8,898	
	8	14,887		97,910	
	9	26,239		33,980	
	10	112,957		93,888	
	11	245,492		239,150	
	12	607,434		348,596	
	1	415,724		589,206	
	2	270,751		182,891	
	3	139,751		130,261	
	4	609,090		111,820	
	5	91,910		40,151	
1	6	37,242	18,621	27,014	13,507
	7	22,126	11,063	13,835	6,918
	8	14,122	7,061	6,770	3,385
	9	19,924	9,962	13,791	6,896
	10	19,534	9,767	25,676	12,838
	11	28,005	14,002	12,552	6,276
	12	7,803	3,902	48,102	24,051
	1	38,078	19,039	143,010	71,505
	2	9,293	4,646	43,558	21,779
	3	12,444	6,222	49,579	24,790
	4	14,103	7,052	38,692	19,346
	5	7,612	3,806	56,365	28,182
2	6		13,507		35,710
	7		6,918		8,805
	8		3,385		12,662
	9		6,896		8,736
	10		12,838		17,362
	11		6,276		19,145
	12		24,051		10,890
	1		71,505		
	2		21,779		
	3		24,790		
	4		19,346		
	5		28,182		

[a]Monthly values for number of young-of-the-year white perch impinged were calculated by summing the NUMBER0 values in Tables A-1, and A-3 through A-9 in Appendix A over power plants for the appropriate month and year.

Monthly values for number of yearling white perch impinged were calculated either by summing the NUMBER1 values over power plants for the appropriate month and year (2 years of vulnerability, corresponding to the assumption that 100% of the yearling and older white perch impinged were yearlings) or by summing the NUMBER1 values over power plants and dividing by 2 (3 years of vulnerability, corresponding to the assumption that 50% of the yearling and older white perch impinged are yearlings).

Monthly values for number of 2-year-old white perch impinged were calculated by summing the NUMBER1 values over power plants, dividing by 2, and tabulating the result for the given month, but one year later (3 years of vulnerability only, corresponding to the assumption that 50% of the yearling and older white perch impinged are 2-year-olds).

As indicated in Table 7, two alternative assumptions were made concerning the age of impinged yearling and older white perch. For one case, it was assumed that all white perch impinged that are yearlings and older are yearlings, resulting in two years of vulnerability to impingement. For the other case, it was assumed that of the yearling and older white perch impinged, 50% were yearlings and 50% were 2-year-olds, resulting in three years of vulnerability to impingement. It is our judgment, based on length-frequency data of impinged white perch at Bowline, Indian Point, and Roseton (see Appendix A, Tables A-3, A-5, 6 & 7, and A-9), that the true age composition of yearling and older white perch impinged (which includes some white perch older than 2 years) results in an effective split between yearlings and 2-year olds that is between the two assumptions just given, that is, (a) 100% yearlings and 0% 2-year-olds and (b) 50% yearlings and 50% 2-year-olds. Because of the lack of 1978 impingement data for January to May, no model estimates of impingement impact assuming three years of vulnerability are given for the 1975 year class.

With this exception, estimates of conditional mortality rate and exploitation rate due to impingement are given in Table 8 for the 1974 and 1975 year classes for combinations of estimates and assumptions involving initial population size (low, best estimate, and high), natural mortality (low and high), and number of years of vulnerability (2 and 3 years).

Estimates of the conditional mortality rate due to impingement are especially relevant in assessing the effects of power plant impingement, since they are equivalent to estimates of the fractional (or percent)

Table 8. Estimates of conditional mortality rate and exploitation rate (in parentheses) due to impingement for the 1974 and 1975 year classes of the Hudson River white perch population for combinations of estimates and assumptions involving initial population size, natural mortality, and number of years of vulnerability[a]

		Initial population size[b]					
		Low		Best estimate		High	
		Natural mortality rate[c]		Natural mortality rate[c]		Natural mortality rate[c]	
Number of years of vulnerability[d]	Year class	Low	High	Low	High	Low	High
2	1974	0.309	0.446	0.177	0.255	0.095	0.137
		(0.165)	(0.200)	(0.094)	(0.114)	(0.051)	(0.061)
	1975	0.166	0.245	0.116	0.172	0.077	0.115
		(0.082)	(0.099)	(0.057)	(0.069)	(0.038)	(0.046)
3	1974	0.387	0.588	0.221	0.336	0.119	0.181
		(0.172)	(0.209)	(0.099)	(0.119)	(0.053)	(0.064)
	1975	--	--	--	--	--	--

[a]Total conditional impingement mortality rate calculated using Eq. (11) in Barnthouse, L. W., D. L. DeAngelis, and S. W. Christensen. 1979. An empirical model of impingement impact. ORNL/NUREG/TM-290. Oak Ridge National Laboratory, Oak Ridge, Tennessee, i.e., $m_T = 1 - \prod_{i=1}^{12} (1 - m_i)$, except with the index i running from 1 to 24 (2 years of vulnerability) or 1 to 36 (3 years of vulnerability). The individual monthly m_i values were calculated in sequence using Eq. (2) and then Eq. (10) in Barnthouse et al. (1979). Total conditional impingement mortality rates are equal to fractional (or percent) reductions in year-class strength due to impingement, assuming no compensation.

Exploitation rate calculated by dividing the total number of white perch impinged in a year class during the entire period of vulnerability by the size of the young-of-the-year population at the start of the period of vulnerability.

[b]See Table 6.

[c]See footnote b to Table 6.

[d]See Table 7.

reduction in the size of a year class due to impingement, assuming no compensation (see Barnthouse et al. 1979). As indicated by the values in Table 8, percent-reduction values (obtained by multiplying by 100) are greater (1) the smaller the initial population size, (2) with high natural mortality rates as opposed to low, and (3) assuming three years of vulnerability instead of two. Furthermore, assuming approximately comparable degrees of uncertainty in the choices of low and high estimates of initial population size, natural mortality, and number of years of vulnerability, it appears that the estimates of percent reduction are most sensitive to (i.e., vary most widely depending on) estimates of initial population size, least sensitive to the number of years of vulnerability assumed, and intermediately sensitive to estimates of natural mortality.

The percent-reduction values range from 9.5 to 45% for the 1974 year class and from 7.7 to 24% for the 1975 year class, assuming only two years of vulnerability. Assuming three years of vulnerability, the percent-reduction values range from 12 to 59% for the 1974 year class. As previously indicated, for the 1975 year class, percent-reduction values cannot be calculated because 1978 impingement data are not currently available.

Exploitation rates show the same pattern of variation as the conditional mortality rates with respect to values used for initial population size, natural mortality, and number of years of vulnerability (Table 8). The exploitation rates range from 5.1 to 20.0% for the 1974 year class and from 3.8 to 9.9% for the 1975 year class, assuming only two years of vulnerability. Assuming three years of vulnerability, the exploitation rates range from 5.3 to 20.9% for the 1974 year class, and, although they cannot be calculated at this time, they would be expected tc be lower for the 1975 year class. As discussed in Barnthouse et al. (1979), because there are competing sources of mortality and each an organism can die only once, an exploitation rate is always lower than the corresponding conditional mortality rate. However, as stated above, it is the conditional mortality rate due to impingement that is equivalent to percent reduction in the size of the year class. Because of this equivalence, the conditional mortality rate is a more meaningful measure of impact than is the exploitation rate.

V. DISCUSSION

A. Comparison with utilities' results

Variations in impingement rate of white perch among years, months, and power plants were summarized by the utilities in McFadden et al. (1978, pp. 14.3-1 to 14.3-8). In contrast to our approach, the utilities did not consider the following: (1) Albany and Astoria Steam Electric Generating Stations, (2) the three units at Indian Point separately, (3) 1972 data available for Danskammer, and (4) the distinction between young-of-the-year and older white perch. Although tables of impingement rate and number of white perch impinged are presented for Indian Point, Bowline, Roseton, Lovett, and Danskammer, essentially no quantitative analyses of these data are included, so comparison of our results in Section II with theirs is not possible, in general. The utilities' qualitative statements on monthly variations on a plant-by-plant basis are in agreement with our results. They made no attempt to test for trends in yearly variations or to rank power plants.

The utilities estimated the conditional mortality rate and exploitation rate due to impingement of white perch for the 1974 year class (Table 9).

> "Impingement impact for the 1974 year class was estimated assuming that 90% of the July 1974-June 1975 impingement consisted of the 1974 year class. Exploitation of this year class was calculated to be 4.4% at Indian Point Unit 2 and 5.9% for the multiplant case (Table 2-VII-1). These exploitation rates are equivalent to conditional mortality rates of 8.5% for Indian Point and 11.2% for multiplant with an assumed total mortality rate of 80%." (McFadden and Lawler 1977, p. 2-VII-3)

Table 9. Estimates of number impinged, exploitation rate, and conditional mortality rate by power plant[a]

Power plant	Number impinged[b]	Exploitation rate (u)	Conditional mortality rate (m)
Bowline	473,043	0.0137	0.0273
Roseton	52,025	0.0015	0.0030
Indian Point Unit 2	1,520,317[c]	0.0441	0.0849
Multiplant	2,045,385	0.0594	0.1126

[a]From Table 2-VII-1 in McFadden, J. T., and J. P. Lawler (eds.). 1977. Supplement I to Influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on striped bass and other fish populations. Consolidated Edison Company of New York, Inc. (Exhibit UT-3). Errata correcting the estimates of the size of the Hudson River young-of-the-year white perch population on October 1, originally given on p. 2-VII-2 of this reference, are contained in Utilities' Exhibits UT-3E-2 and UT-3E-5 which were submitted in December 1977 during the EPA, Region II, adjudicatory hearing in the matter of National Pollutant Discharge Elimination System Permits for Bowline, Indian Point, and Roseton Generating Stations.

[b]Total impingement, of which 90% are assumed to be 1974 year class.

[c]Includes 948 impinged at Indian Point Unit 3.

In terms of the comparability of assumptions and input values used in the utilities' methodology and our methodology, the utilities' conditional mortality rate of 11.3% and exploitation rate of 5.9% in Table 9 for the multiplant case can be compared with our estimates in Table 8 (two years of vulnerability, best estimate of initial population size, and high natural mortality) of a conditional mortality rate (m) of 25.5% and an exploitation rate (u) of 11.4%. The two sets of estimates differ by approximately a factor of two for several reasons (we did not attempt to estimate how much of the two-fold difference is due to each of the following reasons):

(1) We included the Albany, Danskammer, and Lovett Steam Electric Generating Stations, while they did not. These three plants were operating during the years 1974 through 1977 and were impinging white perch. Thus, they should be included in any evaluation of the impact of impingement on the Hudson River white perch population.

(2) We included Indian Point Unit 1, which operated continuously (at least the circulating water pumps) from June 1974 through August 1975, while they did not. Because this unit was operating during part of the period of interest and was impinging white perch, it also should be included in any evaluation of the impact of impingement on the Hudson River white perch population.

(3) Our values of 25.5% (m) and 11.4% (u) reflect two years of vulnerability to impingement, while their values reflect only

one year of vulnerability (i.e., they ignored impingement of yearlin and older white perch from the 1974 year class past June 1975). Since yearling and older white perch, in fact, are impinged in appreciable numbers, they must be considered as such in any credible evaluation of the impact of impingement on the Hudson River white perch population. There is no scientifically, justifiable methodological reason or biological reason for not including these yearling and older white perch in such an evaluation.

(4) We used available data to estimate on a monthly and plant-specific basis the percent of white perch impinged from June 1974 to June 1975 that were from the 1974 year class, whereas they assumed 90%. As the PERCENTO values in Tables A-1 and A-3 through A-9 indicate, their assumption of 90% young-of-the-year may be justified for Lovett and for the three Indian Point units. However, the utilities' assumption of 90% young-of-the-year is clearly too high for Albany, Bowline, Danskammer, and Roseton.

(5) We used the methodology presented in Barnthouse et al. (1979), which permitted us to take into account monthly variations in impingement rates, whereas the utilities' methodology implicitly assumes a constant vulnerability. In reality, as discussed in Section II, the impingement rate fluctuates appreciably on a monthly basis, with rates being substantially higher from December through May than from June through November (Tables 2 and 3). [Also see Table 3 and

associated text in Barnthouse et al. (1979) for a comparison using constant versus variable impingement rates to estimate the conditional mortality rate due to impingement.]

The utilities' choice at every one of the above five "decision points" affects the results in the same direction, namely, to lower the estimates of impingement impact. Yet, given that the purpose of the utilities' analysis and of our own analysis ought to be to realistically and objectively estimate the percent reduction in year-class strength of white perch in the Hudson River due to impingement at power plants, our choice at each of the five decision points is scientifically more sound and defensible for the reasons we have given.

B. Is there a problem?

This report presents two independent lines of evidence evaluating the impingement losses of white perch at the power plants on the Hudson River. The first line of evidence, the analysis of the variation in impingement rate among years (Section II.B), suggests that there is not yet an obvious problem, but that it is too soon to be sure (Appendix D). The second line of evidence, the estimates of conditional mortality rate due to impingement (Section IV), suggests that the level of impingement impact cannot be assessed as acceptable *a priori* from the point of view of managing the white perch population. These two lines of evidence are briefly elaborated on in the following two paragraphs.

The impingement rates provide estimates of year-class strength on a relative scale. As such, they reflect the effect of entrainment and impingement losses during the preceding months, as well as the effect of any compensatory mechanisms which might alter survival during the preceding months. Regression analyses of impingement rates of impinged young-of-the-year white perch suggest that there has been no linear change in the size of the white perch population during the period 1972 through 1977 (Section II.B). In particular, there is little evidence of a statistically significant downward trend. However, given the large variability in impingement rates used in these regressions, the time series are relatively short (i.e., 5-6 years), and thus, the statistical power of the test for a trend is not high. Based on a systematic analysis of minimum detectable differences in annual impingement rates and the number of years required to detect a specified reduction in this index of year-class strength, it is concluded that long times series of year-class strength would be required to detect even substantial reductions (e.g., 50%). A final point relating to the use of impingement rate as a relative index of year-class strength is that a systematic decrease in year-class strength due to impingement mortality would only start to manifest itself with the 1977 (or 1978) and subsequent year classes. This delay is due to the age of sexual maturity for females, the multiple age-class composition of the spawning population of females, and the appreciable increase in impingement mortality starting in 1973 and 1974.

The estimates of percent reduction in year-class strength due to impingement that are presented in Table 8 cover a broad range, as discussed in Section IV. Our analysis shows that the level of impingement impact was probably greater than 20% for the 1974 year class and was probably greater than 15% for the 1975 year class. These estimates do not include consideration of entrainment, so the total power plant conditional mortality rate is obviously greater than the values given here for impingement only. Given the information currently available, it is our judgment that this level of impingement impact is not acceptable *a priori* from the point of view of managing the white perch population. It is important that collection of appropriate data relating to the impingement of white perch continue. Intake flows and impingement rates by age class are needed on a monthly basis for each of the power plants, including Albany.

VI. CONCLUSIONS AND RECOMMENDATIONS

On the basis of our evaluation of impingement losses of white perch at the Indian Point Nuclear Station and other Hudson River power plants presented in this topical report (including appendices B, C, and D), we arrived at the following conclusions and recommendations.

1. There has been no statistically significant reduction in the strength of year classes produced from 1973 through 1977. However, note conclusions below for Appendix D.
2. Impingement rates vary in a consistent manner among months and among power plants for young-of-the-year and for yearling and older white perch.
3. The Peterson mark/recapture estimates of the abundance of young-of-the-year white perch are judged to be more reliable than the combined gear estimates.
4. Our analysis suggests that 50% is a reasonable estimate for total annual mortality for yearling and older white perch. None of the available data appear adequate for deriving reliable estimates of total mortality for impingeable young-of-the-year white perch.
5. The conditional mortality rate is a more meaningful measure of impact than is the exploitation rate, since it is equivalent to estimates of the fractional (or percent) reduction in year-class strength due to impingement, assuming no compensation.
6. Percent-reduction values range from 9.5 to 45% for the 1974 year class and from 7.7 to 24% for the 1975 year class, assuming only two years of vulnerability. Percent-reduction values are greater

(a) the smaller the initial population size, (b) with high natural mortality rates as opposed to low, and (c) assuming three years of vulnerability instead of two. Percent-reduction values are most sensitive to estimates of initial population size.

7. The estimates of conditional mortality rate due to impingement suggest that the level of impingement impact cannot be assessed as acceptable a priori from the point of view of managing the white perch population.
8. The estimate presented by the utilities of conditional mortality rate due to impingement for the 1974 year class differs by approximately a factor of two from the comparable estimate presented in this report. We conclude that our choice at each of five decision points in the analysis is scientifically more sound and defensible.
9. Further research on (a) the impact of impingement on the Hudson River white perch population and (b) the effects of a reduction in white perch year-class strength and total abundance on the Hudson River ecosystem is recommended.

Appendix B

1. The survival of impinged white perch is enhanced by continuous rotation of travelling screens, but it is not consistently enhanced by reductions in screenwash pressure.
2. Although the data are variable and sometimes inconsistent, we tentatively conclude that about 40% of impinged white perch can survive impingement, provided the travelling screens are operated in the continuous mode.

3. We strongly recommend that impingement survival studies, especially studies of survival during the winter, be continued.

Appendix C

1. There was not a statistically significant positive correlation between impingement rates and catch per unit effort by beach seines either among years or within a year for the data sets analyzed.
2. The length-frequency distributions of young-of-the-year white perch in impingement collections at Indian Point Unit 2 differed slightly from those in beach seine samples from the vicinity of Indian Point in 1975.
3. It is not clear which data set (impingement or beach seine) provides the more accurate (less inaccurate) indices of year-class strength.
4. The volume of cooling water withdrawn by Indian Point Units 2 and 3 on any given day does influence the number of white perch impinged on that day, although flow apparently accounts for only a few percent of the total variance in the daily impingement counts over a year.
5. Further study of the feasibility of using impingement rate as an index of year-class strength is strongly recommended, including consideration of other species in other systems.

Appendix D

1. Natural variability in the existing baseline time series of impingement rates and beach seine CPUE is so great that 10

additional years of indices of year-class strength are not likely to provide a very powerful data set for detecting even substantial, actual reductions in year-class strength.

2. Natural variability in the existing baseline time series is so great that an excessive number of years (greater than the expected lifetime of the power plants involved) of additional data would be required to detect an actual 50% reduction in the mean index of year-class strength, even if we are willing to accept a Type II error of 50%.

VII. REFERENCES

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APPENDIX A

IMPINGEMENT DATA BASE

The data base is presented by power plant, arranged in alphabetical order

TABLE A-1

WHITE PERCH IMPINGEMENT DATA FOR THE
ALBANY STEAM ELECTRIC GENERATING STATION

April 1974 - March 1975: Ref. (1)

RATE (collection rate):[1] calculated from monthly data on average observed number of fish of all species collected per million gallons of intake flow at all units (from Table 3, Column B, Plant Av.), and monthly data on percentage composition by species of the fish collected (from Table 4).

NUMBER (number collected): calculated from monthly data on estimated number of fish of all species collected at all units (from Table 2, Column D, Total) and monthly data on percentage composition by species of the fish collected (from Table 4).

PERCENTO (percent of the white perch collected that were young-of-the-year): calculated with the aid of graph paper and a dissecting microscope from the monthly plots in Fig. 10 of frequency versus length intervals of white perch collected at the Albany Steam Electric Generating Station for each month April through November 1974. The "DIVISION" criteria specified by Texas Instruments were used as the cut-off length between young-of-the-year and yearling white perch (see Table A-10 in this appendix).

April 1975 - March 1976: Ref. (2)

RATE (collection rate):[1] calculated from monthly data on average observed number of fish of all species collected per million gallons of intake flow at all units (from Table IVC-16) and monthly data on percentage composition by species of the fish collected (from Table IVC-14).

NUMBER (number collected): calculated from the monthly collection rates (RATE) described immediately above and monthly values of average daily plant flow for all units in millions of gallons per day times the number of days in the particular month.

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[1]All collection rates were converted from number of white perch collected per million gallons to number of white perch collected per million cubic meters by multiplying by 264.17 gallons per cubic meter. Collection rates were assumed to equal impingement rates.

TABLE A-1 (continued)

PERCENTO (percent of the white perch collected that were young-of-the-year): calculated with the aid of graph paper and a dissecting microscope from the plots in Fig. IVC-6 of relative frequency versus length intervals of white perch collected at the Albany Steam Electric Generating Station for each month May through November 1975. The "DIVISION" criteria specified by Texas Instruments were used as the cut-off point between young-of-the-year and yearling white perch (see Table A-10 in this appendix).

RATE, NUMBER, and PERCENTO values were approximated as follows for each month during 1974 through 1977 for which estimates were not directly available from Refs. (1) and (2). These approximations were necessary in order to have a complete data set with which to estimate exploitation rates and the conditional rates of mortality due to impingement (see Section IV).

RATE and NUMBER: approximations for each month were calculated as the average of the two monthly estimates available from the period April 1974 through March 1976. These approximations were used for January through March 1974 and April 1976 through December 1977.

PERCENTO: for May through November, approximations were calculated as just described for RATE and NUMBER. The approximation for November was also used for the months of December and January of all years. The April 1974 value (no estimate for April 1975 was available) was used as the approximation for April 1975, 1976, and 1977 and for the months of February and March of all years.

RATEO = PERCENTO RATE/100 and RATE1 = RATE - RATEO.

NUMBERO = PERCENTO NUMBER/100 and NUMBER1 = NUMBER - NUMBERO.

RATE, NUMBER, and PERCENTO are defined above. RATEO and RATE1 are the collection rates for young-of-the-year and for yearling and older white perch, respectively. NUMBERO and NUMBER1 are number collected for young-of-the-year and for yearling and older white perch, respectively.

TABLE A-1 (continued)

PLANT=ALBANY

YEAR	MONTH	RATE	NUMBER	PERCENTO	RATE0	RATE1	NUMBER0	NUMBER1
1974	1	0.000	3.5	10.70	0.0000	0.000	0.37	3.1
1974	2	0.528	15.5	19.60	0.1036	0.425	3.04	12.5
1974	3	6.868	260.5	19.60	1.3462	5.522	51.06	209.4
1974	4	77.138	3923.0	19.60	15.1190	62.019	768.91	3154.1
1974	5	95.101	5518.0	35.50	33.7609	61.340	1958.89	3559.1
1974	6	133.934	7717.0	0.00	0.0000	133.934	0.00	7717.0
1974	7	211.072	12518.0	0.00	0.0000	211.072	0.00	12518.0
1974	8	105.932	6294.0	5.88	6.2288	99.703	370.09	5923.9
1974	9	178.051	9868.0	2.44	4.3444	173.706	240.78	9627.2
1974	10	305.381	17325.0	1.79	5.4663	299.914	310.12	17014.9
1974	11	61.023	3516.0	9.43	5.7545	55.259	331.56	3184.4
1974	12	0.264	21.0	10.70	0.0283	0.236	2.25	18.8
1975	1	0.000	7.0	10.70	0.0000	0.000	0.75	6.3
1975	2	0.793	31.0	19.60	0.1553	0.637	6.08	24.9
1975	3	0.264	10.0	19.60	0.0518	0.212	1.96	8.0
1975	4	1.057	45.0	19.60	0.2071	0.850	8.82	36.2
1975	5	285.568	11717.0	6.58	18.7904	255.777	770.98	10946.0
1975	6	118.084	5583.0	0.00	0.0000	118.084	0.00	5583.0
1975	7	212.921	8336.0	0.00	0.0000	212.921	0.00	8336.0
1975	8	29.851	1467.0	6.12	1.8269	28.024	89.78	1377.2
1975	9	299.833	14714.0	12.40	37.1793	262.554	1824.54	12889.5
1975	10	133.406	6036.0	7.52	10.0321	123.374	453.91	5582.1
1975	11	69.213	2906.0	11.90	8.2363	60.976	345.81	2560.2
1975	12	0.264	16.0	10.70	0.0283	0.236	1.71	14.3
1976	1	0.000	0.0	10.70	0.0000	0.000	0.00	0.0
1976	2	0.000	0.0	19.60	0.0000	0.000	0.00	0.0
1976	3	13.208	511.0	19.60	2.5889	10.620	100.16	410.8
1976	4	39.097	1984.0	19.60	7.6630	31.434	388.86	1595.1
1976	5	190.202	8617.5	21.00	39.9425	150.260	1809.68	6807.8
1976	6	126.009	8026.5	0.00	0.0000	126.009	0.00	8026.5
1976	7	211.864	10427.0	0.00	0.0000	211.864	0.00	10427.0
1976	8	67.892	3880.5	6.00	4.0735	63.818	232.83	3647.7
1976	9	238.810	12291.0	7.42	17.7197	221.090	911.99	11379.0
1976	10	219.261	11680.5	4.66	10.2176	209.044	544.31	11136.2
1976	11	64.986	3211.0	10.70	6.9535	58.032	343.58	2867.4
1976	12	0.264	18.5	10.70	0.0283	0.236	1.98	16.5
1977	1	0.000	3.5	10.70	0.0000	0.000	0.37	3.1
1977	2	0.528	15.5	19.60	0.1036	0.425	3.04	12.5
1977	3	6.868	260.5	19.60	1.3462	5.522	51.06	209.4
1977	4	39.097	1984.0	19.60	7.6630	31.434	388.86	1595.1
1977	5	190.202	8617.5	21.00	39.9425	150.260	1809.68	6807.8
1977	6	126.009	8026.5	0.00	0.0000	126.009	0.00	8026.5
1977	7	211.864	10427.0	0.00	0.0000	211.864	0.00	10427.0
1977	8	67.892	3880.5	6.00	4.0735	63.818	232.83	3647.7
1977	9	238.810	12291.0	7.42	17.7197	221.090	911.99	11379.0
1977	10	219.261	11680.5	4.66	10.2176	209.044	544.31	11136.2
1977	11	64.986	3211.0	10.70	6.9535	58.032	343.58	2867.4
1977	12	0.264	18.5	10.70	0.0283	0.236	1.98	16.5

REFERENCES FOR TABLE A-1

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2. Lawler, Matusky & Skelly Engineers. Albany Steam Electric Generating Station, 316(a) Demonstration Submission, NPDES Permit NY 0005959. Prepared for Niagara Mohawk Power Corporation, 1976.

TABLE A-2

WHITE PERCH IMPINGEMENT DATA
FOR THE ASTORIA GENERATING STATION (Ref. 1)

RATE (collection rate):[1] calculated from monthly data on observed number of fish and crustaceans of all species collected per million gallons of intake flow at Units 1-5 (from Table 12) and monthly data on the percent of the total number of fish and crustaceans collected that were white perch (calculated from data in Table 4).

NUMBER (number collected): calculated from the collection rate (RATE) described immediately above and the value for full flow through Units 1-6 in gallons per minute (from Table 1) times the number of minutes in the particular month.

Data with which to calculate RATE and NUMBER values were available only for the period January 1972 through December 1972. No data were available from which to estimate PERCENTO, the percent of the white perch collected at Astoria that were young-of the-year. The white perch impingement data for Astoria have been used only in Section II.B on seasonal variations in collection rates among the different power plants.

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[1]All collection rates were converted from number of white perch collected per million gallons to number of white perch collected per million cubic meters by multiplying by 264.17 gallons per cubic meter. Collection rates were assumed to equal impingement rates.

TABLE A-2 (continued)

---------------------------------- PLANT=ASTORIA ----------------------------------

YEAR	MONTH	RATE	NUMBER	PERCENT0	RATE0	RATE1	NUMBER0	NUMBER1
1972	1	1.04611	251	.	.	.	.	.
1972	2	4.62297	1041	.	.	.	.	.
1972	3	1.60087	399	.	.	.	.	.
1972	4	3.13570	757	.	.	.	.	.
1972	5	2.09223	522	.	.	.	.	.
1972	6	0.84534	204	.	.	.	.	.
1972	7	0.87440	218	.	.	.	.	.
1972	8	0.00000	0	.	.	.	.	.
1972	9	0.00000	0	.	.	.	.	.
1972	10	0.00000	0	.	.	.	.	.
1972	11	0.00000	0	.	.	.	.	.
1972	12	6.94767	1733	.	.	.	.	.

REFERENCE FOR TABLE A-2

1. Quirk, Lawler and Matusky Engineers. A Study of Impinged Organisms at the Astoria Generating Station. QL&M Project No. 115-16, prepared for Consolidated Edison Company of New York, Inc., September 1973.

TABLE A-3

WHITE PERCH IMPINGEMENT DATA FOR THE
BOWLINE POINT GENERATING STATION

January 1973 - December 1976: Ref. (1)

Values for RATE (collection rate)[1] and NUMBER (number collected) were taken directly from data sheets in Ref. (1).

January 1977 - December 1977: Ref. (2)

Values for RATE (collection rate)[1] and NUMBER (number collected) were taken directly from data sheets in Ref. (2).

PERCENT0 (percent of the white perch collected that were young-of-the year):

January 1975 through December 1976: Calculated from monthly data on length-frequency in 1-centimeter length intervals of white perch in impingement collections [from Tables 10.2-13 and 10.2-14 in Ref. (3)]. The "DIVISION" criteria specified by Texas Instruments were used as the cut-off length between young-of-the-year and yearling white perch (see Table A-10 in this appendix).

January 1973 through December 1974 and January 1977 through December 1977: in the absence of monthly values during these two periods, estimates were calculated as the average of the 1975 and 1976 PERCENT0 values for each month.

RATE0 = PERCENT0 RATE/100 and RATE1 = RATE - RATE0.

NUMBER0 = PERCENT0 NUMBER/100 and NUMBER1 = NUMBER - NUMBER0.

RATE, NUMBER, and PERCENT0 are defined above. RATE0 and RATE1 are the collection rates for young-of-the-year and for yearling and older white perch, respectively. NUMBER0 and NUMBER1 are number collected for young-of-the-year and for yearling and older white perch, respectively.

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[1]All collection rates were converted from number of white perch collected per million gallons to number of white perch collected per million cubic meters by multiplying by 264.17 gallons per cubic meter. Collection rates were assumed to equal impingement rates.

TABLE A-3 (continued)

PLANT=BOWLINE

YEAR	MONTH	RATE	NUMBER	PERCENTO	RATE0	RATE1	NUMBER0	NUMBER1
1973	1	296.13	17021	82.6	244.51	51.527	14059	2961.7
1973	2	353.99	16184	78.8	278.94	75.045	12753	3431.0
1973	3	288.74	4476	84.8	244.85	43.838	3795	680.4
1973	4	462.56	23903	84.8	392.25	70.309	20270	3633.3
1973	5	235.90	14739	69.0	162.77	73.130	10170	4569.1
1973	6	19.55	809	0.0	0.00	19.549	0	809.0
1973	7	13.74	692	44.8	6.15	7.583	310	382.0
1973	8	45.44	2724	78.2	35.53	9.905	2130	593.8
1973	9	4.76	285	81.6	3.88	0.875	233	52.4
1973	10	5.02	326	92.6	4.65	0.371	302	24.1
1973	11	9.51	500	96.0	9.13	0.380	480	20.0
1973	12	373.01	18060	98.3	366.67	6.341	17753	307.0
1974	1	1092.87	58425	82.6	902.71	190.150	48259	10166.0
1974	2	1219.94	47008	78.8	961.31	258.627	37042	9965.7
1974	3	968.98	51689	84.8	821.59	147.234	43832	7856.7
1974	4	922.48	55907	84.8	782.26	140.217	48257	3649.9
1974	5	91.40	2901	69.0	63.07	28.335	2002	899.3
1974	6	18.49	1423	0.0	0.00	18.492	0	1423.0
1974	7	5.28	533	44.8	2.37	2.915	239	294.2
1974	8	3.43	372	78.2	2.69	0.749	291	81.1
1974	9	4.49	529	81.6	3.66	0.825	432	97.3
1974	10	29.32	3697	92.6	27.15	2.170	3423	273.6
1974	11	497.17	43360	96.0	477.28	19.887	41626	1734.4
1974	12	845.08	90095	98.3	830.71	14.366	88563	1531.6
1975	1	1898.59	176382	69.4	1317.62	580.958	122409	53972.9
1975	2	97.21	7354	68.0	66.11	31.109	5001	2353.3
1975	3	303.00	24651	71.8	217.56	85.447	17699	6951.6
1975	4	1350.70	113509	72.2	975.21	375.495	81953	31555.5
1975	5	173.82	9488	38.1	66.23	107.597	3615	5873.1
1975	6	15.06	1228	0.0	0.00	15.058	0	1228.0
1975	7	19.28	1809	89.5	17.26	2.025	1619	189.9
1975	8	4.23	445	66.7	2.82	1.407	297	148.5
1975	9	1.85	190	75.0	1.39	0.452	143	47.5
1975	10	2.38	133	85.2	2.03	0.352	113	19.7
1975	11	20.34	1051	96.5	19.63	0.7119	1014	36.79
1975	12	622.38	54906	99.1	616.78	5.5015	54412	494.15
1976	1	61.55	2936	95.7	58.90	2.6467	2810	126.25
1976	2	94.84	3805	89.7	85.07	9.7682	3413	391.92
1976	3	261.00	13906	97.7	255.00	5.0030	13586	319.84
1976	4	687.90	57131	97.5	670.70	17.1975	55703	1428.28
1976	5	22.98	1996	100.0	22.98	0.0000	1996	0.00
1976	6	9.25	812	0.0	0.00	9.2459	0	812.00
1976	7	2.91	308	0.0	0.00	2.9059	0	308.00
1976	8	113.86	10878	89.7	102.13	11.7273	9758	1120.43
1976	9	15.32	1512	88.2	13.51	1.8030	1334	178.42
1976	10	1.06	49	100.0	1.06	0.0000	49	0.00
1976	11	610.50	32966	95.4	582.41	28.0829	31450	1516.44
1976	12	1711.03	149371	97.5	1668.25	42.7757	145637	3734.28
1977	1	295.29	25081	82.6	243.91	51.3803	20717	4364.09
1977	2	306.57	24051	78.8	241.58	64.9927	18952	5098.81
1977	3	147.91	12697	84.8	125.43	22.4821	10767	1929.94
1977	4	81.73	7068	84.8	69.31	12.4236	5994	1074.34
1977	5	91.35	8520	69.0	63.03	28.3135	5879	2641.20
1977	6	24.57	1952	0.0	0.00	24.5678	0	1952.00
1977	7	5.26	338	44.8	2.36	2.9019	151	186.58
1977	8	66.36	7822	78.	51.89	14.4664	6117	1705.20
1977	9	1.90	164	81.	1.55	0.3500	134	30.18
1977	10	59.17	5122	92.6	54.80	4.3789	5669	453.03
1977	11	293.47	24756	96.0	282.59	11.7738	23765	990.24
1977	12	359.43	31056	98.3	353.32	6.1103	30528	527.95

REFERENCES FOR TABLE A-3

1. Letter dated March 3, 1978, from William J. Cahill, Jr. of Consolidated Edison Company of New York, Inc. (Con Ed) to Robert P. Geckler of the U. S. Nuclear Regulatory Commission (US NRC), including a response to Question X.1, which is the identification number for a question in Enclosure 2 of a letter dated July 26, 1977, from George W. Knighton (US NRC) to William Cahill, Jr. (Con Ed).

2. Letter dated May 5, 1978, from Edward G. Kelleher of Consolidated Edison Company of New York, Inc. (Con Ed) to Henry Gluckstern of the U. S. Environmental Protection Agency (US EPA), including a response to Question A-4, which is the identification number for a question in the enclosure of a letter dated March 23, 1978, from Henry Gluckstern (US EPA) to Kenneth L. Marcellus (Con Ed).

3. Ecological Analysts, Inc. Bowline Point Generating Station. Near-field Effects of Once-through Cooling System Operation on Hudson River Biota. Prepared for Orange and Rockland Utilities, Inc., July 1977 (Exhibit UT-7).

TABLE A-4

WHITE PERCH IMPINGEMENT DATA FOR
THE DANSKAMMER POINT GENERATING STATION

RATE (collection rate):[1]

January 1972 - December 1976: average of the daily collection rates for each month were copied directly from data sheets in Ref. (1).

January 1977 - December 1977: average of the daily collection rates for each month were copied directly from data sheets in Ref. (2).

NUMBER (number collected):

January 1972 through December 1977: calculated from the monthly collection rates (RATE) described immediately above and monthly values of actual total plant intake flow in millions of gallons for the particular month, from data sheets in Ref. (3) for 1972 through 1976 and from data sheets provided by the U. S. Environmental Protection Agency, Region II, New York, New York for 1977.

PERCENTO (percent of the white perch collected that were young-of-the-year):

No estimates of PERCENTO were available for Danskammer. Consequently, all monthly values for PERCENTO were approximated based on data from Roseton, which is adjacent to Danskammer. (See Table A-9 in this appendix. Monthly PERCENTO values tabulated for Danskammer are exactly the same as those tabulated for Roseton for July 1973 through December 1977; monthly PERCENTO values for January 1972 through June 1973 were calculated as the average of the 1975 and 1976 Roseton values for each month.

RATEO = PERCENTO RATE/100 and RATE1 = RATE - RATEO.

NUMBERO = PERCENTO NUMBER/100 and NUMBER1 = NUMBER - NUMBERO.

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[1]All collection rates were converted from number of white perch collected per million gallons to number of white perch collected per million cubic meters by multiplying by 264.17 gallons per cubic meter. Collection rates were assumed to equal impingement rates.

RATE, NUMBER, and PERCENTO are defined above. RATEO and RATE1 are the collection rates for young-of-the-year and for yearling and older white perch, respectively. NUMBERO and NUMBER1 are number collected for young-of-the-year and for yearling and older white perch, respectively.

TABLE A-4 (continued)

PLANT=DANSKAM

YEAR	MONTH	RATE	NUMBER	PERCENT0	RATE0	RATE1	NUMBER0	NUMBER1
1972	1	22.67	748	66.0	14.959	7.706	493.7	254.3
1972	2	11.23	318	53.0	5.950	5.277	168.5	149.5
1972	3	29.45	768	59.0	17.378	12.077	453.1	314.9
1972	4	137.32	4544	44.0	60.419	75.897	1999.4	2544.6
1972	5	744.57	28668	58.0	431.908	312.761	16627.4	12040.6
1972	6	546.04	23235	0.0	0.000	546.039	0.0	23235.0
1972	7	206.74	9696	4.8	9.923	196.816	465.4	9230.6
1972	8	253.34	12723	64.2	162.644	90.695	8168.2	4554.8
1972	9	172.82	7143	86.5	149.489	23.331	6178.7	964.3
1972	10	477.65	19732	88.6	423.194	54.452	17482.6	2249.4
1972	11	273.07	11098	85.3	232.931	40.142	9466.6	1631.4
1972	12	110.45	3775	73.8	81.512	28.938	2785.9	989.1
1973	1	9.09	281	66.0	5.998	3.090	185.5	95.5
1973	2	3.22	78	53.0	1.708	1.515	41.3	36.7
1973	3	24.22	719	59.0	14.292	9.932	424.2	294.8
1973	4	203.89	6959	44.0	89.710	114.176	3062.0	3897.0
1973	5	352.80	15344	58.0	204.627	148.176	8899.5	6444.5
1973	6	167.48	7931	0.0	0.000	167.484	0.0	7931.0
1973	7	485.17	25608	4.8	23.288	461.886	1229.2	24378.8
1973	8	88.76	4726	64.2	56.985	31.776	3034.1	1691.9
1973	9	171.21	8631	86.5	148.10	23.113	7465.8	1165.2
1973	10	505.41	20165	88.6	448.68	57.731	17866.2	2298.8
1973	11	451.36	17855	85.3	385.01	55.350	15230.3	2624.7
1973	12	77.24	2248	73.8	57.01	20.238	1659.0	589.0
1974	1	20.34	625	66.0	13.43	5.915	412.5	212.5
1974	2	1.29	37	53.0	0.69	0.608	19.6	17.4
1974	3	5.02	153	59.0	2.96	2.058	90.3	62.7
1974	4	668.35	19511	44.0	294.07	374.276	8584.8	10926.2
1974	5	393.96	15508	58.0	220.49	165.452	8994.6	6513.4
1974	6	381.57	12926	0.0	0.00	381.567	0.0	12926.0
1974	7	135.89	6273	4.8	6.52	129.355	301.1	5971.9
1974	8	119.96	5958	64.2	77.01	42.946	3825.0	2133.0
1974	9	53.18	2302	86.5	46.00	7.179	1991.2	310.8
1974	10	134.46	6577	88.6	119.13	15.329	5827.2	749.8
1974	11	137.74	5857	85.3	117.49	20.248	4996.0	861.0
1974	12	200.51	8525	73.8	147.97	52.532	6291.4	2233.6
1975	1	31.78	1006	59.9	19.04	12.744	602.6	403.4
1975	2	16.01	344	35.6	5.70	10.310	122.5	221.5
1975	3	15.93	224	38.5	6.13	9.797	86.2	137.8
1975	4	253.95	3935	7.0	17.78	236.170	275.4	3659.6
1975	5	139.98	3937	17.2	24.08	115.905	677.2	3259.8
1975	6	321.57	14827	0.0	0.00	321.574	0.0	14827.0
1975	7	103.45	4621	2.8	2.90	100.552	129.4	4491.6
1975	8	181.17	8899	39.7	71.92	109.244	3532.9	5366.1
1975	9	150.26	6861	77.7	116.75	33.508	5331.0	1530.0
1975	10	592.61	25015	79.7	472.31	120.300	19937.0	5078.0
1975	11	667.45	26385	76.2	508.60	158.854	20105.4	6279.6
1975	12	79.04	2175	66.0	52.17	26.873	1435.5	739.5
1976	1	43.35	1224	72.0	31.21	12.138	881.3	342.7
1976	2	32.76	766	70.4	23.06	9.696	539.3	226.7
1976	3	56.35	1440	79.6	44.85	11.495	1146.2	293.8
1976	4	1064.18	25709	81.0	861.99	202.195	20824.3	4884.7
1976	5	250.51	8845	98.7	247.26	3.257	8730.0	115.0
1976	6	232.81	8363	0.0	0.00	232.813	0.0	8363.0
1976	7	40.87	1387	6.9	2.82	38.047	95.7	1291.3
1976	8	26.05	972	88.8	23.13	2.917	863.1	108.9
1976	9	106.67	4719	95.3	101.66	5.014	4497.2	221.8
1976	10	553.73	19888	97.5	539.88	13.843	19390.8	497.2
1976	11	1329.25	39827	94.4	1254.81	74.438	37596.7	2230.3
1976	12	140.01	4588	81.5	114.11	25.902	3739.2	848.8
1977	1	21.71	668	66.0	14.33	7.383	440.9	227.1
1977	2	15.00	363	53.0	7.95	7.052	192.4	170.6
1977	3	152.08	4263	59.0	89.73	62.354	2515.2	1747.8
1977	4	1136.41	36174	44.0	500.02	636.388	15916.6	20257.4
1977	5	1205.75	48386	58.0	699.34	505.415	28063.9	20322.1
1977	6	227.74	5808	0.0	0.00	227.741	0.0	5808.0
1977	7	66.07	2725	4.8	3.17	62.898	130.8	2594.2
1977	8	125.01	5329	64.2	80.25	44.752	3421.2	1907.8
1977	9	117.24	4408	86.5	101.41	15.827	3812.9	595.1
1977	10	535.58	13026	88.6	474.52	61.056	15971.0	2055.0
1977	11	467.00	13191	85.3	398.35	68.649	11251.9	1939.1
1977	12	51.96	1490	73.8	38.35	13.614	1099.6	390.4

REFERENCES FOR TABLE A-4

1. Letter dated March 3, 1978, from William J. Cahill, Jr. of Consolidated Edison Company of New York, Inc. (Con Ed) to Robert P. Geckler of the U. S. Nuclear Regulatory Commission (US NRC), including a response to Question IX.1, which is the identification number for a question in Enclosure 2 of a letter dated July 26, 1977, from George W. Knighton (US NRC) to William Cahill, Jr. (Con Ed).

2. Letter dated April 14, 1978, from Kenneth L. Marcellus of Consolidated Edison Company of New York, Inc. (Con Ed) to Henry Gluckstern of the U. S. Environmental Protection Agency (US EPA), including a response to Question A-5, which is the identification number for a question in the enclosure of a letter dated March 23, 1978, from Henry Gluckstern (US EPA) to Kenneth L. Marcellus (Con Ed).

3. Letter dated October 31, 1977, from Kenneth L. Marcellus of Consolidated Edison Company of New York, Inc. to Henry Gluckstern of the U. S. Environmental Protection Agency, including in Attachment 2 a response to Question 7 (9/27/77) of Attachment C which accompanied the October 12, 1977, EPA "Motion to Specify Area of Requestors' Testimony To Be Cross-Examined During Initial Phase of Hearing."

TABLES A-5, A-6, A-7

WHITE PERCH IMPINGEMENT DATA FOR INDIAN POINT UNITS 1, 2, AND 3

RATE (collection rate):[1]

June 1972 through December 1975: Copied directly from data sheets provided in Ref. (1).

January 1976 through December 1977: Copied directly from data sheets provided in Ref. (2).

NUMBER (number collected):

May 1972 through December 1976: Copied directly from appendix tables in Refs. (3) - (6). However, if a NUMBER value in these Texas Instruments (TI) appendix tables was lower than the correspondir NUMBER value in Refs. (1) and (2), then the updated NUMBER value in Refs. (1) and (2) was used. For example, such substitutions were made for Indian Point Unit 2 (Table A-6 in this appendix) for all months of 1973. In general, the NUMBER values presented in the TI appendix tables are the same as or higher than the NUMBER values presented in Refs. (1) and (2), for the reason discussed by Con Edison in their response to Question VI.2 in Ref. 1. Thus, the substituted, higher values from Refs. (1) and (2) can still be low, because they were selected by TI to include only data that represented known flow volumes and associated impingement collections.

January 1977 through December 1977: Copied directly from data sheets provided in Refs. (7) and (8).

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[1]All RATE values are given in the original sources in units of number of white perch collected per million cubic meters, and thus multiplication by 264.17 was not necessary.

Collection rates were <u>not</u> assumed to equal impingement rates. Rather, the collection rates were adjusted upward to account for the calculated efficiencies of less than 100%. For Units 1 and 2, RATE = RATE/0.15 (i.e., 15% efficiency) and for Unit 3, RATE = RATE/0.70 (i.e., 70% efficiency). These efficiency estimates are based on data presented in Ref. (9) for Units 2 and 3; Unit 1 was assumed to have the same collection efficiency as Unit 2, since Units 1 and 2 have similar intake structures.

PERCENTO (percent of the white perch collected that were young-of-the-year):

June 1975 through December 1976: Calculated from data on magnetic tapes provided by Consolidated Edison. The two tapes used were Texas Instruments 1975 Impingement Data (Record Type D) and Texas Instruments 1976 Impingement Data (Record Type D). Monthly estimates of PERCENTO were calculated for each unit for which there were white perch impingement data as follows:

$$\text{PERCENTO} = \frac{\text{Number of impinged white perch in Length Class 1}}{\text{Total number of impinged white perch}} \quad 100 \ ,$$

where the bounds on Length Class 1 are 0 mm to DIVISION, where DIVISION is the seasonally varying, total body length in millimeters which is used as the cut-off length between young-of-the-year and yearling white perch (see Table A-10 of this appendix).

$$\text{RATE0} = \text{PERCENTO} \quad \text{RATE}/100 \text{ and } \text{RATE1} = \text{RATE} - \text{RATE0}.$$

$$\text{NUMBER0} = \text{PERCENTO} \quad \text{NUMBER}/100 \text{ and } \text{NUMBER1} = \text{NUMBER} - \text{NUMBER0}.$$

RATE, NUMBER, and PERCENTO are defined above. RATE0 and RATE1 are the collection rates for young-of-the-year and for yearling and older white perch, respectively. NUMBER0 and NUMBER1 are number collected for young-of-the-year and for yearling and older white perch, respectively.

TABLE A-5 (continued)

PLANT=IP1

YEAR	MONTH	RATE	NUMBER	PERCENTO	RATEO	RATE1	NUMBERO	NUMBER1
1972	5	.	1927	94.4	.	.	1819	107.9
1972	6	65.80	11320	0.0	0.00	65.800	0	11320.0
1972	7	52.40	2127	45.1	23.63	28.768	959	1167.5
1972	8	232.93	10560	84.8	197.53	35.406	8955	1605.1
1972	9	380.07	12037	84.5	321.16	58.910	10213	1873.4
1972	10	2236.00	84607	94.0	2101.84	134.160	79530	5076.4
1972	11	1705.50	35933	96.7	1649.32	56.285	34748	1185.8
1972	12	844.20	17420	96.4	813.81	30.391	16793	627.1
1973	1	62.40	7933	94.0	58.66	3.744	7457	476.0
1973	2	.	64540	97.3	.	.	62797	1742.6
1973	3	.	206403	91.1	.	.	188030	18369.6
1973	4	.	163253	97.8	.	.	159662	3591.6
1973	5	885.50	20633	94.4	836.01	49.594	19478	1155.5
1973	6	186.27	4527	0.0	0.00	185.257	0	4526.7
1973	7	.	2540	45.1	.	.	1146	1394.5
1973	8	11.53	15367	84.8	9.78	1.753	13031	2335.7
1973	9	.	1460	84.5	.	.	1234	226.3
1973	10	.	287	94.0	.	.	269	17.2
1973	11	.	4273	96.7	.	.	4132	141.0
1973	12	.	12187	96.4	.	.	11748	438.7
1974	1	3798.07	32107	94.0	3570.18	227.884	30180	1926.4
1974	2	1661.33	44567	97.3	1616.48	44.856	43363	1203.3
1974	3	1680.33	43213	91.1	1530.78	149.550	39367	3846.0
1974	4	1826.13	56220	97.8	1785.96	40.175	54983	1236.8
1974	5	594.57	15680	94.4	561.37	33.301	14802	878.1
1974	6	161.20	7647	0.0	0.00	161.200	0	7646.7
1974	7	35.73	1573	45.1	16.12	19.618	710	863.8
1974	8	22.60	1140	84.8	19.16	3.435	967	173.3
1974	9	60.20	2973	84.5	50.87	9.331	2512	460.9
1974	10	631.87	30227	94.0	593.95	37.912	28413	1813.6
1974	11	896.00	15733	96.7	866.43	29.568	15214	519.2
1974	12	6241.87	143867	96.4	6016.77	224.593	138687	5179.2
1975	1	4255.13	62007	94.0	3999.83	255.308	58286	3720.4
1975	2	6964.67	102447	97.3	6776.62	188.046	99681	2766.1
1975	3	2460.07	39213	91.1	2241.12	218.946	35723	3490.0
1975	4	4757.20	74073	97.8	4652.54	104.658	72444	1629.6
1975	5	471.73	5180	94.4	445.32	26.417	4890	290.1
1975	6	58.27	827	0.0	0.00	58.257	0	826.7
1975	7	63.87	407	66.0	42.15	21.715	268	138.3
1975	8	63.13	287	90.9	57.39	5.745	261	26.1

TABLE A-6 (continued)

PLANT=IP2

YEAR	MONTH	RATE	NUMBER	PERCENTO	RATEO	RATE1	NUMBERO	NUMBER1
1972	6	42.4	960	0.0	0.0	42.40	0	960
1972	9	34.3	1347	84.5	29.0	5.31	1138	209
1972	10	135.1	1687	94.0	127.0	8.11	1585	101
1973	1	3868.1	7933	94.0	3636.0	232.09	7457	476
1973	2	4578.3	63693	97.3	4454.7	123.62	61974	1720
1973	3	4280.1	201547	91.1	3899.2	380.93	183609	17938
1973	4	4696.1	117680	97.8	4592.8	103.31	115091	2589
1973	5	1136.1	20560	94.4	1072.4	63.62	19409	1151
1973	6	97.9	4527	0.0	0.0	97.93	0	4527
1973	7	38.6	2540	45.1	17.4	21.19	1146	1394
1973	8	187.0	15180	84.8	158.6	28.42	12873	2307
1973	9	31.3	1453	84.5	26.4	4.85	1228	225
1973	10	5.3	287	94.0	5.0	0.32	269	17
1973	11	273.3	4200	96.7	264.3	9.02	4061	139
1973	12	1264.1	12187	96.4	1218.6	45.51	11748	439
1974	1	12814.7	147813	94.0	12045.8	768.88	138945	8869
1974	2	12823.3	153027	97.3	12477.1	346.23	148895	4132
1974	3	9218.7	259980	91.1	8398.2	820.46	236842	23138
1974	4	8378.7	471647	97.8	8194.3	184.33	461270	10376
1974	5	4351.4	395840	94.4	4107.7	243.68	373673	22167
1974	6	420.5	49560	0.0	0.0	420.53	0	49560
1974	7	42.3	4753	45.1	19.1	23.24	2144	2610
1974	8	69.7	8160	84.8	59.1	10.60	6920	1240
1974	9	206.0	23360	84.5	174.1	31.93	19739	3621
1974	10	805.3	75780	94.0	757.0	48.32	71233	4547
1974	11	1887.3	166967	96.7	1825.1	62.28	161457	5510
1974	12	6787.3	370153	96.4	6543.0	244.34	356828	13326
1975	1	4416.0	212387	94.0	4151.0	264.96	199643	12743
1975	2	3496.1	165833	97.3	3401.7	94.40	161356	4478
1975	3	3171.2	89973	91.1	2889.0	282.24	81966	8008
1975	4	5900.1	451100	97.8	5770.3	129.80	441176	9924
1975	5	807.0	83373	94.4	761.8	45.19	78704	4669
1975	6	90.5	12207	0.0	0.0	90.47	0	12207
1975	7	92.7	11713	56.4	52.3	40.40	6606	5107
1975	8	1030.1	89720	98.5	1014.7	15.45	88374	1346
1975	9	640.0	73693	95.0	608.0	32.00	70009	3685
1975	10	657.5	47720	95.8	629.9	27.61	45716	2004
1975	11	1728.9	179340	95.2	1645.9	82.99	170732	8608
1975	12	2847.1	294000	97.9	2787.3	59.79	287826	6174
1976	1	9597.3	610240	94.0	9021.5	575.84	573626	36614
1976	2	3731.8	180087	95.6	3567.6	164.20	172163	7924
1976	3	1563.0	123027	91.1	1423.9	139.11	112077	10949
1976	4	245.0	287	97.7	239.4	5.64	280	7
1976	6	36.9	493	0.0	0.0	36.93	0	493
1976	9	290.3	8227	90.7	263.3	27.00	7462	765
1976	10	2332.7	256380	95.4	2225.4	107.30	244587	11793
1976	11	1432.5	20900	98.3	1408.1	24.35	20545	355
1976	12	22551.3	690520	94.1	21220.8	1330.53	649779	40741
1977	1	36380.7	2164740	94.0	34197.8	2182.94	2034856	129884
1977	2	68453.3	1261787	97.3	66605.1	1848.24	1227718	34068
1977	3	5005.5	458480	91.1	4560.0	445.49	417675	40805
1977	4	10549.3	237347	97.8	10317.2	232.09	232125	5222
1977	5	339.73	25053	94.4	320.71	19.025	24594	1459.0
1977	6	299.87	37567	0.0	0.00	299.857	0	37566.7
1977	7	104.47	947	45.1	47.11	57.352	427	519.7
1977	8	463.07	43460	84.8	392.68	70.335	36854	6605.9
1977	9	146.87	22920	84.5	124.10	22.764	19367	3552.6
1977	10	2064.00	322480	94.0	1940.16	123.840	303131	19348.8
1977	11	9770.67	939973	36.7	9448.23	322.432	908954	31019.1
1977	12	.	543540	96.4	.	.	523973	19567.4

TABLE A-7 (continued)

PLANT=IP3

YEAR	MONTH	RATE	NUMBER	PERCENTO	RATEO	RATE1	NUMBERO	NUMBER1
1974	3	38.93	6	91.1	35.46	3.455	5	0.5
1974	4	999.84	4371	97.8	977.85	21.997	4275	96.2
1974	5	458.90	677	94.4	433.20	25.698	639	37.9
1974	6	84.73	1430	0.0	0.00	84.729	0	1430.0
1974	7	5.71	20	45.1	2.58	3.137	9	11.0
1974	8	0.63	3	84.8	0.53	0.096	2	0.4
1974	9	2.20	13	84.5	1.86	0.341	11	2.0
1974	10	19.13	90	94.0	17.98	1.148	85	5.4
1976	2	446.86	3974	99.0	442.39	4.459	3935	39.7
1976	4	333.39	4554	97.8	326.05	7.334	4454	100.2
1976	5	105.57	7373	94.4	99.66	5.912	6960	412.9
1976	6	26.51	2254	0.0	0.00	26.514	0	2254.3
1976	7	16.81	1509	13.0	2.19	14.628	196	1312.5
1976	8	45.43	4170	64.9	29.48	15.945	2706	1463.7
1976	9	39.27	3199	67.8	26.53	12.645	2169	1029.9
1976	10	221.57	21366	90.9	201.41	20.163	19876	1989.8
1976	11	1332.03	118493	96.6	1286.74	45.239	114464	4028.8
1976	12	819.24	56426	97.2	796.30	22.939	54846	1579.9
1977	1	1953.43	92889	94.0	1836.22	117.206	87315	5573.3
1977	2	5655.71	127396	97.3	5503.98	152.731	123956	3439.7
1977	3	352.47	29314	91.1	321.10	31.370	26705	2609.0
1977	4	559.00	55819	97.8	546.70	12.298	55569	1250.0
1977	5	346.41	62640	94.4	327.02	19.399	59132	3507.8
1977	6	84.86	11370	0.0	0.00	84.857	0	11370.0
1977	7	32.23	4756	45.1	14.54	17.693	2145	2610.9
1977	8	94.06	13183	84.8	79.76	14.297	11179	2003.8
1977	9	40.06	5931	84.5	33.85	6.209	5012	919.4
1977	10	119.64	4010	94.0	112.46	7.179	3769	240.6
1977	12	514.26	18124	96.4	495.74	18.513	17472	652.5

REFERENCES FOR TABLES A-5, A-6, AND A-7

1. Letter dated March 3, 1978, from William J. Cahill, Jr. of Consolidated Edison Company of New York, Inc. (Con Ed) to Robert P. Geckler of the U. S. Nuclear Regulatory Commission (US NRC), including a response to Question VI.3, which is the identification number for a question in Enclosure 2 of a letter dated July 26, 1977, from George W. Knighton (US NRC) to William Cahill, Jr. (Con Ed).

2. Letter dated May 3, 1978, from Kenneth L. Marcellus of Consolidated Edison Company of New York, Inc. (Con Ed) to Henry Gluckstern of the U. S. Environmental Protection Agency (US EPA), including a response to Question A-3, which is the identification number for a question in the enclosure of a letter dated March 23, 1978, from Henry Gluckstern (US EPA) to Kenneth L. Marcellus (Con Ed).

3. Texas Instruments, Inc. Indian Point Impingement Study Report for the Period 15 June 1972 through 31 December 1973. Prepared for Consolidated Edison Company of New York, Inc., December 1974. (Tables A-1.5 through A-1.8).

4. Texas Instruments, Inc. Indian Point Impingement Study Report for the Period 1 January 1974 through 31 December 1974. Prepared for Consolidated Edison Company of New York, Inc., November 1975. (Tables B-2 through B-4).

5. Texas Instruments, Inc. Indian Point Impingement Study Report for the Period 1 January 1975 through 31 December 1975. Prepared for Consolidated Edison Company of New York, Inc., November 1976. (Tables A-4 and A-5).

6. Texas Instruments, Inc. Hudson River Ecological Study in the Area of Indian Point. 1976 Annual Report. Prepared for Consolidated Edison Company of New York, Inc., December 1977. (Tables A-2 and A-3).

7. Monthly letters from Eugene R. McGrath of Consolidated Edison Company of New York, Inc. to Peter A. A. Berle of the New York State Department of Environmental Conservation, which are sent as specified in Section 401 Certification and which include data sheets giving daily fish counts by species for each unit at Indian Point.

8. Monthly letters from William J. Cahill, Jr. of Consolidated Edison Company of New York, Inc. to James P. O'Reilly of the U. S. Nuclear Regulatory Commission, which are sent as specified in Appendix B of Unit Nos. 1, 2, and 3 Technical Specifications and which include data sheets giving daily fish counts by species for each unit at Indian Point.

9. Exhibit UT-105. Table 1. Summary of Collection Efficiency Tests and Related 95% Confidence Intervals at Indian Point Units 2 and 3, 1974-1977. U. S. Environmental Protection Agency, Region II, Adjudicatory Hearing, Docket No. C/II-WP-77-01, introduced into evidence on June 6, 1978.

TABLE A-8

WHITE PERCH IMPINGEMENT DATA FOR THE
LOVETT GENERATING STATION

January 1973 - December 1976: Ref. (1)

Values for RATE (collection rate)[1] and NUMBER (number collected) were taken directly from data sheets in Ref. (1).

January 1977 - December 1977: Ref. (2)

Values for RATE (collection rate)[1] and NUMBER (number collected) were taken directly from data sheets in Ref. (2).

PERCENTO (percent of the white perch collected that were young-of-the-year):

No estimates of PERCENTO were available for Lovett. Consequently, all monthly values for PERCENTO were approximated based on data from Indian Point, which is located only 1.5 miles upriver and across the river from Lovett.

June 1975 - December 1976

Used the average of the observed monthly values for the units at Indian Point for the corresponding month and year (see Tables A-5 to A-7 in this appendix).

January 1973 - May 1975 and January 1977 - December 1977

Used the monthly approximations calculated for Indian Point (same for all units at Indian Point) (see Tables A-5 to A-7 in this appendix).

RATEO = PERCENTO RATE/100 and RATE1 = RATE - RATEO.

NUMBERO = PERCENTO NUMBER/100 and NUMBER1 = NUMBER - NUMBERO.

RATE, NUMBER, and PERCENTO are defined above. RATEO and RATE1 are the collection rates for young-of-the-year and for yearling and older white perch, respectively. NUMBERO and NUMBER1 are number collected for young-of-the-year and for yearling and older white perch, respectively.

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[1]All collection rates were converted from number of white perch collected per million gallons to number of white perch collected per million cubic meters by multiplying by 264.17 gallons per cubic meter. Collection rates were assumed to equal impingement rates.

TABLE A-8 (continued)

PLANT=LOVETT

YEAR	MONTH	RATE	NUMBER	PERCENTO	RATE0	RATE1	NUMBER0	NUMBER1
1973	1	70.80	3536	94.0	66.55	4.248	3323.8	212.16
1973	2	81.63	3585	97.3	79.42	2.204	3488.2	96.80
1973	3	222.43	11055	91.1	202.63	19.796	10071.1	983.90
1973	4	196.54	8569	97.8	192.22	4.324	8380.5	188.52
1973	5	66.04	2703	94.4	62.34	3.698	2551.6	151.37
1973	6	49.40	2247	0.0	0.00	49.400	0.0	2247.00
1973	7	16.38	817	45.1	7.39	8.992	368.5	448.53
1973	8	85.86	4417	84.8	72.81	13.050	3745.6	671.38
1973	9	13.74	600	84.5	11.61	2.129	507.0	93.00
1973	10	2.64	93	94.0	2.48	0.159	87.4	5.58
1973	11	142.12	6037	96.7	137.43	4.690	5837.8	199.22
1973	12	389.65	17292	96.4	375.62	14.027	16669.5	622.51
1974	1	458.33	20058	94.0	430.83	27.500	18854.5	1203.48
1974	2	399.16	12695	97.3	388.38	10.777	12352.2	342.77
1974	4	522.26	18835	97.8	510.77	11.490	18420.6	414.37
1974	5	163.26	6243	94.4	154.11	9.142	5893.4	349.61
1974	6	40.68	1519	0.0	0.00	40.682	0.0	1519.00
1974	7	8.98	184	45.1	4.05	4.931	83.0	101.02
1974	8	12.15	492	84.8	10.30	1.847	417.2	74.78
1974	9	10.57	396	84.5	8.93	1.638	334.6	61.38
1974	10	108.84	2921	94.0	102.31	6.530	2745.7	175.26
1974	11	302.74	11753	96.7	292.75	9.990	11365.2	387.85
1974	12	311.72	12071	96.4	300.50	11.222	11636.4	434.56
1975	1	850.36	35169	94.0	799.34	51.022	33998.9	2170.14
1975	2	121.52	4325	97.3	118.24	3.281	4208.2	116.78
1975	3	168.80	4249	91.1	153.78	15.02[illegible]	3870.8	378.16
1975	4	546.30	11864	97.8	534.28	12.01[illegible]	11603.0	261.01
1975	5	25.15	786	94.4	24.69	1.465	742.0	44.02
1975	6	26.68	958	0.0	0.00	25.6[illegible]	0.0	958.00
1975	7	7.40	273	61.2	4.53	2.8[illegible]	167.1	105.92
1975	8	42.80	1642	94.7	40.53	2.25[illegible]	1555.0	87.03
1975	9	24.30	642	95.0	23.09	1.215	609.9	32.10
1975	10	30.38	977	95.8	29.10	1.276	936.0	41.03
1975	11	540.49	16622	95.2	514.55	25.944	15824.1	797.86
1975	12	143.97	4458	97.9	140.95	3.023	4364.4	93.62
1976	1	362.71	11876	94.0	340.94	21.762	11163.4	712.56
1976	2	42.27	1265	97.3	41.13	1.141	1230.8	34.16
1976	3	94.04	2692	91.1	85.67	8.370	2452.4	239.59
1976	4	186.50	4765	97.8	182.40	4.103	4660.2	104.83
1976	5	8.19	90	94.4	7.73	0.459	85.0	5.04
1976	6	26.68	610	0.0	0.00	25.681	0.0	610.00
1976	7	10.30	221	13.0	1.34	8.963	28.7	192.27
1976	8	17.70	554	64.9	11.49	6.212	359.5	194.45
1976	9	22.19	514	79.2	17.57	4.616	407.1	106.91
1976	10	12.42	167	93.[illegible]	11.57	0.844	155.6	11.36
1976	11	570.08	10200	97.4	555.26	14.822	9934.8	265.20
1976	12	534.94	13166	95.6	511.41	23.538	12586.7	579.30
1977	1	1225.83	39689	94.0	1152.28	73.550	37307.7	2381.34
1977	2	751.96	13633	97.3	731.66	20.303	13264.9	368.09
1977	3	106.46	1719	91.1	96.99	9.475	1566.0	152.99
1977	4	162.62	2783	97.8	159.05	3.578	2721.8	61.23
1977	5	21.24	370	94.4	20.05	1.189	349.3	20.72
1977	6	209.355	4732	0.0	0.000	209.355	0.0	4732.00
1977	7	19.179	576	45.1	8.650	10.529	259.78	316.22
1977	8	37.433	1408	84.8	31.743	5.690	1193.98	214.02
1977	9	4.755	121	84.5	4.018	0.737	102.24	18.76
1977	10	227.847	5519	94.0	214.176	13.671	5187.86	331.14
1977	11	490.405	9767	96.7	474.222	16.183	9444.69	322.31
1977	12	42.716	669	96.4	41.179	1.538	643.95	24.05

REFERENCES FOR TABLE A-8

1. Letter dated March 3, 1978, from William J. Cahill, Jr. of Consolidated Edison Company of New York, Inc. (Con Ed) to Robert P. Geckler of the U. S. Nuclear Regulatory Commission (US NRC), including a response to Question X.1, which is the identification number for a question in Enclosure 2 of a letter dated July 26, 1977, from George W. Knighton (US NRC) to William Cahill, Jr. (Con Ed).

2. Letter dated May 5, 1978, from Edward G. Kelleher of Consolidated Edison Company of New York, Inc. (Con Ed) to Henry Gluckstern of the U. S. Environmental Protection Agency (US EPA), including a response to Question A-4, which is the identification number for a question in the enclosure of a letter dated March 23, 1978, from Henry Gluckstern (US EPA) to Kenneth L. Marcellus (Con Ed).

TABLE A-9

WHITE PERCH IMPINGEMENT DATA FOR THE
ROSETON GENERATING STATION

RATE (collection rate):[1]

July 1973 through December 1976: average of the daily collection rates for each month were copied directly from data sheets in Ref. (1).

January 1977 through December 1977: average of the daily collection rates for each month were copied directly from data sheets in Ref. (2).

NUMBER (number collected):

July 1973 through December 1976: copied directly from Table 10.2-14 of Ref. (3).

January 1977 through December 1977: calculated from the monthly collection rates (RATE) described immediately above and monthly values of actual total plant intake flow in millions of gallons for the particular month (from data sheets provided by the U. S. Environmental Protection Agency, Region II, New York, New York).

PERCENT0 (percent of the white perch collected that were young-of-the-year):

January 1975 through December 1976: Calculated from monthly data on length-frequency in 1-centimeter length intervals of white perch in impingement collections (from Tables 10.2-15 and 10.2-16 in Ref. (3)). The "DIVISION" criteria specified by Texas Instruments were used as the cut-off length between young-of-the-year and yearling white perch (see Table A-10 in this appendix).

July 1973 through December 1974 and January 1977 through December 1977: calculated as the average of the 1975 and 1976 PERCENT0 values for each month.

RATE0 = PERCENT0 RATE/100 and RATE1 = RATE - RATE0.

NUMBER0 = PERCENT0 NUMBER/100 and NUMBER1 = NUMBER - NUMBER0.

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[1]All collection rates were converted from number of white perch collected per million gallons to number of white perch collected per million cubic meters by multiplying by 264.17 gallons per cubic meter. Collection rates were assumed to equal impingement rates.

TABLE A-9 (continued)

RATE, NUMBER, and PERCENTO are defined above. RATE0 and RATE1 are the collection rates for young-of-the-year and for yearling and older white perch, respectively. NUMBER0 and NUMBER1 are number collected for young-of-the-year and for yearling and older white perch, respectively.

TABLE A-9 (continued)

------------------------------------ PLANT=ROSETON ------------------------------------

YEAR	MONTH	RATE	NUMBER	PERCENT0	RATE0	RATE1	NUMBER0	NUMBER1
1973	7	9.272	81	4.8	0.445	8.827	3.9	77.1
1973	8	98.430	980	64.2	63.192	35.238	629.2	350.8
1973	9	428.008	1094	86.5	370.227	57.781	946.3	147.7
1973	10	654.270	4522	88.6	579.583	74.537	4006.5	515.5
1973	11	197.837	1996	85.3	168.755	29.082	1702.6	293.4
1973	12	27.527	484	73.8	20.315	7.212	357.2	126.8
1974	1	1.162	5	66.0	0.767	0.395	3.3	1.7
1974	2	0.000	0	53.0	0.000	0.000	0.0	0.0
1974	3	0.423	5	59.0	0.249	0.173	2.9	2.1
1974	4	148.701	4897	44.0	65.429	83.273	2154.7	2742.3
1974	5	413.637	5272	58.0	239.910	173.728	3637.8	2634.2
1974	6	106.566	1105	0.0	0.000	106.566	0.0	1105.0
1974	7	0.687	10	4.8	0.033	0.654	0.5	9.5
1974	8	54.023	3263	64.2	34.683	19.340	2094.8	1168.2
1974	9	23.617	1131	86.5	20.429	3.188	978.3	152.7
1974	10	43.007	1038	88.6	38.104	4.903	919.7	118.3
1974	11	188.829	12313	85.3	161.071	27.758	10503.0	1810.0
1974	12	104.030	7351	73.8	76.774	27.256	5425.0	1926.0
1975	1	18.228	1307	59.9	10.918	7.309	782.9	524.1
1975	2	14.318	1059	35.6	5.097	9.221	377.0	682.0
1975	3	14.926	1047	38.5	5.746	9.179	403.1	643.9
1975	4	340.092	23288	7.0	23.806	315.286	1630.2	21657.8
1975	5	164.314	14599	17.2	28.262	136.052	2511.0	12088.0
1975	6	19.707	1613	0.0	0.000	19.707	0.0	1613.0
1975	7	42.928	3865	2.8	1.202	41.726	108.2	3756.8
1975	8	128.413	9571	39.7	50.980	77.433	3799.7	5771.3
1975	9	118.348	7804	77.7	91.957	26.392	6063.7	1740.3
1975	10	442.960	33541	79.7	353.039	89.921	26732.2	6808.8
1975	11	615.727	40851	76.2	469.184	146.543	31128.5	9722.5
1975	12	21.107	844	66.0	13.931	7.176	557.0	287.0
1976	1	19.575	1008	72.0	14.094	5.481	725.8	282.2
1976	2	34.712	2287	70.4	24.437	10.275	1610.0	677.0
1976	3	17.779	1129	79.6	14.152	3.627	898.7	230.3
1976	4	463.513	31493	81.0	375.445	88.057	25509.3	5983.7
1976	5	242.719	20841	98.7	239.564	3.155	20570.1	270.9
1976	6	75.870	6455	0.0	0.000	75.870	0.0	6455.0
1976	7	3.408	326	6.9	0.235	3.173	22.5	303.5
1976	8	22.692	2100	88.8	20.151	2.542	1864.8	235.2
1976	9	28.927	2346	95.3	27.567	1.360	2235.7	110.3
1976	10	140.459	9927	97.5	136.948	3.511	9678.8	248.2
1976	11	563.316	23006	94.4	531.770	31.546	21717.7	1288.3
1976	12	63.876	3258	81.5	52.059	11.817	2655.3	602.7
1977	1	23.036	1696	66.0	15.204	7.83[illegible]	1119.4	576.6
1977	2	13.314	851	53.0	7.057	6.258	451.0	400.0
1977	3	67.178	5183	59.0	39.635	27.543	3058.0	2125.0
1977	4	303.954	15486	44.0	133.740	170.214	7253.8	9232.2
1977	5	735.106	51444	58.0	426.361	308.744	29837.5	21606.5
1977	6	20.552	1964	0.0	0.000	20.552	0.0	1964.0
1977	7	10.620	1004	4.8	0.510	10.110	48.2	955.8
1977	8	248.346	25808	64.2	159.438	88.908	16568.7	9239.3
1977	9	78.247	7248	86.5	67.584	10.553	6269.5	978.5
1977	10	142.493	10176	88.6	126.249	16.244	9015.9	1160.1
1977	11	119.484	7834	85.3	101.920	17.564	6682.4	1151.6
1977	12	32.942	2296	73.8	24.311	8.631	1694.4	601.6

REFERENCES FOR TABLE A-9

1. Letter dated March 3, 1978, from William J. Cahill, Jr. of Consolidated Edison Company of New York, Inc., (Con Ed) to Robert P. Geckler of the U. S. Nuclear Regulatory Commission (US NRC), including a response to Question IX.1, which is the identification number for a question in Enclosure 2 of a letter dated July 26, 1977, from George W. Knighton (US NRC) to William Cahill, Jr. (Con Ed).

2. Letter dated April 14, 1978, from Kenneth L. Marcellus of Consolidated Edison Company of New York, Inc. (Con Ed) to Henry Gluckstern of the U. S. Environmental Protection Agency (US EPA), including a response to Question A-5, which is the identification number for a question in the enclosure of a letter dated March 23, 1978, from Henry Gluckstern (US EPA) to Kenneth L. Marcellus (Con Ed).

3. Ecological Analysts, Inc. Roseton Generating Station. Near-field Effects of Once-through Cooling System Operation on Hudson River Biota. Prepared for Central Hudson Gas & Electric Corporation, July 1977.

TABLE A-10. "DIVISION" CRITERIA SPECIFIED BY TEXAS INSTRUMENTS AS THE CUT-OFF LENGTH BETWEEN YOUNG-OF-THE-YEAR AND YEARLING WHITE PERCH[a]

DATE[b]	DIVISION[c] (mm)	YEAR CLASSES[d]	DATE[b]	DIVISION[c] (mm)	YEAR CLASSES[d]
750101	95	1973-1974	760105	105	1974-1975
750101	95		760119	105	
750116	95		760202	105	
750116	95		760216	105	
750201	95		760301	105	
750201	95		760315	105	
750215	95		760405	105	
750215	95		760419	105	
750301	95		760419	105	
750301	95		760503	105	
750315	95		760517	105	
750315	95		760607	50	1975-1976
750401	95		760607	50	
750401	95		760621	50	
750415	95		760705	50	
750415	95		760719	60	
750501	95		760802	60	
750501	95		760816	85	
750515	95		760816	85	
750515	95		760830	100	
750601	29	1974-1975	760830	100	
750601	29		760913	100	
750615	50		760913	100	
750615	50		760927	100	
750701	50		760927	100	
750701	50		761011	100	
750715	60		761011	100	
750715	60		761025	100	
750805	85		761025	100	
750805	85		761108	100	
750818	95		761108	100	
750901	95		761122	100	
750915	100		761206	100	
751006	105		761206	100	
751020	105		761220	100	
751103	105		761220	100	
751117	105				
751201	105				
751215	105				

[a]Obtained from computer data tapes entitled Texas Instruments 1975 Impingement Data (Record Type E) and Texas Instruments 1976 Impingement Data (Record Type E).

[b]The format for DATE is year-month-day.

[c]The seasonally varying, total body length which is used to discriminate between young-of-the-year and yearling white perch.

[d]The two year classes separated by DIVISION.

APPENDIX B

SURVIVAL OF IMPINGED WHITE PERCH

The survival of impinged white perch was studied at Bowline, Roseton, Danskammer, and Indian Point Unit 1. Since comparatively limited survival data are available for Indian Point, the results obtained at the other three plants are the primary subject of this appendix. Our analysis of these results includes: (1) descriptions of the methods used in the Bowline, Roseton, and Danskammer survival studies, (2) evaluations of the effects of screenwash procedures on white perch survival, (3) a discussion of seasonal variations in survival, (4) assessments of indirect mortality and handling mortality, and (5) estimates of the fraction of white perch that survive impingement at Bowline, Lovett, Roseton, Danskammer, and Albany and of the fraction that could survive at Indian Point if fish impinged at this plant were returned to the river.

Methods used in impingement survival studies

Sections 10.3.2 of the Roseton Near-Field Report (Central Hudson 1977) and the Bowline Near-Field Report (Orange and Rockland 1977) contain descriptions of the methods used in impingement survival studies conducted by Ecological Analysts (EA) at Roseton and Bowline. Ecological Analysts's 1977 Progress Report to Central Hudson indicates that the methods used at Danskammer are virtually identical to the procedures at Roseton and Bowline. In most of the studies at Bowline, impinged fish are collected in a nylon mesh bag suspended in the impingement collection pit. In some of the experiments at Bowline, fish are collected at the end of the screenwash discharge pipe in an effort to assess whether the screenwash discharge system imposes stresses in addition to those caused by the impingement experience itself. At Roseton and Danskammer, fish are collected in a basket that floats in the river at the end of the discharge pipe. After collection, the fish are sorted immediately by species and are classified as live, dead, or stunned. The live and stunned fish are then transferred to a holding facility and observed for latent mortality. The holding period at Bowline is 96 hr; at Roseton and Danskammer it is 84 hr. The use of control fish was an important element in all the impingement survival studies. In the first such studies (conducted at Roseton and Danskammer in 1975), control fish were exposed only to the holding facilities. Subsequently, control fish have been exposed to the entire process of collection, holding, and observation.

Effects of screenwash procedures on survival

Table B-1 contains a summary of the results obtained from white perch impingement survival studies conducted at Bowline, Roseton, Danskammer, and Indian Point Unit 1. Even a superficial inspection of Table B-1 shows that white perch survival is considerably higher when the travelling screens at Bowline are operated in the continuous mode than when the intermittent mode is employed. However, this pattern was not consistently observed at Roseton and Danskammer. The highest survival of white perch at both of these plants was obtained during continuous operation: ten out of twelve observations of 40% latent survival or higher. But in many of the experiments, in particular in the April-May 1977 experiments at Roseton, survival of white perch

Table B-1 Summary of white perch impingement survival data

Power plant and time	Collection point	Operating mode and screenwash pressure	Number of fish tested[a]	% survival[b]	Source
BOWLINE					
January-December 1976	Collection pit	Continuous, high pressure	2483[c]	61	Ref. 9, Table 10.3-4
		Continuous, low pressure	3701[c]	49	
		Intermittent, high pressure	1339[c]	26	
		Intermittent, low pressure	1281[c]	23	
	Discharge pipe	Continuous, high pressure	390[c]	20	Ref. 9, Table 10.3-6
		Continuous, low pressure	274[c]	17	
		Intermittent, high pressure	609[c]	10	
		Intermittent, low pressure	966[c]	9	
January-February 1977	Collection pit	Continuous, high pressure	958[c]	28	Ref. 9, Table 10.3-9
		Continuous, low pressure	988[c]	21	
	Discharge pipe	Continuous, high pressure	25	29	
		Continuous, low pressure	28	0	

Table B-1. (continued)

Power plant and time	Collection point	Operating mode and screenwash pressure	Number of fish tested[a]	% survival[b]	Source
BOWLINE					
November-December 1974	Collection pit	Continuous, high pressure	837[c]	26	Ref. 9, Table 10.3-10
January 1975	Collection pit	Continuous, high pressure	678[c]	7	Ref. 9, Table 10.3-10
April 1975	Collection pit	Continuous, high pressure	55[c]	35	Ref. 9, Table 10.3-10
November-December 1974	Discharge pipe	Continuous, high pressure	807[c]	23	Ref. 9, Table 10.3-11
March-April 1975	Discharge pipe	Continuous, high pressure	543[c]	7	Ref. 9, Table 10.3-11
March 1975	Discharge pipe	Intermittent, 2-hr hold, high pressure	51	5	Ref. 9, Table 10.3-11
March-April 1975	Discharge pipe	Intermittent, 4-hr hold, high pressure	848[c]	0	Ref. 9, Table 10.3-11
ROSETON					
Fall 1975	Collection basket	Continuous, high pressure	201	8	Ref. 2, Table 10.3-3
		Intermittent, 2-hr hold, high pressure	667	1	
		Intermittent, 4-hr hold, high pressure	239	0	

Table B-1. (continued)

Power plant and time	Collection point	Operating mode and screenwash pressure	Number of fish tested[a]	% survival[b]	Source
ROSETON					
		Intermittent, 6-hr hold, high pressure	684	0	
April-June 1976	Collection basket	Continuous, high pressure	275 (yearling and adult)	16	Ref. 2, Table 10.3-2
April-June 1976	Collection basket	Intermittent, 2-hr hold, high pressure	96 (yearling and adult)	9	Ref. 2, Table 10.3-2
		Intermittent, 4-hr hold, high pressure	66 (yearling and adult)	0	
November-December 1976	Collection basket	Continuous, low pressure	285	44	Ref. 2, Table 10.3-4
		Continuous, high pressure	707	4	
		Intermittent, 2-hr hold, low pressure	389	8	
		Intermittent, 2-hr hold, high pressure	344	5	
		Intermittent, 4-hr hold, low pressure	25	16	
		Intermittent, 4-hr hold, high pressure	70	0	

Table B-1. (continued)

Power plant and time	Collection point	Operating mode and screenwash pressure	Number of fish tested[a]	% survival[b]	Source
ROSETON					
		Continuous, low pressure	10 (yearling)	40	
		Continuous, high pressure	9 (yearling)	0	
		Intermittent, 2-hr hold, low pressure	22 (yearling)	14	
November-December 1976	Collection basket	Intermittent, 2-hr hold, high pressure	9 (yearling)	11	Ref. 2, Table 10.3-4
		Intermittent, 2-hr hold, low pressure	7 (adult)	14	
		Intermittent, 2-hr hold, high pressure	4 (adult)	25	
January-March 1977	Collection basket	Continuous, low pressure	15	0	Ref. 3, Table 4-14[d]
		Continuous, high pressure	49	0	
		Intermittent, 2-hr hold, low pressure	16	0	
		Intermittent, 2-hr hold, high pressure	39	0	

Table B-1. (continued)

Power plant and time	Collection point	Operating mode and screenwash pressure	Number of fish tested[a]	% survival[b]	Source
ROSETON					
April-May 1977	Collection basket	Continuous, low pressure	229	19	Ref. 3, Table 4-17[d]
		Continuous, high pressure	378	45	
		Intermittent, 2-hr hold, low pressure	74	20	
		Intermittent, 2-hr hold, high pressure	68	22	
April-May 1977	Collection basket	Intermittent, 4-hr hold, low pressure	144	23	Ref. 3, Table 4-17
		Intermittent, 4-hr hold, high pressure	231	4	
		Continuous, low pressure	153 (yearling)	6	
		Continuous, high pressure	171 (yearling)	2	
		Intermittent, 2-hr hold, low pressure	46 (yearling)	22	
		Intermittent, 2-hr hold, high pressure	74 (yearling)	4	
		Intermittent, 4-hr hold, high pressure	26 (yearling)	4	

Table B-1. (continued)

Power plant and time	Collection point	Operating mode and screenwash pressure	Number of fish tested[a]	% survival[b]	Source
ROSETON					
		Continuous, low pressure	89 (adult)	11	
		Continuous, high pressure	53 (adult)	7	
		Intermittent, 2-hr hold, low pressure	20 (adult)	15	
		Intermittent, 2-hr hold, high pressure	56 (adult)	11	
April-May 1977	Collection basket	Intermittent, 4-hr hold, low pressure	2 (adult)	0	Ref. 3, Table 4-17[d]
		Intermittent, 4-hr hold, high pressure	15 (adult)	13	
October-December 1977		Continuous, low pressure	33	3	Ref. 4, Table 4-3
		Continuous, high pressure	98	7	
		Intermittent, 2-hr hold, low pressure	22	0	
		Intermittent, 2-hr hold, high pressure	123	9	
		Continuous, low pressure	6 (yearling)	0	
		Continuous, high pressure	49 (yearling)	17	

Table B-1. (continued)

Power plant and time	Collection point	Operating mode and screenwash pressure	Number of fish tested[a]	% survival[b]	Source
DANSKAMMER					
Fall 1975	Collection basket	Continuous[e]	268	3	Ref. 3, Table 4-25
		Intermittent, 2-hr hold	236	3	
		Intermittent, 4-hr hold	924	0	
		Intermittent, 6-hr hold	137	0	
April-May 1976	Collection basket	Continuous	99 (yearling and adult)	21	Ref. 3, Table 4-26
		Intermittent, 2-hr hold	71 (yearling and adult)	21	
		Intermittent, 4-hr hold	41 (yearling and adult)	0	
November-December 1976	Collection basket	Continuous	201	24	Ref. 3, Table 4-27
		Intermittent, 2-hr hold	258	9	
		Continuous	17 (yearling)	53	
		Intermittent, 2-hr hold	17 (yearling)	6	
		Continuous	2 (adult)	100	

Table B-1. (continued)

Power plant and time	Collection point	Operating mode and screenwash pressure	Number of fish tested[a]	% survival[b]	Source
DANSKAMMER					
April-May 1977	Collection basket	Continuous	122	43	Ref. 3, Table 4-34
		Intermittent, 2-hr hold	29	25	
		Intermittent, 4-hr hold	158	6	
		Continuous	248 (yearling)	33	
		Intermittent, 2-hr hold	162 (yearling)	40	
		Intermittent, 4-hr hold	62 (yearling)	0	
		Continuous	347 (adult)	45	
		Intermittent, 2-hr hold	223 (adult)	28	
		Intermittent, 4-hr hold	137 (adult)	3	
November-December 1977	Collection basket	Continous	37	63	Ref. 4, Table 4-9
		Intermittent, 2-hr hold	71	18	
		Continuous	13 (yearling)	62	
		Intermittent, 2-hr hold	8 (yearling)	43	

Table B-1. (continued)

Power plant and time	Collection point	Operating mode and screenwash pressure	Number of fish tested[a]	% survival[b]	Source
INDIAN POINT					
October-December 1977		Continuous	221	24	Ref. 8 Attachment 1
June-December 1977		Continuous	37 (yearling and older)	16	
SURVIVAL OF CONTROLS EXPOSED ONLY TO COLLECTION AND HOLDING PROCEDURE					
BOWLINE					
November-December 1976	Collection pit		28 (yearling and adult)	86	Ref. 9, Table 10.3-5
			302	32	
	Discharge pipe		134	14	Ref. 9, Table 10.3-7
ROSETON					
November-December 1976	Collection basket		53	68	Ref. 2, Table 10.3-6
			28 (yearling)	100	
			1 (adult)	100	

Table B-1. (continued)

Power plant and time	Collection point	Operating mode and screenwash pressure	Number of fish tested[a]	% survival[b]	Source
ROSETON					
April-May 1977	Collection basket		26	46	Ref. 3, Table 4-18
			22 (yearling)	59	
			230 (adult)	89	
October-December 1977	Collection basket		79	95	Ref. 4, Table 4-5
			35 (yearling)	94	
			48 (adult)	96	
DANSKAMMER					
November-December 1976	Collection basket		11	91	Ref. 3, Table 4-28
			5 (adult)	100	
April-May 1977	Collection basket		53	81	Ref. 3, Table 4-35
			38 (yearling)	79	
			159 (adult)	84	

Table B-1. (continued)

Power plant and time	Collection point	Operating mode and screenwash pressure	Number of fish tested[a]	% survival[b]	Source
DANSKAMMER					
November-Deremher 1977	Collection basket		67	100	Ref. 4, Table 4-10
			23 (yearling)	100	
			31 (adult)	100	

[a]Young-of-the-year unless otherwise noted.

[b]Percent alive at end of observation period (96 hr at Bowline, 84 hr at Roseton and Danskammer).

[c]Data collected under the same conditions (sampling point, operating mode, and screenwash pressure) are pooled.

[d]Entries in the column labeled "84 hr" must be multiplied by the corresponding entries in the column labeled "Initial" to obtain the correct latent survival percentages (Ref. 8).

[e]Screenwash pressure for all impingement survival studies at Danskammer is 55 to 65 psi.

impinged during intermittent operation with a 2-hr wash cycle was as high as or higher than that of fish impinged during continuous operation. The lowest white perch survival at both Roseton and Danskammer was generally observed during intermittent operation with a 4-hr cycle.

The results of tests designed to measure the effect of screenwash pressure on survival also differed from plant to plant. Most of the tests at Roseton indicated that under both continuous and intermittent operation white perch survival is higher at 3515 g/cm^2 (50 psi) screenwash pressure than at 7031 g/cm^2 (100 psi). Ecological Analysts (EA) stated this conclusion both in the Roseton Near-Field Report (Central Hudson 1977, p. 10.3-35) and in the 1977 Progress Report to Central Hudson (Ecological Analysts 1977, p. 5-1). The data in Table B-1 generally support this conclusion, although no pressure effects were observed in the most recent experiments conducted in the fall of 1977 (Ecological Analysts 1978).

At Bowline no increase in survival has been noted when screenwash pressure is reduced from the normal 4218 to 1406 g/cm^2 (60 to 20 psi) or less. Ecological Analysts found no significant effect of pressure on survival under either continuous or intermittent travelling screen operation. Ecological Analysts offered two possible explanations (Orange and Rockland 1977, pp. 10.3-26 to 10.3-28):

> ".... The absence of an apparent effect of screenwash pressure has at least two possible interpretations. First, the damage incurred by the white perch from being washed off the screens may be negligible at screenwash pressures of 50-60 psi and below. Second, the spray from the low pressure

> system may have been insufficient to remove fish from the screens. As a result, the fish may have been exposed to the high pressure nozzels located just below the low pressure system. In this case pressure exposures would have been similar in both the low and high pressure wash tests."

Although EA found no statistically significant difference, the January-December 1976 survival percentages in Table B-1 suggest that the low-pressure screenwash system may actually reduce the survival of white perch. In all cases in which it is possible to compare results obtained under conditions that were identical except for screenwash pressure (i.e., same collecting location and screenwash schedule), higher survival was observed among fish exposed only to the high pressure spray.

Seasonal variations in survival

The data compiled in Table B-1 suggest that the survival of impinged white perch varies seasonally. In tests performed during the winter of 1977 (January-March), EA observed 100% mortality of juvenile white perch under all operating conditions. Ecological Analysts's explanation (Ecological Analysts 1977, p. 4-25) was that these fish are more susceptible to handling and holding stresses when water temperatures are near freezing. We agree that since young-of-the-year white perch are already under stress because of low temperatures, they should be more vulnerable to the additional stress of handling and observation. However, for the exact same reason, they should also be more susceptible to the stress of impingement. Survival of white perch impinged at Bowline during this same period was also low (Table B-1).

Nearly 2000 impinged white perch were sampled at the Bowline collection pit during January-February 1977. All were obtained while the screens were operating in the continuous mode, i.e., the mode under which the highest survival is obtained. Only 28% of the fish collected when the high pressure spray was used, and only 21% of the fish collected when the low pressure spray was used, survived for as long as 96 hours after collection. Relatively high survival was observed among white perch collected at the Bowline discharge pipe (high pressure spray), but the sample size was low, only 25 fish. These results suggest, although they are not conclusive, that the survival of impinged white perch is lower during the winter than during other seasons.

Indirect mortality and handling mortality

Do the data summarized in Table B-1 provide reliable estimates of the survival of those white perch that are impinged, washed off the screens, and returned to the river rather than collected and observed? It is not possible to reproduce in the laboratory the conditions faced by these fish in their natural habitat. A stunned or otherwise weakened fish is more vulnerable to predators, and these predators may congregate in the vicinity of the screenwash discharge because it provides an abundant supply of prey. Congregations of predators were, in fact, observed at fish return sites in the Sacramento-San Joaquin estuary (Skinner 1972, California Department of Fish and Game et al. 1978). Moreover, analyses of the stomach contents of these predators indicate that they feed heavily on released fish (Skinner 1972, California Department of Fish and Game et al. 1978). A fish that survives these predators may develop fungal or bacterial infections because of wounds and/or lost scales caused by impingement. Such infections may not be observable in the holding facility because they take longer than 96 hrs to develop, or because they are suppressed by biocides. According to p. 10.3-6 of Central Hudson (1977), water used at the Roseton holding facility has occasionally been treated with potassium permanganate to reduce the incidence of infections.

On the other hand, the collection and holding procedure imposes stresses of its own that an impinged fish does not suffer if it is returned directly to the river. It is for this reason that EA attempted to measure the mortality of control fish, exposed only to collection and holding, at all three plants. The control survival data for white perch are summarized in Table B-1. Ecological Analysts's results indicate that handling mortality is substantial. The survival of white perch controls at Bowline was no better than that of the comparable impinged fish. The survival of impinged white perch sampled at the collection pit in 1976 ranged from 23 to 61%. Survival of the corresponding control fish was 32%. White perch survival at the Bowline discharge pipe in 1976 ranged from 9 to 20%. The corresponding control survival was 14%. Survival of yearling and adult white perch controls was high (86%), but there are no impinged fish with which they can be compared. White perch controls at Roseton and Danskammer fared better, although mortality was fairly high among young-of-the-year controls. In only one case (Roseton, April-May 1977, young-of-the-year, continuous high-pressure screenwash) was mortality among impinged fish lower than that of control fish.

Despite the sometimes high mortality observed among control fish, it appears unlikely that all of the observed mortality among impinged fish is caused by collection and handling. If all mortality were due to collection and handing, then no effects of screenwash procedure on survival could be observed. If, as appears to be the case, collection and holding cause substantial mortality, then EA's procedure ensures that control fish will suffer more of this mortality than will impinged fish. According to p. 10.3-18 of Orange and Rockland (1977), control fish are held for at least 72 hrs before use in impingement survival experiments. If the holding system stresses fish, then controls are exposed to this stress for much longer than are impinged fish. However, it may be the collection process itself that imposes the stress. At all three plants control fish are inserted into the collection device at the beginning of the sampling period and left there for the entire sampling period. If impinged fish arrive in the net more or less continuously throughout the sampling period, then each control fish is exposed to the stress of collection for twice as long as the average impinged fish. In addition, control fish suffer a stress that is not imposed at all on impinged fish: stress due to marking. Texas Instruments (TI) found that marking does induce mortality (Texas Instruments 1975). Texas Instrument's mark/recapture population estimates for white perch are adjusted to account for this mortality. Ecological Analysts did not attempt to measure the effect of marking on the survival of control fish used in impingement survival studies.

Because control fish suffer more collection, handling (including marking), and holding stress than do impinged fish, we do not believe that the mortality of control fish is a reliable measure of the true sampling/observation mortality suffered by impinged fish. The control survival percentages should not be used to compute adjusted impingement survival percentages, e.g., as is done in Table 10.3-7 of Central Hudson (1977). It may be concluded that the results tabulated in Table B-1 represent overestimates of the actual fraction of impinged white perch that die as a direct result of being impinged. However, an additional fraction, one that cannot be estimated at this time, probably die indirectly because of increased vulnerability to predators, pathogens, or parasites.

Fraction of white perch that survive impingement

It is possible to make rough estimates of the fraction of white perch impinged during the normal operation of the Bowline, Lovett, Roseton, and Danskammer plants that are returned to the river and survive. It is also possible to estimate the fraction that could survive impingement at Indian Point, if the requirement that all impinged fish be collected were relaxed. The highest survivals of white perch at Bowline, Roseton, and Danskammer were obtained under continuous travelling screen rotation and, at least at Roseton, low screenwash pressure. These are not the standard operating conditions at any of these plants (Table B-2). At Roseton and Danskammer, the most relevant results in Table B-1 are those obtained from experiments conducted under intermittent screenwash with the high-pressure spray.

Table B-2. Normal operating procedures for travelling screens operating at five Hudson River power plants

Plant	Mode	Screenwash pressure (psi)	Source of information
Bowline	Intermittent; 4-hr hold[a]	30/60[b]	Exhibit 7, pp. 2.2-10, 2.2-11; transcript pp. 5099-100
Lovett	Intermittent; 8-hr hold[c]	100	Attachment 2 to letter from K. Marcellus of Consolidated Edison to H. Gluckstern of EPA, dated November 30, 1977; Transcript p. 5098
Roseton	Intermittent; 2-hr hold[d]	100	Letter from T. Huggins of Central Hudson to H. Gluckstern of EPA, dated November 29, 1977; Transcript p. 5098
Danskammer	Intermittent; variable depending on debris load	55-65	Letter from T. Huggins of Central Hudson to H. Gluckstern of EPA, dated November 29, 1977; EA 1977 Progress Report to Central Hudson, Table 4-26
Albany	Screens washed automatically for 3 min every 15 min	84	Attachment 2 to letter from K. Marcellus of Consolidated Edison to H. Gluckstern of EPA, dated November 30, 1977

[a]Operated in continuous mode when impingement exceeds 1000 fish per day.

[b]Low pressure (2109 g/cm^2 or 30 psi) wash system mounted below high pressure (4218 g/cm^2 or 60 psi) system. 1 psi = 70.307 g/cm^2.

[c]Operated in continuous mode during periods of high debris loading.

[d]Operated in continuous mode during periods of high debris loading and icing (such conditions generally occur between October and April).

Survival percentages under these conditions ranged from 0 to 25% at Roseton and from 0 to 43% at Danskammer. During conditions of high debris loading or icing, the travelling screens at Roseton are rotated continuously and washed with the high pressure spray. The survival percentages obtained under this operating mode ranged from 0-51%. At Bowline both intermittent and continuous rotation have been employed during normal operation. Survival percentages ranging from 0 to 61% were obtained from the collection pit experiments, with most of the observations falling between 10 and 40%. The generally lower survivals obtained at the Bowline discharge pipe were largely a function of sampling mortality, as evidenced by the relatively poor survival of the discharge-pipe controls.

Given that a substantial fraction of the impingement mortality observed among white perch is caused by collection and/or observation, it is conceivable that as many as 40% may survive the immediate effects of impingement if returned directly to the river. At all three plants impingement abundance collections are made at least once a week. On these days no fish are returned to the river. Moreover, it is normal procedure at Bowline to hold all fish impinged during the 24 hrs preceding an impingment sample. If, on the average, 40% of the fish returned to the river survive, then about 29% (40% x 5/7) of all white perch impinged at Bowline during a week would survive. At Roseton and Danskammer, about 34% (40% x 6/7) would survive. The possibility remains that survival of impinged white perch may be lower during the winter, a season of high impingement at Bowline and of low impingement at Roseton and Danskammer. It is also possible that, due to the effects of sampling mortality, the survival of this species may be higher than is indicated by the results of the experiments. However, biases introduced into the direct impact assessment (Section IV) by underestimating or overestimating the survival of impinged white perch at Bowline, Roseton, and Danskammer are likely to be small in comparison to biases introduced by errors in the estimates of population size and total mortality (Section III).

It can be seen from Table B-2 that travelling screen operating conditions at Albany are similar to those at Bowline, Roseton, and Danskammer. Therefore, it seems reasonable to assume that the survival of impinged fish at this plant is probably similar to that observed at the three plants where extensive studies have been conducted. At Lovett, however, the screens are rotated only once every eight hours. Since reduced survival was observed at other plants when a 4-hr screenwash cycle (as compared to continuous) is employed, it is reasonable to suppose that survival would be even lower (perhaps approaching zero) with an 8-hr cycle.

The results obtained from the preliminary experiments conducted at Indian Point Unit 1 (Table B-1) are similar to results obtained at Bowline, Roseton, and Danskammer, although the survival percentages observed (24% for young-of-the-year and 16% for yearling and older white perch) are near the low end of the ranges observed at the other three plants. Thus, it is possible that if white perch impinged at Indian Point were returned to the river, the fraction surviving would be similar to the fraction surviving impingement at other plants, provided that the travelling screens are operated in the continuous mode. Because of the presence of fixed screens in the intake forebays at Indian Point Unit 2, intake modifications at this unit would be required if continuous rotation of the traveling screens is to be of any value.

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APPENDIX C

IMPINGEMENT RATE AS AN INDEX OF POPULATION ABUNDANCE

C.1 Introduction

The purpose of this appendix is to examine the validity of the assumption made in Section II of this report that the impingement rate of young-of-the-year white perch at the Hudson River power plants is an approximate index of the size of the young-of-the-year white perch population in the Hudson River estuary. Two lines of evidence are presented: (1) comparison of young-of-the-year white perch impingement rates and catch per unit effort (CPUE) by beach seines and (2) comparison of the length-frequency distributions of young-of-the-year white perch in impingement collections and in beach-seine samples. In the final section of this appendix, we examine the relationship between daily cooling water withdrawals and daily impingement counts, and we comment on impingement rate as a CPUE index.

C.2 Comparison of impingement rates and beach seine CPUE

We start by assuming that the Texas Instruments beach seine survey provides one index of year-class strength of white perch in the Hudson River estuary. Next, we assume that impingement rate of young-of-the-year white perch at the various Hudson River power plants considered together provides an alternative index of year-class strength. We would expect a positive correlation between the two sets of indices. The lack of adequate impingement data prior to 1972 and the lack of beach seine data after 1976 (at least at present) limit the analysis to the 5-year period of 1972 through 1976.

The beach seine survey is described in Texas Instruments (1979); methods used to calculate riverwide indices of abundance are given (p. IV-10) and values for 1972 through 1976 are tabulated (Table IV-31) and repeated here in Table C-1. The survey is riverwide (Yonkers through Albany) and the index is calculated based on data collected from mid-July through early September. This period is the time when young-of-the-year white perch tend to concentrate in shore and shoal areas, and thus, this is the period when we would hope that the beach seine survey could provide a reasonable estimate of year-class strength. The index of abundance for 1972 cannot be viewed with the same reliability as the values for 1973 through 1976 because of the much lower level of effort and number caught and the limited region of the river sampled in 1972.

For each power plant we selected the four to five months when the impingement rate of young-of-the-year white perch tended to be highest year after year. Our reasoning was that high impingement rates of young-of-the-year white perch at a given power plant are, in part, indicative of relatively high abundance of young-of-the-year white perch in the vicinity of that power plant. Young-of-the-year white perch tend to migrate downriver during their first summer and fall, where they overwinter, and then they tend to disperse back up the river the following spring. As a result, impingement rates during the winter at the more downriver power plants (i.e., Bowline, Lovett, and Indian Point) would be expected to provide reasonable indices of the size of the overwintering young-of-the-year population. Impingement rates at the more upriver power plants (i.e., Roseton and Danskammer) would be expected to provide reasonable indices of year-class strength during the fall downriver migration and the spring upriver dispersion.

Table C.1. Beach seine data used to calculate a riverwide index of abundance (catch per 10,000 ft^2) for young-of-the-year white perch in the Hudson River estuary, 1972 through 1976[a]

Year	Sample dates	Number caught	Area swept (ft^2)[b]	Index of abundance
1972	7/16 - 9/2	131	302,451	4.3
1973	7/15 - 9/8	4308	2,145,892	20.1
1974	7/14 - 9/7	1943	2,853,116	6.8
1975	7/13 - 9/6	9343	3,599,092	26.0
1976	7/11 - 9/4	9502	3,758,944	25.3

[a]Modified from Table IV-31 in Texas Instruments Inc. 1979. 1976 year-class report for the multiplant impact study of the Hudson River estuary. Prepared for Consolidated Edison Company of New York, Inc.

[b]1 ft^2 = 0.0929 m^2.

Based on the above reasoning, we selected impingement rates during December through April for Bowline, Lovett, and Indian Point Unit 2 and October through November of one year and April through May of the following year for Roseton and Danskammer (see Table 2, Section II, of this report and plant-specific tables in Appendix A). We calculated the average impingement rate for these four- to five-month periods for each of the five power plants for each year 1972 through 1976; then the average impingement rate over power plants was calculated for each year and these five averages were ranked (Table C-2). In addition, the yearly average rates were ranked for each power plant, and the average rank over power plants was calculated for each year (Table C-2). Ranking the impingement rates averaged over power plants gives weight to each power plant according to the magnitude of the impingement rates at that plant. For young-of-the-year white perch the average impingement rates are dominated by the impingement rate values for Indian Point Unit 2. Averaging the ranks over power plants gives equal weight to each power plant. It is not obvious which of these two computational alternatives is the more appropriate, but in this case the conclusion from the analysis is the same for both alternatives.

The Spearman rank correlation coefficient (r_s) between the ranks of the impingement rates averaged over power plants and the Texas Instruments (TI) beach seine index of abundance is -0.10, which is not significantly different from zero at even the 10% level. For the average of the ranks over plants and the TI beach seine index of abundance, r_s = 0.67, which also is not different from zero at the 10% level. In other words, there is not a statistically significant

Table C.2. Impingement rates (number/10^6 m^3) for young-of-the-year white perch at five Hudson River power plants for the years 1972 through 1976[a]

Year	Bowline		Lovett		Indian Point Unit 2		Roseton		Danskammer		Average			Texas Instruments beach seine index of abundance	
	Impingement rate	Rank	Impingement rate	Rank	Impingement rate	Rank	Impingement rate	Rank	Impingement rate	Rank	Impingement rate	Rank	Average rank[b]	CPUE[c]	Rank
1972	290	1	135	1	4146	2	---	-	238	2	1202[d]	3	1.5	4.3	1
1973	767	5	426	4	8467	4	263	2	339	3	2053	4	3.6	20.1	3
1974	681	4	381	3	4551	3	63	1	70	1	1149	2	2.4	6.8	2
1975	337	2	158	2	3408	1	359	4	523	4	957	1	2.6	26.0	5
1976	470	3	530	5	27380	5	307	3	749	5	5887	5	4.2	25.3	4

[a]Impingement rate for each power plant for each year was calculated as the average of the impingement rates (RATEO values from tables in Appendix A) for December - April (Bowline, Lovett, and Indian Point Unit 2) or for October - November of one year and April - May of the following year (Roseton and Danskammer). These yearly average impingement rates were ranked for each power plant. The average impingement rate across power plants was calculated and these five averages were ranked.

[b]Average of the ranks for the five power plants (four power plants for 1972).

[c]Obtained from Table C-1.

[d]Does not include Roseton.

positive correlation between these two sets of indices of year-class strength, contrary to our expectation. These results are consistent, however, with another analysis we performed comparing impingement rates at Indian Point Unit 2 with the beach seine CPUE averaged over the seven standard beach seine sites in the vicinity of Indian Point for the eight biweekly periods starting July 13, 1975, and ending November 2, 1975 (Table C-3). The Spearman correlation coefficient between these two time series was -0.29, which does not differ significantly from zero.

C.3 Comparison of length-frequency distributions

In this section we compare the length-frequency distributions of young-of-the-year white perch in impingement collections at Indian Point Unit 2 and in beach seine samples from the seven standard beach seine sites in the vicinity of Indian Point for the eight biweekly periods starting July 13, 1975, and ending November 2, 1975. The null hypothesis is that the length-frequency distributions will be the same. This hypothesis assumes that the various size classes of young-of-the-year white perch are distributed laterally and vertically in approximately the same manner at the intake structures and in the shore/shoal areas in the immediate vicinity of the intake structures and that they will be collected with approximately the same efficiency by intake screens and beach seines.

Length data for young-of-the-year white perch impinged at Indian Point Unit 2 and collected at the standard beach seine sites during 1975 were obtained from magnetic tapes provided us by Texas Instruments through Consolidated Edison Company of New York. Table C-4 summarizes

Table C-3. Comparison of impingement rates of young-of-the-year white perch at Indian Point Unit 2 with beach seine CPUE data for young-of-the-year white perch in the vicinity of Indian Point for eight biweekly periods during 1975

Biweekly period		Impingement rate[a]		Beach seine CPUE[b]	
Number[c]	Dates	(no./10^6 m^3)	Rank	(no. per haul)	Rank
9	7/13 - 7/26	10.15	2	3.36	2
10	7/27 - 8/9	5.08	1	16.36	8
11	8/10 - 8/23	236.40	8	8.50	4
12	8/24 - 9/6	52.65	4	5.79	3
13	9/7 - 9/20	134.90	6	11.29	7
14	9/21 - 10/4	49.50	3	9.29	5
15	10/5 - 10/18	72.81	5	10.07	6
16	10/19 - 11/2	137.81	7	1.21	1

[a]Calculated from daily impingement rate data for white perch of all ages at Indian Point Unit 2. Source: Table A-3 of Texas Instruments Inc., Indian Point Impingement Study Report for the Period 1 January 1975 through 31 December 1975, prepared for Consolidated Edison Company of New York, Inc., November 1976. The biweekly impingement rates for white perch of all ages were then multiplied by biweekly PERCENTO values obtained from Table A-5, Appendix A of this report to give the biweekly impingement rates for young-of-the-year white perch tabulated in this table.

[b]Calculated as the average over the seven beach-seine sampling stations for 1975 data for young-of-the-year white perch in Table A-3 (see footnote c for reference).

[c]Number of the biweekly period as designated by Texas Instruments Inc., Hudson River Ecological Study in the Area of Indian Point, 1975 Annual Report, prepared for Consolidated Edison Company of New York, Inc., December 1976.

Table C-4. Summary statistics for length-frequency distributions of young-of-the-year white perch in impingement collections at Indian Point Unit 2 and in beach seine samples from the seven standard beach seine sites in the vicinity of Indian Point for the eight biweekly periods starting July 13, 1975, and ending November 2, 1975[a]

Biweekly period	n	Length (mm) Minimum	Mean	Maximum	Test for normality D-Max	P	Test for skewness G_1	P_1
Indian Point Unit 2 impingement samples								
1	50	39	47	58	0.09	> [illegible]	0.44	0.20
2	49	30	56	74	0.13	0.05	-0.94	0.01
3	25	45	56	78	0.20	0.05	0.97	0.04
4	25	40	54	79	0.14	> 0.20	1.24	0.01
5	25	48	63	85	0.13	> 0.20	0.68	0.14
6	--	--	--	--	--	--	--	--
7	25	53	69	85	0.13	> 0.20	-0.28	0.55
8	25	58	76	95	0.10	> 0.20	-0.06	0.90
Texas Instruments beach-seine samples								
1	42	21	35	47	0.09	> 0.20	-0.27	0.47
2	102	20	48	70	0.15	0.01	-0.54	0.02
3	118	31	58	78	0.15	0.01	-0.50	0.03
4	71	39	67	95	0.12	0.01	-0.22	0.44
5	103	48	70	90	0.13	0.01	-0.36	0.13
6	81	52	63	90	0.15	0.01	0.22	0.41
7	84	49	74	98	0.08	0.20	-0.25	0.35
8	17	57	76	96	0.10	> 0.20	-0.03	0.96

[a]n is the number of young-of-the-year white perch included in the length-frequency distribution; D-max is the Kolmogorov-Smirnov D-statistic for testing normality, P is the Lilliefors significance level for D-max, G_1 is the coefficient of skewness, and P_1 is the significance level for G_1. Source: Barr, A. J., J. H. Goodnight, J. P. Sall, and J. T. Helwig. 1976. A user's guide to SAS 76. SAS Institute, Inc., Raleigh, North Carolina.

the properties of the individual length-frequency distributions in terms of number of fish, minimum, mean, and maximum lengths, test for normality, and test for skewness. Approximately half of the distributions do not differ significantly from a normal distribution. Those distributions that do differ tend to be skewed more commonly to the left than to the right, i.e., a greater tendency for a few relatively short white perch as opposed to a few relatively long white perch.

We tested the null hypothesis of similar length-frequency distributions for each biweekly period using the chi-square approximation to the Kolmogorov-Smirnov two-sample test, which is a test of whether two independent samples have been drawn from populations with the same distribution (Siegel 1956). The mean lengths of the two sets of distributions are not significantly different (Wilcoxon matched-pairs signed-ranks test). However, the two sets of distributions do tend to differ (Table C-5); five of the seven pairs of distributions differ significantly ($P < 0.05$). The difference appears to be due to a narrower range (Table C-4) and smaller variance for impinged young-of-the-year white perch as compared to young-of-the-year white perch collected in the beach seines.

C.4 Discussion

Our results lead to the obvious question: Which data set (impingement or beach seine) provides the more accurate (less inaccurate?) indices of year-class strength? Unfortunately, the answer to this question is not black and white. There are two obvious differences between the two sampling programs. The volume of water

Table C-5. Tests of the null hypothesis that the length-frequency distributions of young-of-the-year white perch impinged at Indian Point Unit 2 and collected in beach seine samples are the same for each of seven biweekly periods in 1975

Biweekly period	D[a]	χ^2[b]	p[c]
1	0.91	75.94	< 0.001
2	0.30	11.92	< 0.01
3	0.32	8.56	< 0.02
4	0.53	20.46	< 0.001
5	0.35	9.97	< 0.01
6	--	--	--
7	0.24	4.44	> 0.05
8	0.06	0.13	> 0.05

[a]D is the maximum difference between the two sample cumulative length-frequency distributions.

[b]χ^2 is the chi-square approximation to the Kolmogorov-Smirnov two-sample test, calculated as $4D^2n_1n_2/(n_1 + n_2)$, where n_1 and n_2 values are available from Table C-4.

[c]p is the significance level for the calculated chi-square value (df = 2).

sampled (i.e., effort) and the number of fish collected are much greater for the impingement data, which argues in favor of the impingement data being the more accurate. However, the five power plants included in the analysis in Section C.1 represent only five sampling points, whereas there are over 100 beach seine stations located between RM 12 (George Washington Bridge) and RM 152 (Troy Dam), a difference which argues in favor of the beach-seine data being the more accurate. This side of the argument is weakened, however, by the fact that the beach-seine survey was specifically designed for young-of-the-year striped bass and not young-of-the-year white perch.

C.5 Relationship between daily cooling water withdrawals and daily impingement counts

Impingement rate is an index of catch per unit effort that is conceptually equivalent to catch/effort indices based on seine or trawl data. Such indices are computed under the assumption that the catch is proportional to the effort, in this case measured as the volume of cooling water withdrawn during an impingement sampling period. As for any other sampling gear, this assumption should be tested when availability of data permits. Texas Instruments (1974, p. II-29), for example, found no clear relationship between the number of white perch impinged at Indian Point Unit 1 and either the volume of cooling water withdrawn or the intake velocity. If the number impinged is, for all practical purposes, independent of flow, then it is possible that a simple count of fish impinged per hour of operation could be as good an index of abundance as is the impingement rate.

We used white perch impingement data collected at Indian Point Unit 2 in 1975 and 1976 at Unit 3 in 1976 to determine whether the number of fish impinged on a given day is in fact related to volume of cooling water withdrawn on that day. The necessary daily impingement and flow data, for each day during these two years on which these generating units were operating, were extracted from data tapes obtained from the Consolidated Edison Co.

It is known that the impingement of white perch at Indian Point varies seasonally, being highest in the winter and early spring and lowest in the summer and fall (Section II, Tables 2 and 3 of this report). To reduce the marked effects of seasonal variation in impingement (thus increasing the probability of detecting the effects of flow), we stratified the data by months within each year and used covariance analysis, treating month as a block effect. The three data sets, i.e., the two years of data for Unit 2 and the single year for Unit 3, were analyzed separately, and parallel analyses were performed using untransformed and log-transformed impingement counts.

In two of the three untransformed data sets, the effect of flow was found to be significant at the 5% level (Table C-6). Somewhat stronger relationships were found between flow and the log-transformed impingement counts; in all three of these analyses the effect of flow was significant at the 2% level or lower (Table C-7). Although statistically significant flow effects were detected, the effect of flow is clearly less important than the effect of months (Tables C-6 and C-7).

Table C-6. Analysis of the relationship between daily cooling water flow and untransformed daily impingement counts, with data stratified by month[a]

Power plant and year	R^2	Overall model		Month effect		Flow-within-month effect	
		F	P	F	P	F	P
Indian Point Unit 2, 1975	0.19	6.56	0.0001	6.02	0.0001	12.42	0.0005
Indian Point Unit 2, 1976	0.28	6.88	0.0001	7.38	0.0001	2.94	0.09
Indian Point Unit 3, 1976	0.44	18.91	0.0001	20.58	0.0001	3.88	0.05

[a]The covariance model used was $Y_{ij} = \mu + \tau_j + \beta (X_{ij} - \overline{X}_{..}) + \varepsilon_{ij}$, where Y_{ij} is the impingement count of white perch of all ages on day i of month j, X_{ij} is the cooling water withdrawal (in cubic meters) on day i of month j, $\overline{X}_{..}$ is the average daily cooling water withdrawal over all months (excluding days of zero flow), is the mean impingement count over all months, τ_j is the mean impingement count for month j, β is the slope of the straight-line regression between daily cooling water withdrawal and daily impingement count, and ε_{ij} is the random error for day i of month j (p. 309 in Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Company, New York. 481 pp.

Table C-7. Analysis of the relationship between daily cooling water flow and log-transformed daily impingement counts, with data stratified by month[a]

Power plant and year	R^2	Overall model		Month effect		Flow-within-month effect	
		F	P	F	P	F	P
Indian Point Unit 2 - 1975	0.46	24.01	0.0001	22.48	0.0001	40.90	0.0001
Indian Point Unit 2 - 1976	0.51	17.96	0.0001	19.53	0.0001	5.38	0.02
Indian Point Unit 3 - 1976	0.73	52.32	0.0001	64.31	0.0001	66.74	0.0001

[a]The covariance model used was $Y_{ij} = \mu + {}_j + \beta (X_{ij} - \bar{X}_{..}) + {}_{ij}$, where Y_{ij} is the impingement count of white perch of all ages on day i of month j, X_{ij} is the cooling water withdrawal (in cubic meters) on day i of month j, $\bar{X}_{..}$ is the average daily cooling water withdrawal over all months (excluding days of zero flow), μ is the mean impingement count over all months, τ_j is the mean impingement count for month j, β is the slope of the straight-line regression between daily cooling water withdrawal and daily impingement count, and ε_{ij} is the random error for day i of month j (p. 309 in Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Company, New York. 481 pp.

The statistical analyses described in this section indicate that the volume of cooling water withdrawn by Indian Point Units 2 and 3 on any given day does influence the number of white perch impinged on that day. This result supports the validity of using the impingement rate as a catch/effort index as done in Section II. However, the fact that flow apparently accounts for only a few percent of the total variance in the daily impingement counts suggests that alternative indices of effort (e.g., hours of operation or kilowatt-hours of electricity produced), that might be more readily available than daily cooling water withdrawals, might serve the same purpose equally well.

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APPENDIX D

MINIMUM DETECTABLE REDUCTION IN YEAR-CLASS STRENGTH AND NUMBER OF YEARS REQUIRED TO DETECT A SPECIFIED REDUCTION

D.1 Introduction

In Section II.B we concluded, based on regression analyses of impingement rate of young-of-the-year white perch on year,[1] that there has been no statistically significant change in year-class strength during the period 1972 through 1977. Given this situation we can use impingement rates for 1972 through 1977 as baseline data to provide a measure of "natural" variability in year-class strength, and then we can address the following two questions:

(1) Based on a given number of years of additional impingement data, what is the minimum detectable fractional reduction in year-class strength of white perch in the Hudson River which we can hope to detect?

(2) Given that we want to be able to detect a specified fractional reduction in year-class strength of white perch in the Hudson River (e.g., say a 25 or 50% reduction), how many additional years of impingement data are required?

Obviously these two questions are related in that for the first question fractional reduction is the dependent variable and number of additional years of data is the independent variable, whereas for the second question the two variables are reversed. However, the two

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[1] A similar regression analysis for CPUE of young-of-the-year white perch in beach seines on year (i.e., CPUE = a + b YEAR) also supports the conclusion of no statistically significant linear change in year-class strength during the period 1972 through 1976 (r^2 = 0.54; b = 4.79; P = 0.16).

questions merit separate answers because they represent different points of view on monitoring the Hudson River white perch population in years to come.

D.2 Methods

In general, to study the relationship between the power of a statistical test and the sample size, it is first necessary to specify the null and alternative hypotheses. Our null hypothesis is that there is no difference between the underlying means of two samples, i.e.,

$$H_0: \ \mu_1 = \mu_2 \ , \qquad (1)$$

where μ_1 is the underlying mean index of year-class strength for young-of-the-year white perch in the Hudson River during the period 1973 through 1977, and μ_2 is the underlying mean index of year-class strength for the period starting 1978. The set of alternative hypotheses is that the underlying mean of the second sample (μ_2) is less than the underlying mean of the first sample (μ_1), i.e.,

$$H_A: \ \mu_1 > \mu_2 \ . \qquad (2)$$

In other words, H_A is one-tailed and includes those cases where there is a reduction in the underlying mean index of year-class strength for the period starting 1978 relative to that for the period 1973 through 1977.

If we assume an underlying normal distribution for each of the two samples, as well as a common underlying variance, then the appropriate test statistic for the difference between the two means is given by

$$t = \frac{\overline{X}_1 - \overline{X}_2}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} , \tag{3}$$

where $\overline{X}_1$ and $\overline{X}_2$ are the sample means of the first and second samples, respectively; n_1 and n_2 are the sample sizes (i.e., number of years, since only one index of year-class strength is obtained each year) of the first and second samples, respectively; and s_p is the pooled standard deviation such that

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} , \tag{4}$$

where s_1^2 and s_2^2 are the sample variances of the first and second samples, respectively. This test statistic is distributed as a central t-distribution with (= n_1+n_2-2) degrees of freedom. The null hypothesis is rejected when the calculated t (or test statistic) is greater than the tabled value for $t_{\nu,\alpha}$ (see Fig. D-1).

Thus, under the null hypothesis ($H_o: \mu_1 - \mu_2 = 0$):

$$Pr\ \{t > t_{\nu,\alpha}\} = \alpha , \tag{5}$$

where Pr { } indicates the probability of occurrence for the event within the braces. But, under the set of alternative hypotheses ($H_A: \mu_1 - \mu_2 > 0$), the difference is positive such that

$$Pr\ \{t > t_{\nu,\alpha}\} = 1 - \beta , \tag{6}$$

where β is the probability of accepting the null hypothesis when it is

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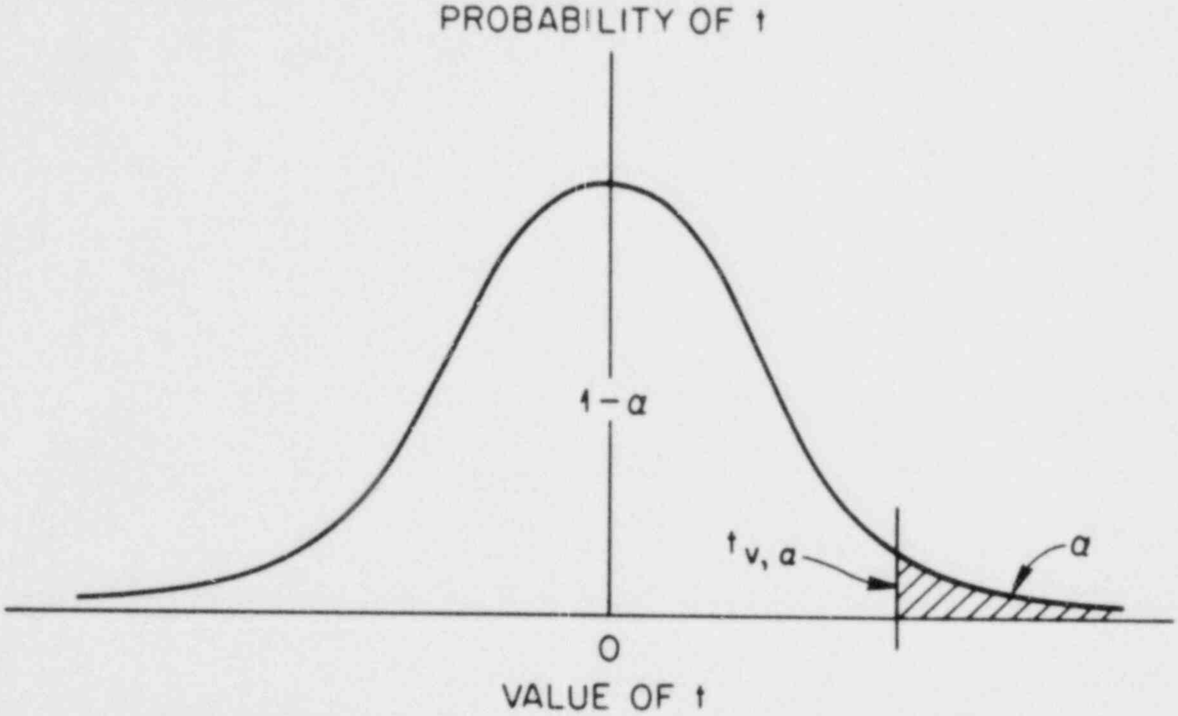

Fig. D-1. Probability distribution of the central t statistic with ν degrees of freedom. The shaded area comprises 100α% of the total area, where α is the type I error or level of significance.

false. The power of a statistical test $(1-\beta)$ is the probability of correctly rejecting the null hypothesis.

Under the alternative hypotheses the test statistic, t, is no longer distributed as a central t-distribution. Subtracting Eq. (3) from each of the two terms within the braces of Eq. (6), we obtain

$$\Pr\left\{ t - \frac{\overline{X}_1 - \overline{X}_2}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} > t_{\nu,\alpha} - \frac{\overline{X}_1 - \overline{X}_2}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \right\} = 1 - \beta \,. \tag{7}$$

The difference on the left side of the inequality in Eq. (7) is distributed under H_A as a central t-distribution. Therefore, the difference on the right side of the inequality in Eq. (7) can be set equal to a central t, analogous to Eq. (5), i.e.,

$$t_{\nu,1-\beta} = t_{\nu,\alpha} - \frac{\overline{X}_1 - \overline{X}_2}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \,. \tag{8}$$

If the first sample has already been obtained, then n_1 and estimates of $\overline{X}_1$ and s_1^2 are available. Using s_1 as an estimate of s_p, then

$$t_{\nu,1-\beta} = t_{\nu,\alpha} - \frac{\overline{X}_1 - \overline{X}_2}{S_1 \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \,, \tag{9}$$

where the degrees of freedom are appropriately reduced to (Baker 1935)

$$\nu = n_1 - 1 \tag{10}$$

instead of

$$\nu = n_1 + n_2 - 2 \quad . \tag{11}$$

General discussions of the concepts of statistical power of a significance test and minimum detectable difference may be found in McCaughran (1977), Sokal and Rohlf (1969, Section 7.8), and Zar (1975).

In the present application the null and alternative hypotheses are most usefully defined in terms of a mean fractional reduction in year-class strength for the period starting 1978 relative to the mean year-class strength during the period 1973 through 1977. Thus, we define the mean of the second sample ($\overline{X}_2$) as a fraction (1-b) of the mean of the first sample ($\overline{X}_1$), i.e.,

$$\overline{X}_2 = (1-b)\ \overline{X}_1 \quad , \tag{12}$$

where b is the fractional reduction in year-class strength for the period starting 1978, with possible values ranging from 0.0 (i.e., no reduction and $\overline{X}_2 = \overline{X}_1$) to 1.0 (i.e., the white perch population is eliminated and $\overline{X}_2 = 0.0$). Note that because of the one-tailed form of the alternative hypothesis (Eq. 2), we are not considering cases with b less than zero (i.e., an increase in year-class strength for the period starting 1978 such that $\overline{X}_2 > \overline{X}_1$).

The difference between the two sample means in Eq. (9) may now be expressed as

$$\overline{X}_1 - \overline{X}_2 = \overline{X}_1 - (1-b)\overline{X}_1 = b\ \overline{X}_1 \quad , \tag{13}$$

and Eq. (9) becomes

$$\begin{aligned} t_{\nu,1-\beta} &= t_{\nu,\alpha} - b\,\bar{X}_1 \Big/ s_1\sqrt{1/n_1 + 1/n_2} \\ &= t_{\nu,\alpha} - b \Big/ CV\sqrt{1/n_1 + 1/n_2} \quad , \end{aligned} \tag{14}$$

where $CV(= s_1/\bar{X}_1)$ is the coefficient of variation for the sample of indices of year-class strength for the period 1973 through 1977.

Addressing the first question posed in the introduction to this appendix requires that Eq. (14) be solved for b, the fractional reduction in year-class strength for the period starting 1978. Since a central t-distribution is symmetrical about 0.0,

$$t_{\nu,1-\beta} = -\,t_{\nu,\beta} \quad ,$$

and we get

$$b = [t_{\nu,\beta} + t_{\nu,\alpha}]\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}\ (CV) \quad . \tag{15}$$

Then, for given values of α, β, n_1 and CV, one can solve Eq. (15) for a range of n_2 values to explore how b, the minimum detectable fractional reduction in the year-class strength of young-of-the-year white perch in the Hudson River, varies as a function of the number of years (starting with 1978) for which indices of year-class strength are available. Note in Eq. (15) that as n_2 becomes very large, the minimum detectable fractional reduction approaches a lower bound, B, given by

$$B = [t_{\nu,\beta} + t_{\nu,\alpha}]\sqrt{\frac{1}{n_1}}\ (CV)\ . \qquad (16)$$

Addressing the second question posed in the introduction requires that Eq. (14) be solved for n_2, the number of years (starting with 1978) for which indices of year-class strength are available:

$$n_2 = \frac{(cv)^2\ n_1\ [t_{\nu,\beta} + t_{\nu,\alpha}]^2}{b^2\ n_1 - [t_{\nu,\beta} + t_{\nu,\alpha}]^2\ (CV)^2}\ . \qquad (17)$$

Then, for given values of α, β, n_1 and CV, one can solve Eq. (17) for a range of b values to explore how the number of years of additional data (starting in 1978) varies as a function of the minimum fractional reduction in year-class strength that one judges should be detectable.

D.3 Results

Application of Eqs. (15) and (17) requires that the coefficient of variation (CV) be specified. To make this analysis of statistical power as relevant as possible to the two questions posed in the introduction to this appendix, coefficients of variation associated with beach-seine indices and impingement-rate indices of year-class strength for the young-of-the-year white perch population in the Hudson River were examined.

The beach-seine indices for the years 1972 through 1976 are tabulated in Table C-1 of Appendix C; the coefficient of variation is 62%. The impingement-rate indices were examined in more detail. The coefficient of variation, number of years of data, mean, and standard deviation for impingement rates presented in Appendix A are given in

Table D-1 for each of the twelve months for each of five Hudson River power plants. In addition, these statistics are tabulated by month for impingement rates averaged over the five plants and by plant for impingement rates averaged over the twelve months. The frequency distribution of the 71 CV values from Table D-1 is plotted in Fig. D-2. Based on this frequency distribution, we selected 50% and 100% for use in Eqs. (15) and (17). These two values for the coefficient of variation bracket the median CV value of 78% and more than half of the frequency distribution, although both smaller and larger variations in impingement rate were not uncommon.

Application of Eqs. (15) and (17) also requires specification of values for α and β, the type I and type II errors, respectively, and of n_1, the number of years of impingement rate data available for the period prior to 1978. For the limited sensitivity analysis included in this appendix, we have selected only one value of α (α = 0.05), which means that we are accepting a 5% risk of falsely rejecting the null hypothesis of no reduction in year-class strength in favor of the set of one-tailed alternative hypotheses that there is a reduction. For each of the two values of the coefficient of variation, we selected a range of values of β to illustrate the importance of the concept of the power of a statistical test. The value of n_1 is 5, corresponding to the period 1973 through 1977.

The answer to the first question posed in the introduction to this appendix is illustrated in Fig. D-3. For example (Fig. D-3(b)), if the coefficient of variation is assumed to be 50% and if impingement data are collected for the next 10 years (1978 - 1987), then there is only a

Table D-1. Coefficient of variation, number of years, mean (over years), and standard deviation for impingement-rate indices of year-class strength of the young-of-the-year white perch population in the Hudson River; calculated from values presented in Appendix A[a]

Month	Bowline	Lovett	Indian Point 2	Roseton	Danskammer	By month over plant
January	108 (5/553.55/597.29)	55 (5/557.99/307.10)	78 (5/12610.44/9895.51)	32 (4/10.25/3.29)	49 (6/16.49/8.10)	72 (5/2788.93/1999.85)
February	118 (5/326.60/386.49)	106 (5/271.77/287.07)	130 (5/18101.25/23567.42)	124 (4/9.15/11.32)	103 (6/7.51/7.72)	127 (5/3791.10/4828.15)
March	86 (5/332.90/285.31)	17 (4/134.77/22.98)	67 (5/4234.06/2832.53)	50 (4/14.95/7.41)	86 (6/29.22/25.06)	71 (5/1079.51/761.51)
April	66 (5/577.95/384.70)	65 (5/315.74/206.41)	75 (5/5822.79/4370.12)	114 (4/149.61/171.29)	87 (6/303.10/264.77)	53 (5/1490.45/786.17)
May	54 (5/75.62/40.95)	101 (5/53.79/54.50)	120 (4/1565.67/1874.96)	68 (4/233.52/157.64)	81 (6/305.95/248.54)	83 (5/390.10/340.80)
June	(No young-of-the-year white perch impinged during June)					
July	137 (5/5.63/7.72)	64 (5/5.19/3.33)	40 (4/33.97/13.64)	105 (5/0.48/0.51)	82 (6/8.10/6.64)	70 (5/9.29/6.51)
August	105 (5/39.01/41.01)	77 (5/33.37/25.59)	120 (4/406.27/487.97)	83 (5/65.69/54.40)	52 (6/78.66/41.28)	88 (5/106.56/94.17)
September	119 (5/4.80/5.70)	65 (5/13.04/8.52)	106 (5/239.19/252.49)	110 (5/115.57/127.47)	35 (6/110.57/38.50)	56 (5/95.10/53.15)
October	129 (5/17.94/23.150	115 (5/71.93/82.44)	42 (5/111.47/468.76)	83 (5/246.80/205.72)	38 (6/412.95/158.10)	23 (5/371.81/86.85)
November	101 (5/274.23/276.19)	28 (5/394.84/108.66)	94 (5/2918.33/2741.95)	78 (5/286.54/224.78)	80 (6/482.87/387.28)	45 (5/881.36/393.06)
December	79 (5/767.15/606.78)	72 (5/273.93/198.60)	85 (5/7942.42/6776.79)	80 (5/37.48/30.28)	56 (6/81.85/46.16)	140 (5/1507.45/2113.55)
By plant over month	52 (5/247.95/129.87)	25 (4/172.79/43.64)	59 (4/2942.56/2922.64)	27 (4/88.13/23.88)	39 (6/153.18/60.00)	

[a]The top entry in each cell is the coefficient of variation. The bottom entries in each cell are (number of years/mean/standard deviation). The means and standard deviations have units of number of young-of-the-year white perch impinged per million cubic meters.

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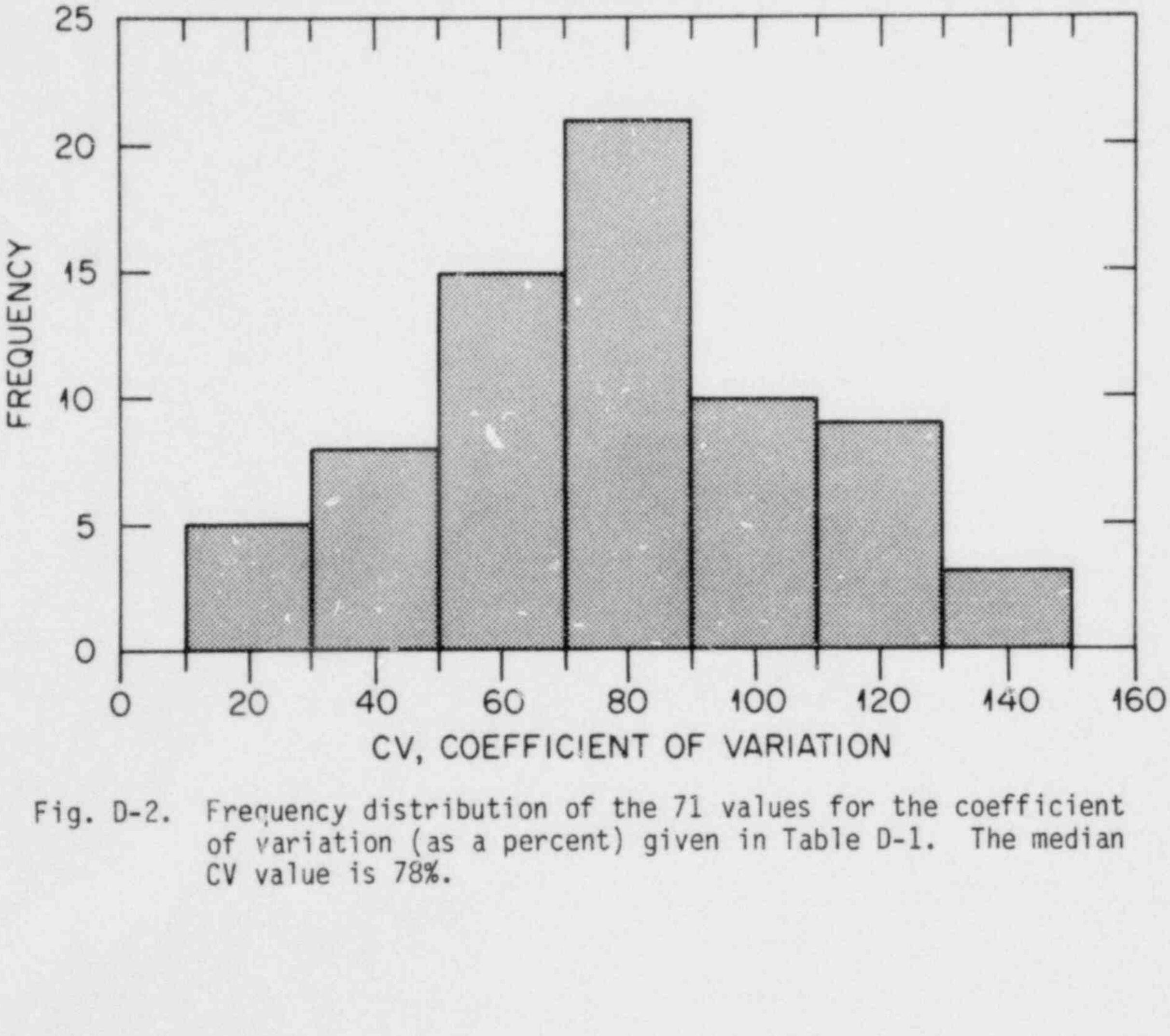

Fig. D-2. Frequency distribution of the 71 values for the coefficient of variation (as a percent) given in Table D-1. The median CV value is 78%.

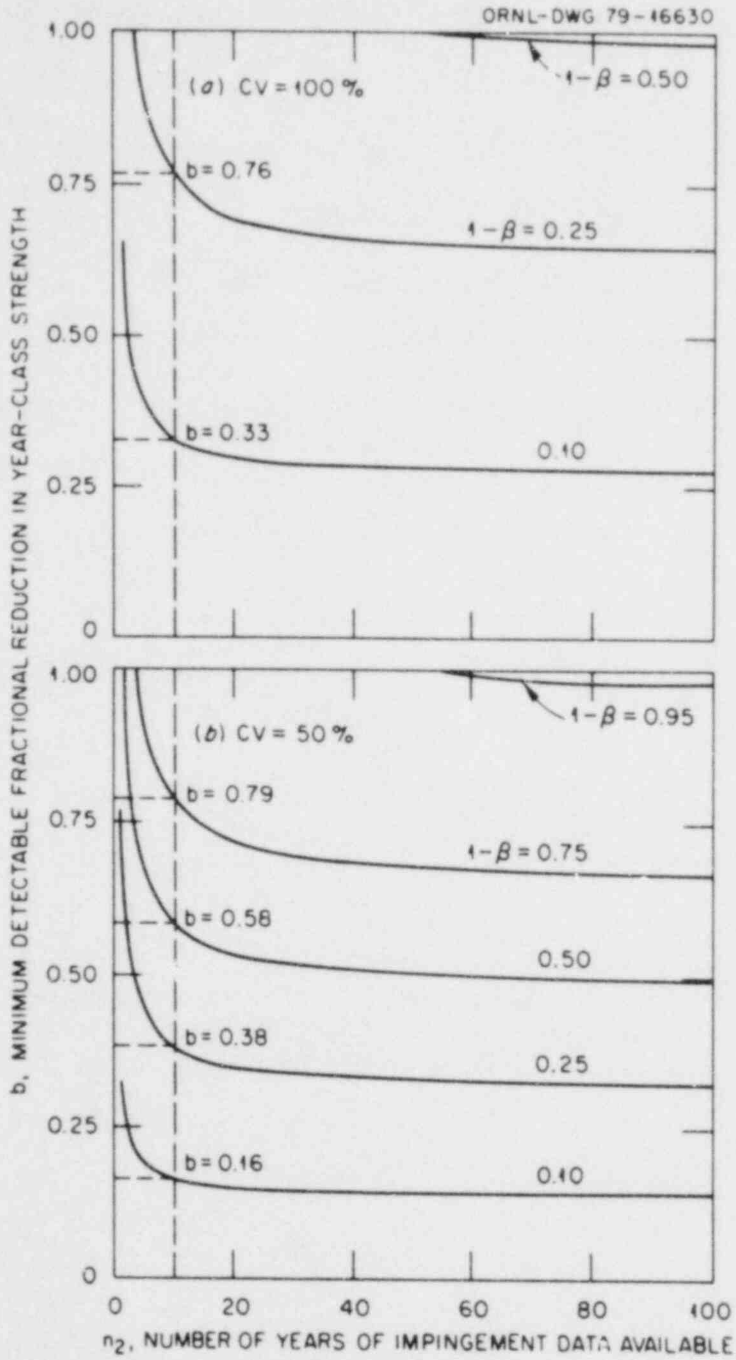

Fig. D-3. Minimum detectable fractional reduction in year-class strength of young-of-the-year white perch in the Hudson River as a function of the number of years for which impingement data are available (starting in 1978). Curves are drawn for $\alpha = 0.05$ over a range of powers $(1 - \beta)$ for $n_1 = 5$ years and for two values of the coefficient of variation (CV): (a) CV = 100% and (b) CV = 50%.

10% chance that a reduction in year-class abundance of 16% would be detected. The smallest fractional reduction that can be detected with a probability of 50% or higher given ten additional years of data is 0.58, and the smallest that can be detected with a probability of 75% or higher is 0.79. For a coefficient of variation of 100%, the situation is far worse (Fig. D-3(a)). In this case there is only a 25% chance that a fractional reduction of 0.76 would be detected from 10 more years of data, and there is essentially no level of impact short of extinction that could be detected with a probability of 50% or higher.

The answer to the second question posed in the introduction is illustrated in Fig. D-4. For example, if the coefficient of variation is 50% and if it is necessary, perhaps as directed by a regulatory agency, to be able to detect a 50% reduction in the mean size of the young-of-the-year white perch population in the Hudson River, 3 years ($1-\beta = 0.25$) or 47 years ($1-\beta = 0.50$) of additional impingement data (starting in 1978) would be required. Again, this result depends on the risk we are willing to take of concluding that there has been no reduction in year-class strength when in fact there has been.

D.4 Discussion

The results presented in this appendix are rather sobering. They indicate that the "natural" variability in the existing baseline time series of impingement rates and beach seine CPUE is so great that: (1) 10 additional years of indices of year-class strength is not likely to provide a very powerful data set for detecting even substantial, actual reductions in year-class strength; (2) an excessive number of

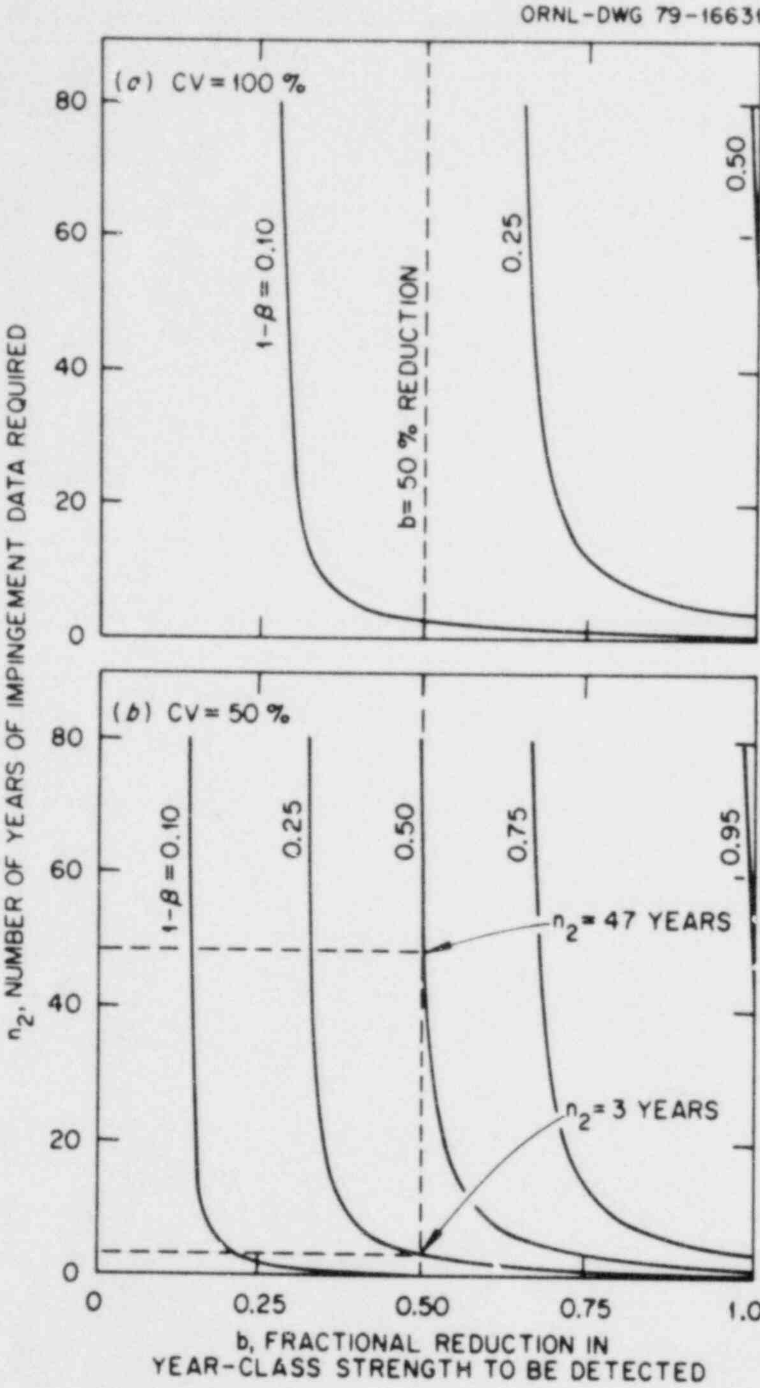

Fig. D-4. Number of years of impingement data (starting in 1978) required to detect a specified fractional reduction in year-class strength of young-of-the-year white perch in the Hudson River. Curves are drawn for $\alpha = 0.05$ over a range of powers $(1 - \beta)$ for $n_1 = 5$ years and for two values of the coefficient of variation (CV): (a) CV = 100% and (b) CV = 50%.

years (greater than the expected lifetime of the power plants involved) of additional data would be required to detect an actual 50% reduction in the mean index of year-class strength, even if we are willing to accept a Type II error of 50%. In reality the situation is even worse, because if there actually were a long-term reduction in the size of the white perch population, it would not occur as a step function but more likely as a gradual decline.

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