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HUDSON RIVER ECOLOGICAL STUDY IN THE AREA OF INDIAN POINT

1979 ANNUAL REPORT

December 1980

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Prepared by  
TEXAS INSTRUMENTS INCORPORATED  
ECOLOGICAL SERVICES  
P.O. Box 225621  
Dallas, Texas 75265

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Front cover: Indian Point Nuclear Generating Station as viewed from  
the west shore of the Hudson River by D.B. Pizzuto



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SECTION I  
SUMMARY

This 1979 Annual Report, written in part to comply with some of the operating requirements for the Indian Point Electric Generating Station, is one of a series of reports prepared by Texas Instruments Incorporated over an eight year period under contract to Consolidated Edison Company of New York, Inc. The report was designed to serve two basic functions: to make available and discuss recent fish abundance, fish impingement, and water quality data associated with the Indian Point region [river mile (RM) 39 through RM 46] of the Hudson River ecosystem and to analyze and interpret these latest study results in conjunction with findings from previous years.

A. IMPINGEMENT COLLECTIONS

The number of fish impinged on intake screens which protect the once-through cooling system is a factor of prime interest in establishing the effect of the Indian Point Generating Station on the ecosystem. Therefore, counts of impinged fish were monitored on a daily basis. However, because some impinged fish have routinely been lost to the river, to scavengers, or decomposed before reaching the collection area, it was necessary to "scale up" actual impingement counts (on the basis of tests designed to estimate collection efficiency) to reflect those numbers presumed to have been impinged.

In past years, a single adjustment factor was utilized to "scale up" impingement counts at each generating unit (3.5 at Unit No. 2, 1.4 at Unit No. 3). Continual refinement of the testing procedures and accumulation of several years' data now permit confirmation of earlier observations that seasonal differences in collection efficiency occur. Thus, in 1979, it was possible to develop two adjustment factors for each unit which were subsequently applied to impingement counts. A "warm period" adjustment factor (3.8 at Unit No. 2 and 1.5 at Unit No. 3) was applied to the count of fish in each impingement collection from



May through October, and a "cold period" adjustment factor (2.1 at Unit No. 2 and 1.2 at Unit No. 3) was applied to each count in the remaining months of 1979.

#### B. IMPINGEMENT PATTERNS

Patterns of impingement during 1979 for 15 important and/or predominant species were similar to those of previous years. Seasonally, impingement counts were highest during late fall and winter with collections at that time dominated mostly by white perch. Cold water months were also the primary period of impingement for striped bass, adult Atlantic tomcod, white catfish, and spottail shiner. A considerably smaller secondary peak impingement period occurred in summer (involving mostly young Atlantic tomcod and bay anchovy) and in fall (when blueback herring, alewife, and American shad, emigrated out of the estuary). Hogchoker and rainbow smelt exhibited a slightly different impingement pattern than in previous years, i.e., a large rise in numbers impinged during the spring or summer and a slight rise in numbers impinged in late summer or early fall. Shortnose sturgeon and Atlantic sturgeon were impinged in such low numbers (4 and 70, respectively) that seasonal patterns were difficult to establish.

Impingement collections of all species were dominated by small (mostly young-of-the-year) fish. For species where specific size or age information was available, at least 90% of fish impinged were less than 12 months old. Qualitative examination of monthly impingement rate plots revealed that in 1979, as previously reported for 1977 and 1978, Unit No. 2 rates frequently and substantially exceeded those of Unit No. 3.

#### C. SPECIES COMPOSITION AND ABUNDANCE

During 1979, 74 species of fish were impinged at the Indian Point Generating Station. Three of these species, American sand lance, striped anchovy, and Atlantic mackerel were not previously collected in



the Indian Point region. In field sampling, 42 species were collected in the Indian Point nearfield; 38 by beach seine, 25 by bottom trawl, and 11 by surface trawl. These values are consistent with previous years. No species new to the estuary were collected by nearfield sampling, and, except for the absence of emerald shiner, all species present every year during 1974 through 1978 were collected in 1979.

The predominant fish species impinged at the Indian Point Generating Station during 1979 were white perch, blueback herring, Atlantic tomcod, and bay anchovy. These species comprised 91.3% of the total unadjusted impingement collection for the year (unadjusted for collection efficiency). White perch was the most abundant species impinged during 1979; the total number impinged was higher than any previous year (1972 through 1978). Blueback herring, on the other hand, declined considerably in total number impinged during 1979 which appeared to be a result of decreased year class abundance.

Nearfield samples were also numerically dominated by individuals of a small number of species. Ten species comprised 85% of beach seine collections, seven species comprised 93% of lined and unlined bottom trawl collections, and only three species comprised 99% of surface trawl collections. These results are similar to previous years, although overall catches were lower in 1979 than in most previous years primarily due to the reduction of blueback herring catches.

#### D. HATCHERY-REARED STRIPED BASS

Beginning in 1973, TI began an investigation to determine the feasibility of mitigating entrainment and impingement losses of striped bass by a program of artificial hatching and stocking. A total of 318,000 marked young-of-the-year striped bass were stocked from 1973 through 1975. As of 30 June 1980, 1925 have been recaptured. Evaluations of distribution, growth, and sexual maturity of these recaptured fish indicate that hatchery fish grow and behave in a manner similar to



wild striped bass, supporting the position that a stocking program for this species may be a viable mitigative procedure.

#### E. IMPINGEMENT VARIATION

Daily impingement counts at Indian Point provided an opportunity to compare less-than-daily impingement sampling designs with the actual values derived during 1976 through 1979 daily sampling. Variation in impingement data was analyzed and used to investigate three sampling designs: simple random (nonstratified), seasonal (stratified by three month seasonal periods), and empirical (stratified on the basis of empirical observation of variation in estimated maximum daily impingement counts). Precision of estimating the true mean daily number of fish impinged increased logarithmically for each of the designs as more days of the year were sampled. Simple random sampling proved to be least precise, stratified random sampling using three month seasonal periods was intermediate in precision, and stratified random sampling using empirically determined periods was the most precise design at both Units No. 2 and No. 3 at all fractions of the year sampled. However, differences in precision among the three designs were small, especially between the seasonal and empirical designs. Computer simulated sampling procedures indicated that sampling impingement during only 20% of the days in an average year at Unit No. 3 and 30% of the days at Unit No. 2 provided an estimate of the true mean daily impingement count which was 93% to 95% accurate. This was true for either three month seasonal or empirical stratified random sampling design. The selection and implementation of a reduced impingement sampling program at Indian Point would require an assessment of the desired level of precision and accuracy needed to meet future goals of the study.

#### F. IMPINGEMENT AS AN INDEX OF ABUNDANCE

Generating stations act as year-round sampling gear as a result of the continuous withdrawal of cooling water from the adjacent water body. Therefore, the possibility of using impingement collection data to monitor fish abundance in the Hudson River estuary was



investigated by comparing annual counts of impinged fish at Indian Point and at Bowline, Lovett, Roseton, Danskammer, and Indian Point generating stations combined (corrected for variation due to plant operations and freshwater flow) to annual changes in riverwide abundance for white perch, striped bass, and Atlantic tomcod. These comparisons indicated that impingement collections at the five stations combined can be used to obtain a general indication of juvenile abundance for white perch. However, juvenile abundance of white perch has not been shown to reflect year class strength; thus, changes in annual impingement may not indicate relative year class strength at older ages. The annual ranking of striped bass abundance (measured by a catch-per-effort index of juvenile abundance in seines) and Atlantic tomcod abundance (measured by absolute estimate of spawning stock size) did not significantly correlate with the annual ranking of either Indian Point impingement alone or impingement at all five generating stations combined.

#### G. EVALUATION OF STANDARD STATION DATA

Fishes in the Indian Point area have been sampled by two distinct programs since 1973: Standard Stations Program and Long River Surveys. The programs originated for different purposes, but both have been capable of gathering the same types of information. Thus, tests were performed to evaluate comparability of inferences which can be drawn from each survey. Gear differences confound comparisons between standard stations and long river bottom trawl data; however, beach seines used in the two surveys are identical and were therefore the basis for this analysis. Past comparisons focused on the degree to which the Indian Point region reflected trends in abundance of individual species and species composition of the estuary in general. The present analyses compared standard stations and long river sampling in the Indian Point region to determine if similar inferences concerning the Indian Point fish community could be drawn from both surveys. Species composition was essentially identical for both surveys, and trends in abundance were usually, but not always, the same. The design



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of the Long River Survey has several advantages over the Standard Stations Program and may give a better representation of the Indian Point fish community.





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## SECTION II INTRODUCTION

### A. THE INDIAN POINT ELECTRIC GENERATING STATION

The Indian Point Electric Generating Station began commercial operation with the completion of Unit No. 1 in 1962. Units No. 2 and No. 3 were completed and began commercial operation in 1973 and 1976, respectively. Each unit of this nuclear plant utilizes a once-through cooling system which results in the entrainment of eggs, larvae, and small fish and impingement of primarily juvenile fish.

The combined pumping capacity of the three units for cooling purposes is  $7790 \text{ m}^3 \cdot \text{min}^{-1}$  ( $2,058,000 \text{ gal} \cdot \text{min}^{-1}$ ). Unit No. 1, which has two [ $530 \text{ m}^3 \cdot \text{min}^{-1}$  ( $140,000 \text{ gal} \cdot \text{min}^{-1}$ )] circulator pumps, was retired from commercial operation in October 1974. The two currently operating units (No. 2 and No. 3) each have six ( $530 \text{ m}^3 \cdot \text{min}^{-1}$ ) circulator pumps. Several service pumps with much lower capacities ( $144 \text{ m}^3 \cdot \text{min}^{-1}$  at Unit No. 1;  $114 \text{ m}^3 \cdot \text{min}^{-1}$  at both Units No. 2 and No. 3) are also associated with each unit. During winter (approximately December to April) of each year when water temperatures fall below about  $4^\circ\text{C}$ , the amount of water drawn through the intake screen associated with each circulator pump is reduced to 60% of the normal pumping capacity to reduce fish impingement. Units No. 1 and No. 2 each have fixed intake screens at the river's edge and traveling screens within each intake forebay. Unit No. 3 has traveling screens at the river's edge but no fixed screens. Details of the plant and associated intake structures have been presented previously (TI 1975b, Con Edison 1977).

### B. REPORT OBJECTIVES AND ORGANIZATION

During 1969, a series of ecological studies were initiated to study the effects of operation of the Indian Point Electric Generating Station on the aquatic biota of the Hudson River estuary. This 1979 Indian Point Annual Report, representing the eighth consecutive year of studies conducted by Texas Instruments Incorporated (TI), serves two



primary functions: to make available and discuss 1979 data, particularly that related to impinged fish and nearfield river fish populations; and to analyze and interpret these latest study results in conjunction with findings from previous years. Compilations of data from 1979 impingement and nearfield fish collections are provided in Section III along with a summary of all hatchery-reared striped bass recaptured through June 1980 from stockings made during 1973 through 1975. Detailed tabulations of impingement, water quality, and field data in addition to sampling methods are provided in the appendices.

Analytical interpretations and discussions focus on three primary topics. First, daily variations in numbers of impinged fish are examined to determine the sampling frequencies necessary to reliably estimate impingement magnitude given a choice of desired precision levels (Section IV). Second, the reliability of annual impingement counts are evaluated for their value as an index to long-term trends in the annual abundance of selected fish species populations (Section V). Third, nearfield community composition and abundance are examined (Section VI) for presence or absence of long-term trends. TI has been collecting coincident fish samples in the vicinity of the Indian Point Generating Station during Long River (riverwide) Surveys and during the Nearfield Standard Station Program since 1973. Thus, a comparison is now possible of the inferences derived from each of the two programs which sample the same geographic area but with differing temporal and spatial sample allocation schemes.



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### SECTION III

#### 1979 IMPINGEMENT AND HUDSON RIVER FISH COLLECTIONS

##### A. INTRODUCTION

The impingement of fish has been monitored at Indian Point since the late 1960's to provide information used to assess the impact of plant operation on the fish populations in the Hudson River estuary. In this section, the total number of fish impinged at each unit throughout 1979 is presented, and seasonal impingement patterns as well as species composition of impingement and nearfield collections are compared with those of previous years. Annual changes in these seasonal patterns are evaluated for selected species to provide an indication of trends in relative abundance near the power plant. Age distribution of impinged fish is provided to evaluate the age structure of the impingeable portion of each species population. This is important because a given level of mortality inflicted on a population prior to establishment of year class strength should have less impact than a comparable level of mortality of older age classes.

Although intake screens at Indian Point are cleaned daily (Appendix C), not all impinged fish are collected. Losses occur due to a variety of causes such as predation, water currents, and disintegration of fish after impingement. Such losses were aggravated at Unit No. 2 by the screen wash procedure itself in which fish were washed from the fixed screens and into the river prior to being reimpinged on and collected from the traveling screens. This section includes an analysis of collection efficiency testing and subsequent development of adjustment factors which correct total counts for fish impinged but not collected. Impingement counts presented here and throughout the report have been adjusted unless otherwise specified.

This section, in its capacity of making available the most recent data on Hudson River fish populations, also includes a cumulative



tabulation of the numbers and biocharacteristics of hatchery-reared striped bass that have been recaptured since TI's initial stocking during the summer of 1973.

## B. COLLECTION EFFICIENCY

Previous studies of collection efficiency indicated that fish were lost from intake screens prior to collection (McFadden et al. 1978, TI 1979b, 1980a). To account for this loss, when estimating numbers of fish impinged, it is necessary to apply adjustment factors (based on tests of collection efficiency) to counts of impinged fish. In previous years (1974 through 1978) a single annual adjustment factor had been derived from these test results. By 1979, however, the combined data base (1974 through 1979) was sufficiently large to permit the development of cool and warm water adjustment factors.

Efficiency tests consisted of marking and releasing test fish at each unit's intakes followed by recovery of marked fish beginning with the first screen wash after each release and continuing during all succeeding screen washes. During 1979, collection efficiency tests were performed using colored tags to mark fish in addition to the dyes used in previous years (TI 1980a). Tagging was implemented on an experimental basis to assess its potential for reducing decomposition (thought to be accelerated by the dyeing process) and to permit identification of each test fish. Thus, efficiency tests could be performed more frequently without intertest mixing of returns which could occur with the limited number of distinguishable dye colors available. Collection efficiency methods are described in Appendix C.

### 1. Derivation of Adjustment Factors

#### a. Unit No. 2

At Unit No. 2 there was no significant difference ( $\alpha = 0.05$ ) in collection efficiency between tagged and dyed fish (Table III-1, Appendix Tables A-17 and A-19). Therefore, adjustment factors were based on efficiency test results using dyed fish to maintain consistency with previous years and because the use of tags was still considered experimental.



Table III-1

Summary of Collection Efficiency Test Results  
at Indian Point Unit No. 2 during 1979

Mark Type	Number Released	Number Recovered	Percent Efficiency*
Dye	4,020	1,666	41.4
Tag	3,300	1,551	47.0

\*Analysis of variance of transformed ( $\arcsin \sqrt{x}$ ) efficiencies indicated no significant ( $\alpha=0.05$ ) difference between tests using dye versus tag marking methods

Previous analyses (1974 through 1978) indicated that efficiency increased significantly at Unit No. 2 as temperature decreased (TI 1980a). The pattern of this relationship during 1974 through 1979 (Figure III-1) indicated that collection efficiency decreased when water temperatures were greater than 15°C. Efficiency tests conducted at temperatures below 15°C yielded significantly greater ( $\alpha = 0.05$ ) recovery of marked fish i.e., greater collection efficiency, than tests conducted at or above 15°C (Table III-2). Of the dyed test fish returned while temperatures were less than 15°C, 37.1% were returned on the first day after their release and 30.1% on the second day. When the water temperature was at or above 15°C, 29.5% of the test fish recovered were returned on the first day and 31.4% on the second day. This is somewhat lower than return rates for the first two days after release reported for 1978 collection efficiency tests (50% and 38%, respectively, with no breakdown by temperature) at Unit No. 2 (TI 1980a). Consequently, the year was partitioned into warm and cool water months. Inspection of the water temperature curve in the Indian Point region (Appendix Figure B-1) indicated that during January through April and November through December, temperatures were generally below 15°C, while during May through October, temperatures were generally above 15°C. Thus, a cool water adjustment factor of 2.1 based on combined releases divided by combined recoveries from tests conducted at less than 15°C (Table III-2) was applied to each impingement count during the

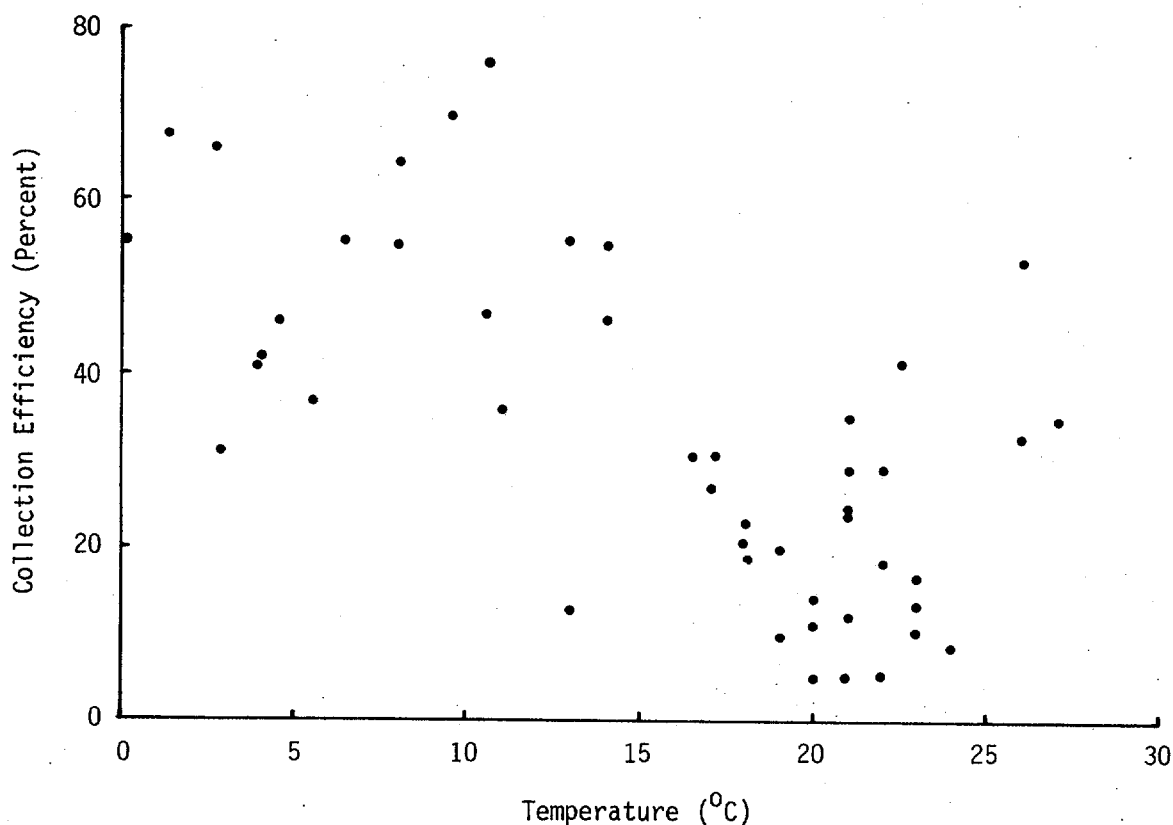


Figure III-1. Variation in Collection Efficiency with Respect to Water Temperature for Dyed Fish at Indian Point Unit No. 2 during 1974 through 1979 (each point represents one test)

Table III-2

Summary of Collection Efficiency Test Results for Dyed Fish at Less Than 15°C and Equal to or Greater Than 15°C at Indian Point Unit No. 2 during 1979

Temperature Range (°C)	Number Released	Number Recovered	Percent Efficiency* (R/Mx100) <sup>†</sup>	Adjustment Factor (M/R)
0 - 14.9	2,700	1,317	48.8	2.1
15 - 30	1,320	349	26.4	3.8

\*Based on a t-test of transformed (arc sin  $\sqrt{x}$ ) efficiencies, tests performed in cold water (0°C - 14.9°C) were significantly higher in efficiency than those in warm water (15°C - 30°C)

<sup>†</sup>R = number recovered  
M = number marked and released



cool water months (January through April, November and December). A warm water adjustment factor of 3.8 was determined in the same manner from efficiency test results at 15°C and greater (Table III-2) and applied to each impingement count during the warm water months (May through October).

b. Unit No. 3

Comparable to Unit No. 2, there was no significant difference ( $\alpha = 0.05$ ) in collection efficiency between tagged and dyed fish at Unit No. 3 (Table III-3, Appendix Tables A-18 and A-20). Also, as at Unit No. 2, efficiency has been shown to increase at Unit No. 3 as temperature decreased (TI 1980a). When 1976 through 1979 efficiencies were plotted, the pattern of this efficiency-temperature relationship was not as distinct as it was at Unit No. 2 (Figure III-2). A higher proportion of recovered fish were recovered the first day after test releases at Unit No. 3 (80.3% at less than 15°C and 79.2% at 15°C or higher) compared to Unit No. 2 (37.1% and 29.5%, respectively). In warm water, impinged fish can be expected to decompose more quickly than in cool water; thus, the extra day required for recovery of impinged fish at Unit No. 2 may explain the greater efficiency differential between warm

Table III-3  
Summary of Collection Efficiency Test Results  
at Indian Point Unit No. 3 during 1979

Mark Type	Number Released	Number Recovered	Percent Efficiency*
Dye	3,660	2,693	73.6
Tag	2,940	1,945	66.2

\*Analysis of variance of transformed ( $\arcsin \sqrt{x}$ ) efficiencies indicated no significant ( $\alpha=0.05$ ) difference between tests using dye versus tag marking methods



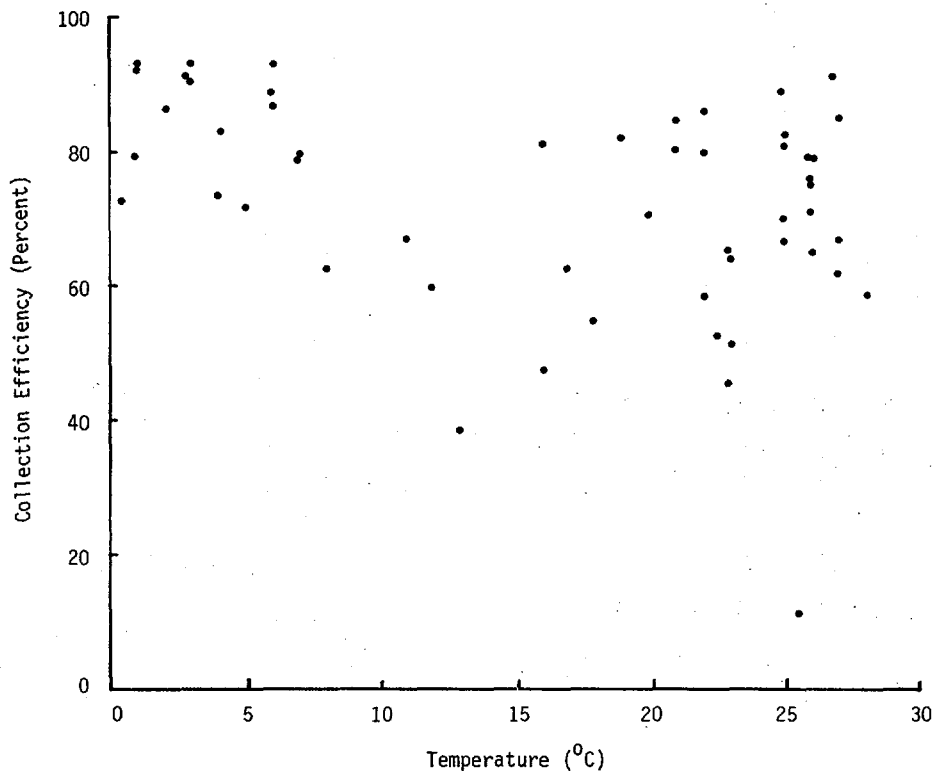


Figure III-2. Variation in Collection Efficiency with Respect to Water Temperature for Dyed Fish at Indian Point Unit No. 3 during 1976 through 1979 (each point represents one test)

and cold water at Unit No. 2 than was seen at Unit No. 3. Thus, due to the low number of tests conducted between 10°C through 20°C and the variable nature of the results, the cutoff temperature between warm and cool water could not be determined. Therefore, for consistency, the same cutoff temperature used for Unit No. 2 (15°C) was used at Unit No. 3. Collection efficiency tests at Unit No. 3 when temperatures were less than 15°C were significantly ( $\alpha = 0.05$ ) greater than those at or above 15°C (Table III-4). The year was thus partitioned into warm and cool water months for Unit No. 3 in the same manner as it was for Unit No. 2. Adjustment factors of 1.2 for the cool water months (January through April, November and December) and 1.5 for the warm water months (May through October) were applied to each impingement count during 1979.



Table III-4

Summary of Collection Efficiency Test Results for Dyed Fish at  
Less Than 15°C and Equal to and Greater Than 15°C Water  
Temperature at Indian Point Unit No. 3 during 1979

Temperature Range (°C)	Number Released	Number Recovered	Percent Efficiency* (R/Mx100) <sup>†</sup>	Adjustment Factor (M/R)
0 - 14.9	1,440	1,206	83.8	1.2
15 - 30	2,220	1,487	67.0	1.5

\*Based on a t-test of transformed (arc sin  $\sqrt{x}$ ) efficiencies, tests performed in cold water (0°C - 14.9°C) were significantly higher in efficiency than those in warm water (15°C - 30°C)

<sup>†</sup>R = number recaptured  
M = number marked and recovered

## 2. Collection Efficiency of Fish Released at Individual Screens

Marking fish with tags allowed sufficient discrimination among marked fish to test for differences in collection efficiency between release points in front of Units No. 2 and No. 3. As dictated by standard procedure, efficiency tests were routinely performed utilizing screen nos. 2 and 6 at each unit. At Unit No. 2, collection efficiency was significantly greater ( $\alpha = 0.05$ ) for fish released in front of screen no. 2 than screen no. 6 throughout the year (Table III-5). At Unit No. 3, however, significantly greater efficiency was noted for fish released in front of screen no. 6 than screen no. 2. The difference at Unit No. 3 appears to have been attributable to collection efficiencies on 3 May, 28 June, and 4 July (Table III-6); however, only the 3 May and 28 June tests differed significantly between screens in a-posteriori comparisons.

Differences in collection efficiency between fish released at different points in front of the units can be influenced by differences in screen operation, such as differing water pressures during washes. However, numerous other factors such as differential trash loading among screens, order of screen washing, or movement of fish from one screen to another (especially important at Unit No. 2 because of fixed screen



Table III-5

Collection Efficiency Test Results for Tagged Fish Released  
at Screens no. 2 and no. 6 at Indian Point Unit No. 2 during 1979

Test Date	Percent Efficiency	
	Screen no. 2*	Screen no. 6
15 Jan	63.3	33.3
19 Apr	73.3	60.0
26 Apr	75.6	75.6
05 May	15.6	18.9
10 May	22.2	26.7
24 May	15.6	14.4
20 Sep	70.0	58.9
20 Dec	58.9	31.1
Pooled <sup>†</sup>	49.3	39.9

\*Indicates significantly greater efficiency  
( $\alpha = 0.05$ ) based on replicated goodness of  
fit tests (Sokal and Rohlf 1969)

<sup>†</sup>Derived by dividing total number recovered  
by total number released for all tests  
combined

washing) may confound any attempt to assign specific efficiencies to the various screens.

### 3. Summary

In summary, collection efficiency was found to be significantly greater in cool water (less than 15°C) than warm water (15°C and greater) at both Unit No. 2 and Unit No. 3. The cool water adjustment factors were 2.1 at Unit No. 2 and 1.2 at Unit No. 3. The warm water adjustment factors were 3.8 at Unit No. 2 and 1.5 at Unit No. 3. Statistically significant differences in efficiency were observed between the two screens routinely tested at each unit. These



Table III-6  
Collection Efficiency Test Results for Tagged Fish Released  
at Screens no. 2 and no. 6 at Indian Point Unit No. 3 during 1979

Test Date	Percent Efficiency	
	Screen no. 2	Screen no. 6*
05 Apr	94.4	93.3
11 Apr	92.2	80.0
03 May <sup>†</sup>	36.7	83.3
17 May	58.9	74.4
31 May	70.0	82.2
14 Jun	71.1	88.9
21 Jun	52.2	82.2
28 Jun <sup>†</sup>	38.9	83.3
04 Jul	33.3	74.4
19 Jul	73.3	77.8
27 Jul	43.3	48.9
02 Aug	54.4	67.8
09 Aug	82.2	78.9
16 Aug	81.1	82.2
Pooled**	63.0	78.4

\*Indicates significantly greater efficiency ( $\alpha=0.05$ ) based on replicated goodness of fit tests (Sokal and Rohlf 1969)

<sup>†</sup>Indicates significantly greater differences based on a-posteriori comparisons

\*\*Derived by dividing total number recovered by total number released for all tests combined



differences support the procedural change made for the sampling year in progress (1980) where test releases are made at each operating screen to further improve development of a representative estimate of collection efficiency.

### C. SEASONAL AND YEARLY IMPINGEMENT PATTERNS

As in previous Indian Point annual reports (TI 1979b, 1980a), this section provides information on seasonal patterns of impingement for the dominant species. Where available, total monthly impingement rates (adjusted unselected monthly counts  $\div$  total monthly unit discharge) were separated into young-of-the-year (YOY) and yearling and older groupings to evaluate size selectivity in impingement collections. In previous years, selected impingement rates were used for the analysis of impingement patterns (TI 1979b, 1980a) because they provided the most accurate and reliable data available. (Selected rates were developed to precisely match, on a daily basis, fish counts to volumes pumped for examination of daily impingement variation as in Section IV of this report, TI 1979b and 1980a). A new data filing system has improved access to both selected and unselected rate information. Thus, unselected rates have now become the preferred choice for examination of impingement patterns because the objective of seasonal pattern definition is better met by the most complete set of data than by the precision afforded by selected daily rates.

Overall, unselected impingement rates (all species combined) at the Indian Point Generating Station in 1979 were higher during the fall and winter (October through March) than during the spring and summer. Similar seasonal patterns have been seen each year since 1972 (TI 1974b, 1975c, 1979b, 1980a). A rigorous comparison of the seasonal patterns of 1979 impingement to those of previous years could not be readily made since refinements in estimates of collection efficiency resulted in adjustment of 1979 impingement counts in a manner different than was used for the years 1972 through 1978. Impingement collections during previous years were adjusted for collection efficiency with a single, annual adjustment factor at each unit. During 1979, however,



two adjustment factors were applied: a warm water (May through October) adjustment which was slightly higher than that in previous years, and a cool water (January through April and November through December) adjustment which was slightly lower (Subsection III.B.1). The net effect of the change on seasonal patterns of overall impingement rates, if the 1979 patterns are compared to earlier years, is to decrease the normally high winter rates and slightly increase the normally lower summer rates. Seasonal patterns are relatively unchanged from previous years despite this "leveling" effect. Impingement rates adjusted by seasonal adjustments are contrasted with rates adjusted by an annual adjustment factor in Appendix Figures A-1 through A-4.

A graphical comparison of impingement rates for Units No. 2 and No. 3 (Figure III-3) indicates that impingement rates were higher at Unit No. 2. A portion of this apparent difference was actually due to an outage during 19 September through 31 December at Unit No. 3. However, during periods when both units operated (January through June),

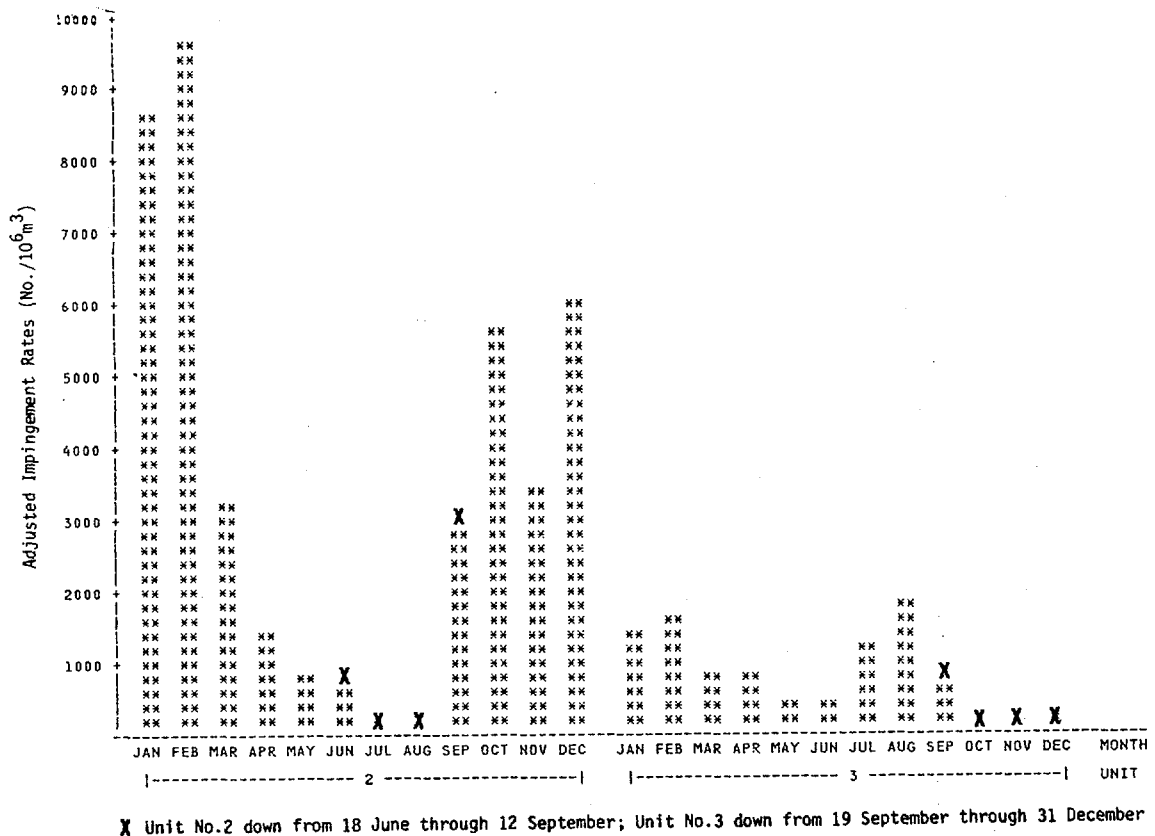


Figure III-3. Monthly Adjusted Impingement Rates for Species Combined at Indian Point Units No. 2 and No. 3 during 1979



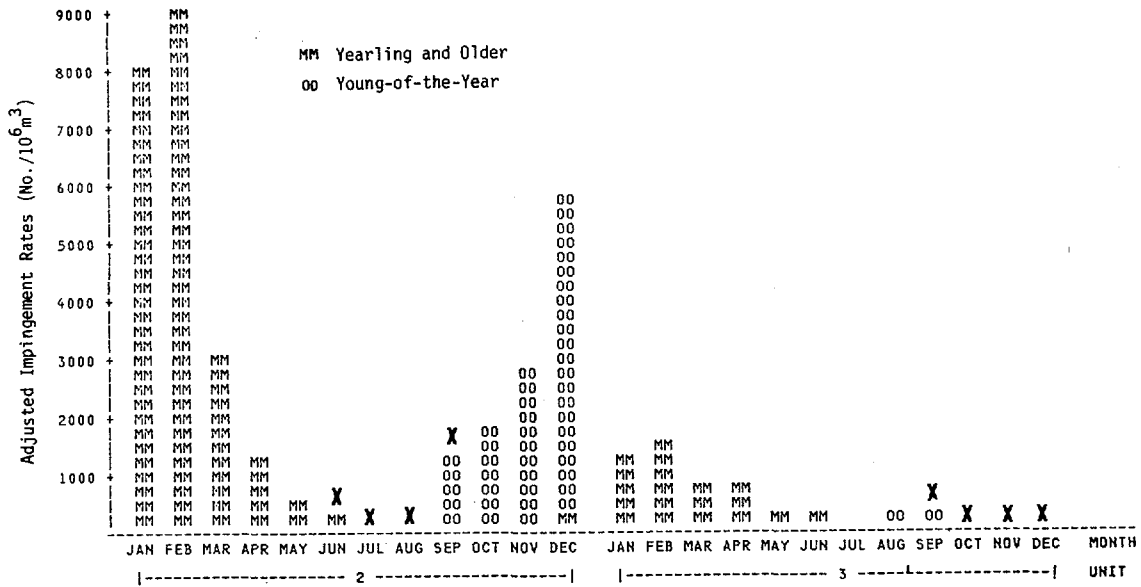
impingement rates were still higher at Unit No. 2. This is consistent with results of previous statistical comparisons of impingement rates at the two units during 1977 and 1978 (TI 1979b, 1980a).

Impingement rates for individual species were examined to provide further insight into the overall pattern of impingement observed at the Indian Point Generating Station. The following species were selected due to their designation by the United States Environmental Protection Agency (EPA) as representative important species, due to relative abundance in impingement collections, classification as an endangered species, and/or importance as sport or commercial fish:

Striped bass	Spottail shiner	Blueback herring
White perch	White catfish	American shad
Atlantic tomcod	Bay anchovy	Hogchocker
Shortnose sturgeon	Weakfish	Bluefish
Atlantic sturgeon	Alewife	Rainbow smelt

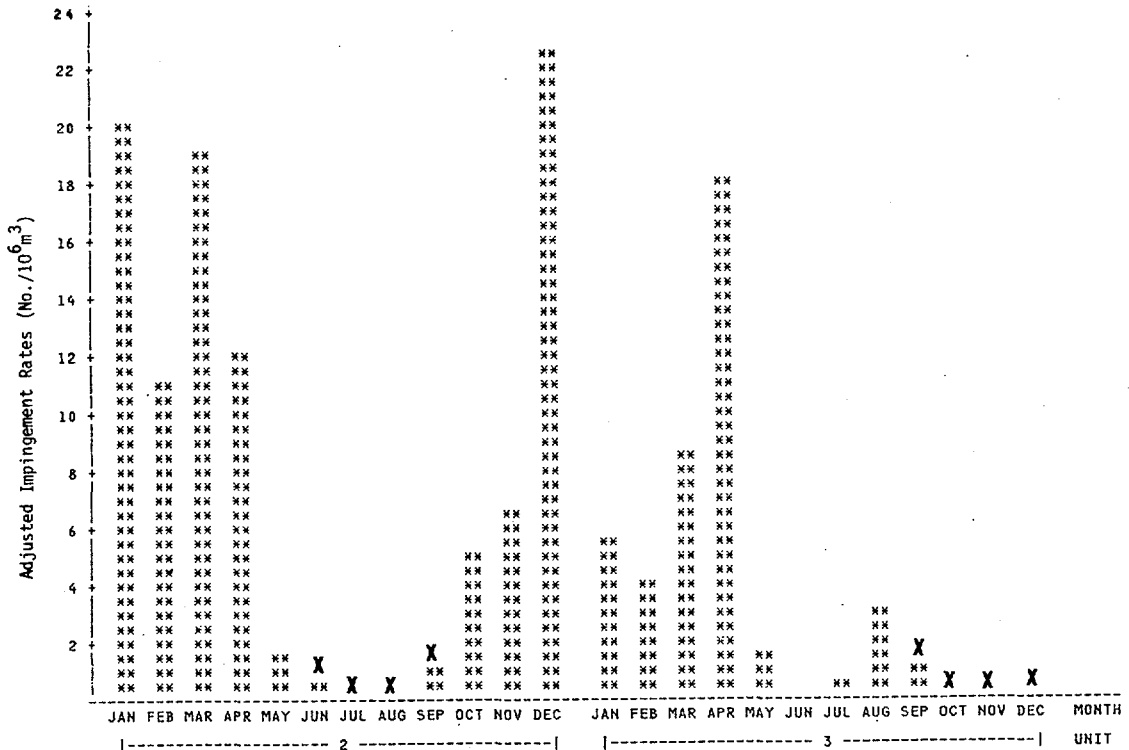
White perch, spottail shiner, striped bass, and white catfish were impinged mainly during late fall, winter, or early spring (Figures III-4 through III-7). These species inhabit the deeper channel portion of the river during the fall and winter then move into the shoreline regions in the spring as water temperatures increase (TI 1978). Thus, they are impinged mainly while in or moving to and from the channel. Impingement rates for white perch, the most abundant species in the 1979 impingement collections, were partitioned into YOY (i.e., age from time of spawning through 31 December) and yearling and older life stages (Figure III-4). Of the total 1979 white perch impingement, 7.9% (124,757 fish) were older than 12 months. To place this number in perspective, the white perch population estimate of yearling and older white perch in September 1978 was 12.1 million (TI 1980b). Only 10% of the striped bass impinged were YOY; however, 96.2% were less than 12 months old since impingement was heaviest during January through March when they were 9 or 10 months old.

Those species mainly impinged during the summer of 1979 were primarily bay anchovy, bluefish, and weakfish (Figures III-8 through



X Unit No.2 down from 18 June through 12 September; Unit No.3 down from 19 September through 31 December

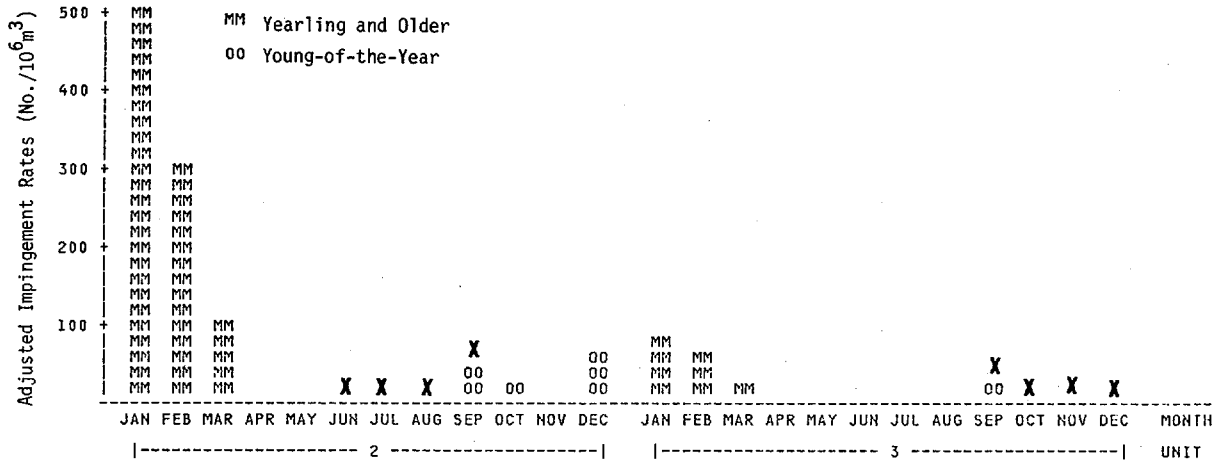
Figure III-4. Monthly Adjusted Impingement Rates for White Perch (yearling and older, and young-of-the-year) at Indian Point Units No. 2 and No. 3 during 1979



X Unit No.2 down from 18 June through 12 September; Unit No.3 down from 19 September through 31 December

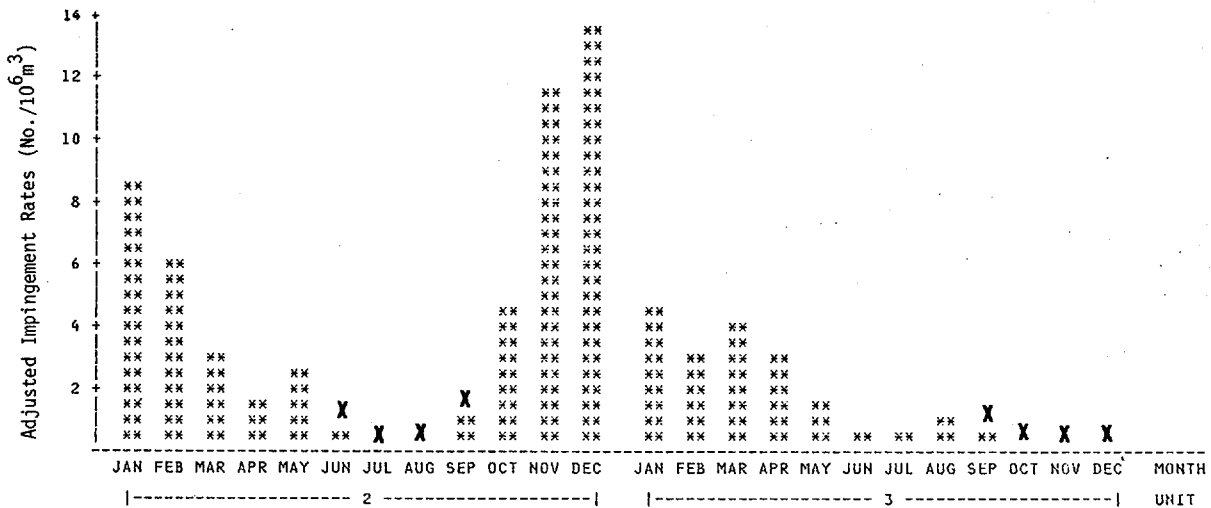
Figure III-5. Monthly Adjusted Impingement Rates for Spottail Shiner (all ages) at Indian Point Units No. 2 and No. 3 during 1979





X Unit No.2 down from 18 June through 12 September; Unit No.3 down from 19 September through 31 December

Figure III-6. Monthly Adjusted Impingement Rates for Striped Bass (yearling and older, and young-of-the-year) at Indian Point Units No. 2 and No. 3 during 1979



X Unit No.2 down from 18 June through 12 September; Unit No.3 down from 19 September through 31 December

Figure III-7. Monthly Adjusted Impingement Rates for White Catfish (all ages) at Indian Point Units No. 2 and No. 3 during 1979



III-10). The young of these species use the estuary as a nursery area during the summer and are impinged as they move into the Indian Point region. When temperatures begin falling and the salt front moves down river in the late summer and early fall, these YOY migrate to a lower portion of the estuary or emigrate to the ocean (Bigelow and Schroeder 1953, U.S. Atomic Energy Commission 1972, TI 1976, Con Edison 1977).

In previous years, alewife, American shad, rainbow smelt, Atlantic tomcod, and hogchoker have exhibited bimodal patterns of impingement (TI 1980a). During 1979, these bimodal patterns were repeated for Atlantic tomcod and hogchoker but were not as evident for alewife, American shad, and rainbow smelt (Figures III-11 through III-15) due to unit outages during periods of high abundance. Alewife

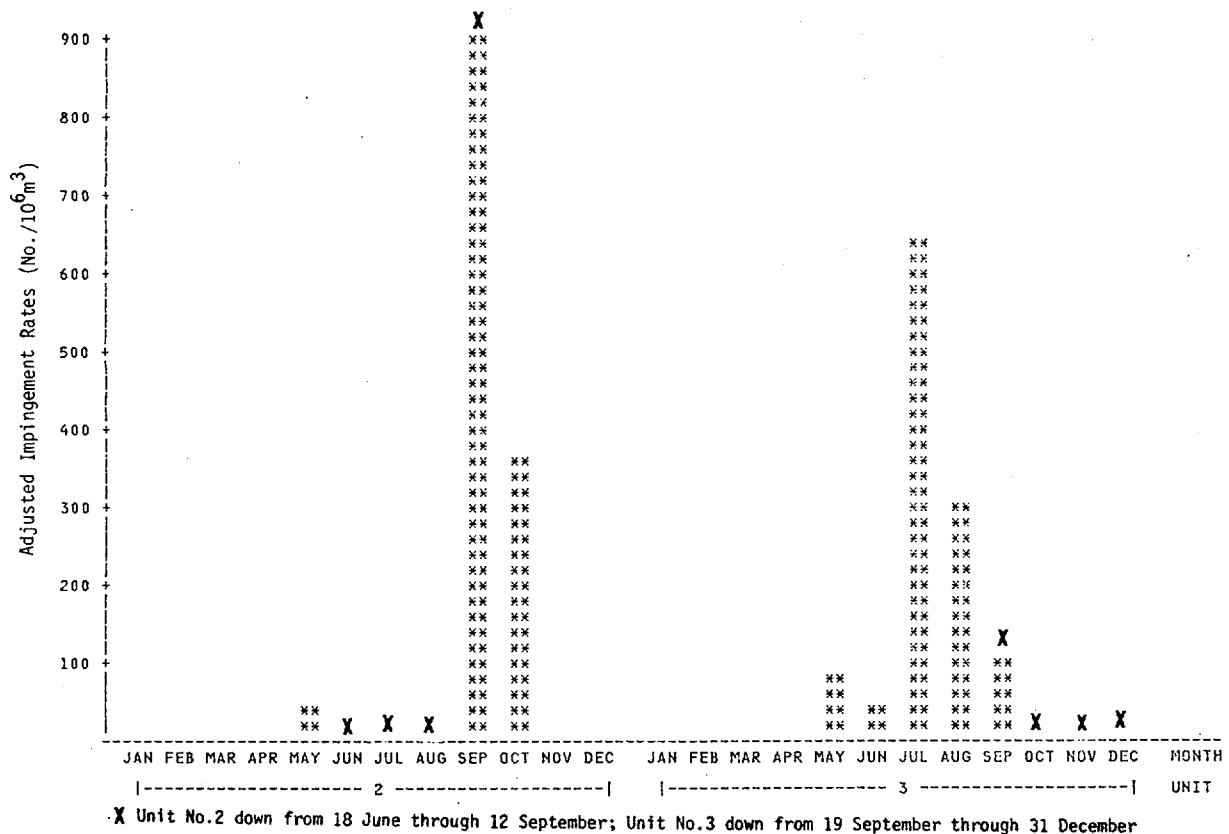


Figure III-8. Monthly Adjusted Impingement Rates for Bay Anchovy (all ages) at Indian Point Units No. 2 and No. 3 during 1979

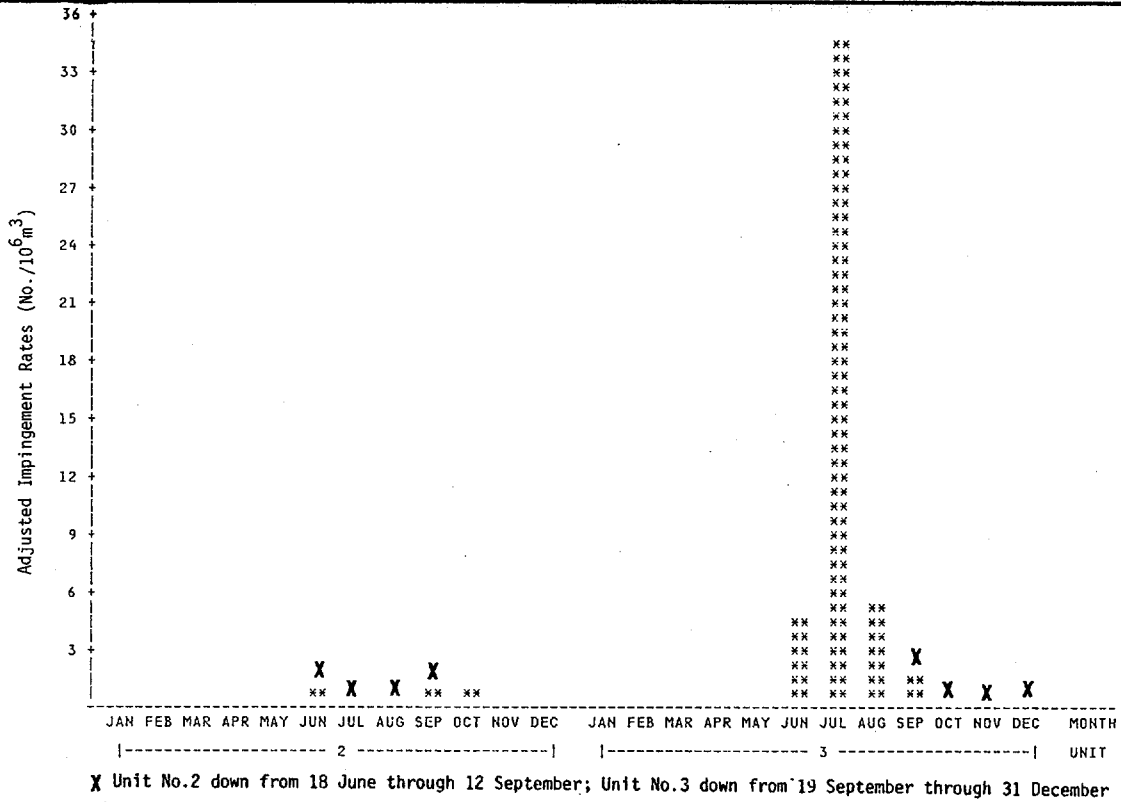


Figure III-9. Monthly Adjusted Impingement Rates for Bluefish (all ages) at Indian Point Units No. 2 and No. 3 during 1979

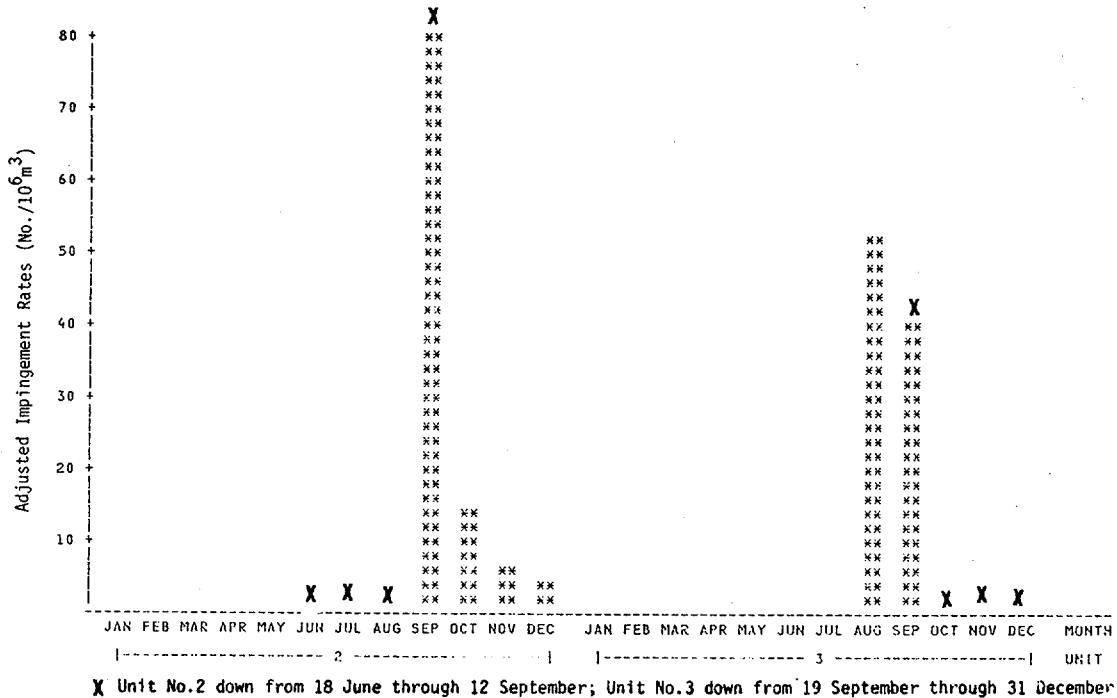


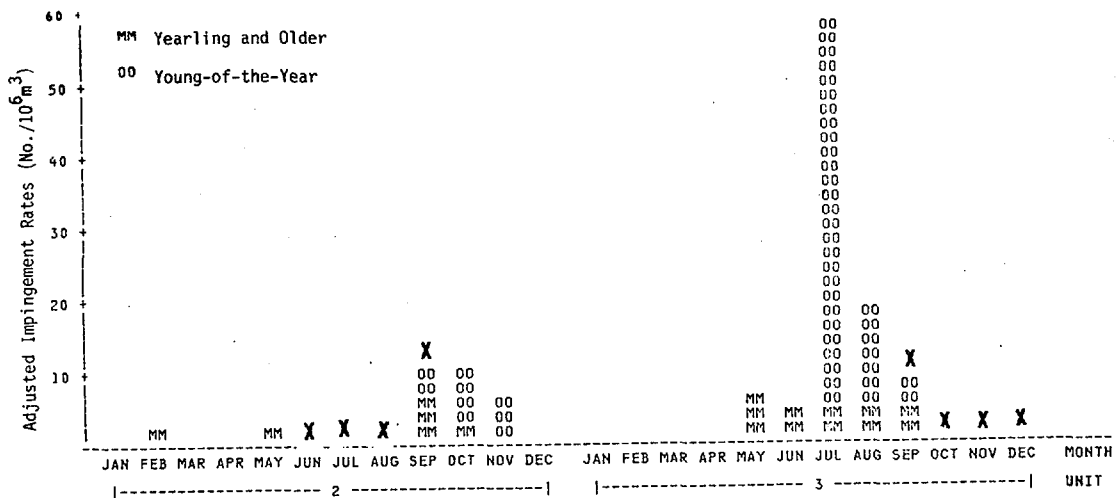
Figure III-10. Monthly Adjusted Impingement Rates for Weakfish (all ages) at Indian Point Units No. 2 and No. 3 during 1979



and American shad, which move about the middle estuary during the summer, were impinged mostly during July and August at Unit No. 3 while Unit No. 2 was not operational. The fall emigration of YOY alewife and American shad was apparent only at Unit No. 2 because Unit No. 3 was not operational at that time.

The early spring peak of rainbow smelt impingement (Figure III-13), reflecting their spawning run, was seen at both units while impingement during the fall emigration of YOY rainbow smelt occurred only at Unit No. 2 since Unit No. 3 was not operational. The outage at Unit No. 3 also obscured the typical fall peak impingement of emigrating YOY blueback herring which was seen only at Unit No. 2 (Figure III-16). The number of Atlantic and shortnose sturgeon (70 and 4, respectively) impinged during 1979 were not sufficient to identify a seasonal pattern; however, their monthly impingement rates are presented in Figures III-17 and III-18.

The clupeids (alewife, American shad, and blueback herring), and Atlantic tomcod impingement rates were partitioned into YOY and yearling and older categories to provide further examples of the age composition of impingement collections. Young-of-the-year comprised 96.6% of all the clupeids impinged and 96.0% of Atlantic tomcod impinged.



X Unit No.2 down from 18 June through 12 September; Unit No.3 down from 19 September through 31 December

Figure III-11. Monthly Adjusted Impingement Rates for Alewife (yearling and older, and young-of-the-year) at Indian Point Units No. 2 and No. 3 during 1979

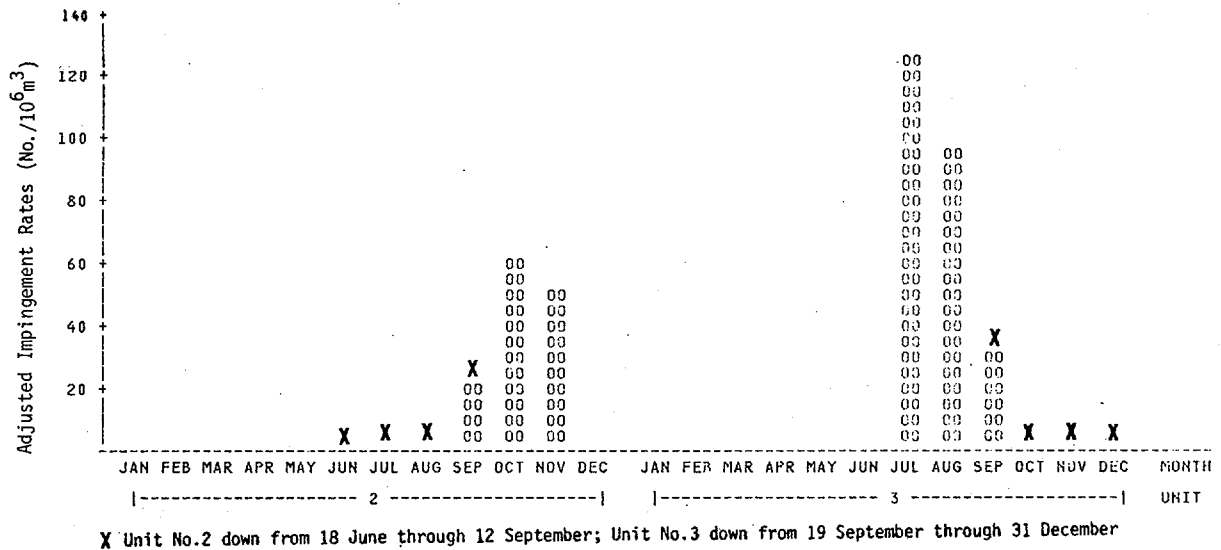


Figure III-12. Monthly Adjusted Impingement Rates for American Shad (young-of-the-year) at Indian Point Units No. 2 and No. 3 during 1979

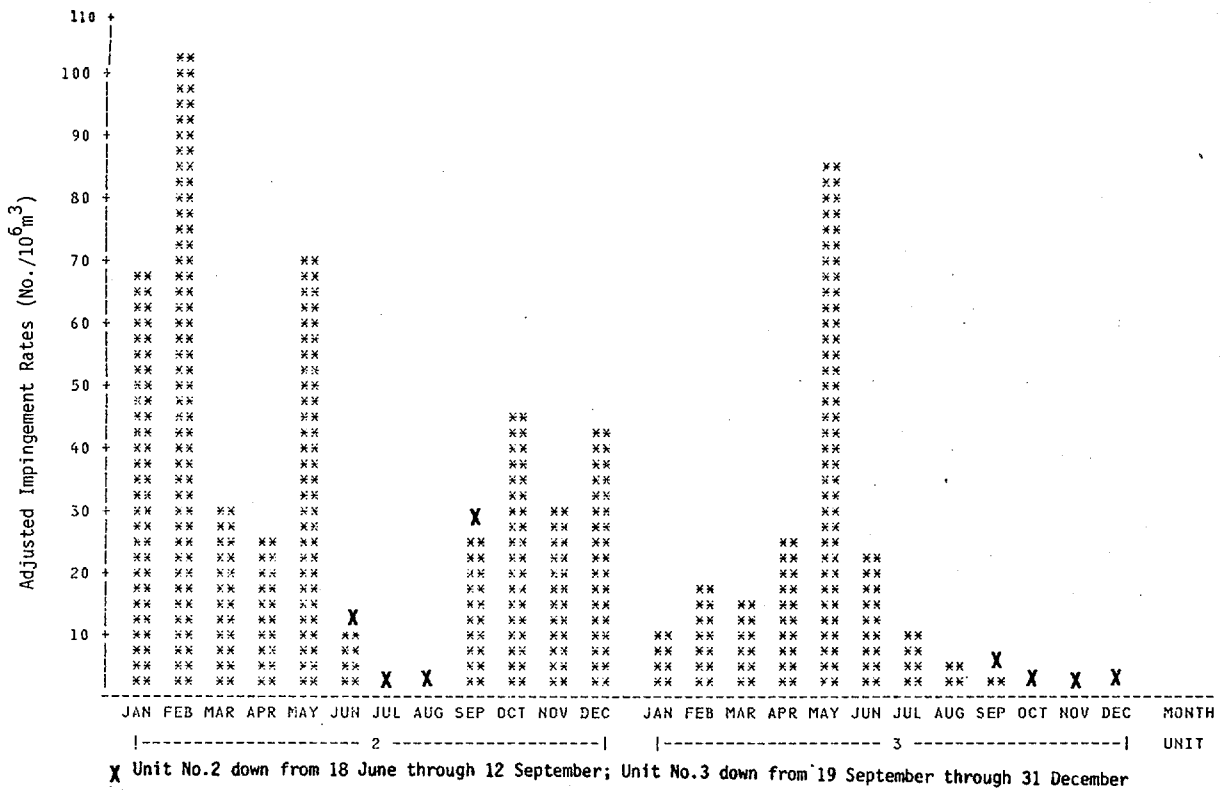
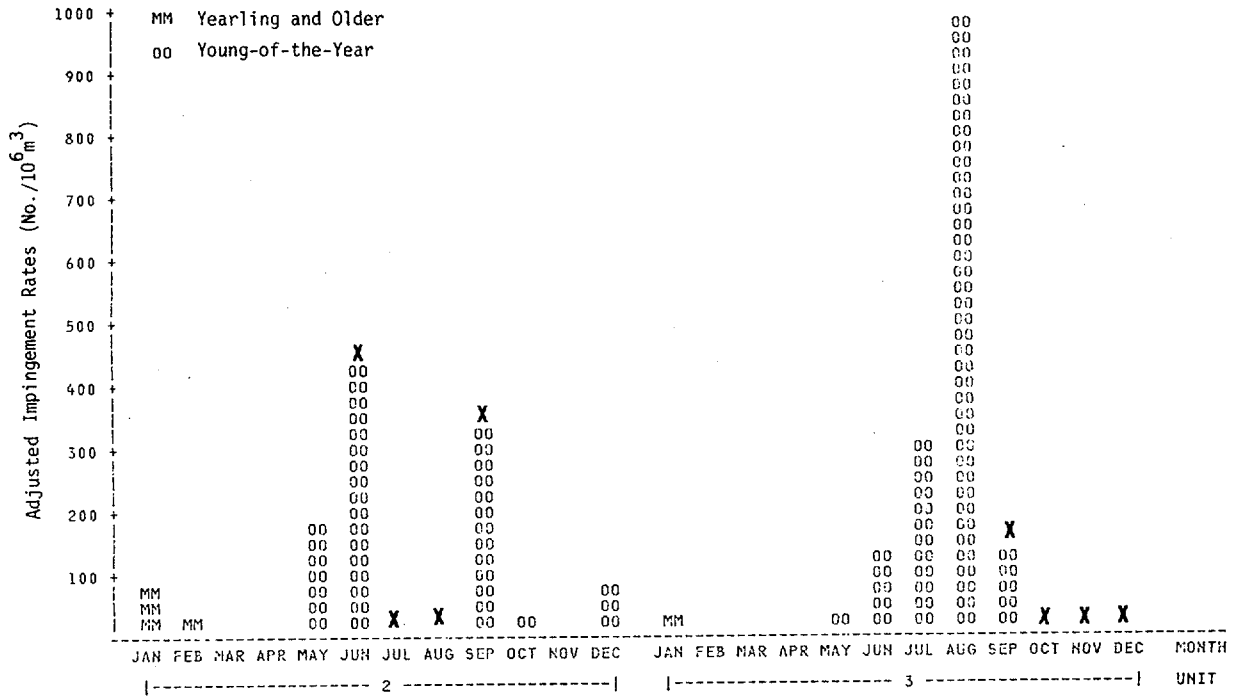
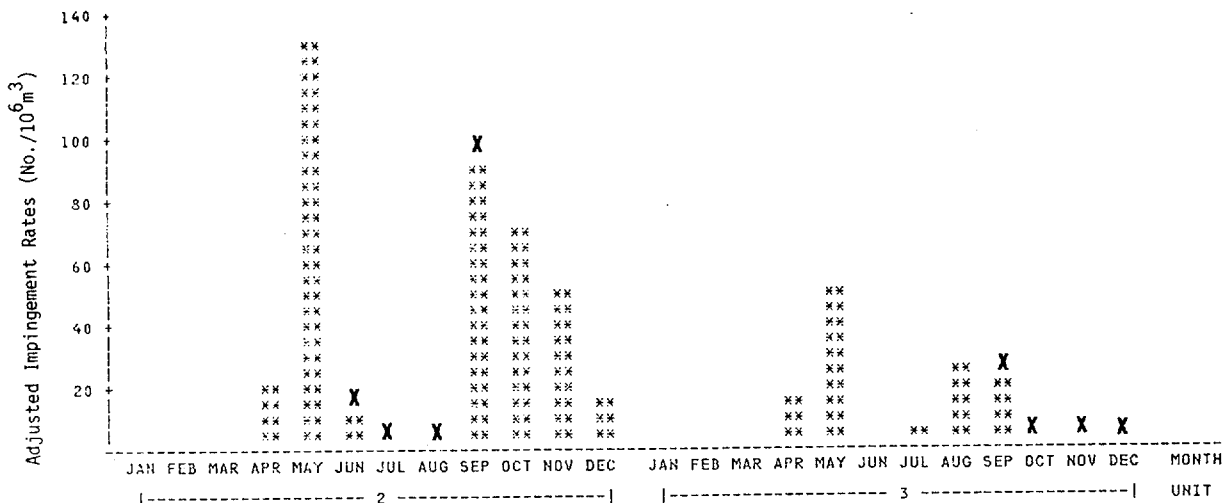


Figure III-13. Monthly Adjusted Impingement Rates for Rainbow Smelt (all ages) at Indian Point Units No. 2 and No. 3 during 1979



X Unit No.2 down from 18 June through 12 September; Unit No.3 down from 19 September through 31 December

Figure III-14. Monthly Adjusted Impingement Rates for Atlantic Tomcod (yearling and older, and young-of-the-year) at Indian Point Units No. 2 and No. 3 during 1979



X Unit No.2 down from 18 June through 12 September; Unit No.3 down from 19 September through 31 December

Figure III-15. Monthly Adjusted Impingement Rates for Hogchoker (all ages) at Indian Point Units No. 2 and No. 3 during 1979

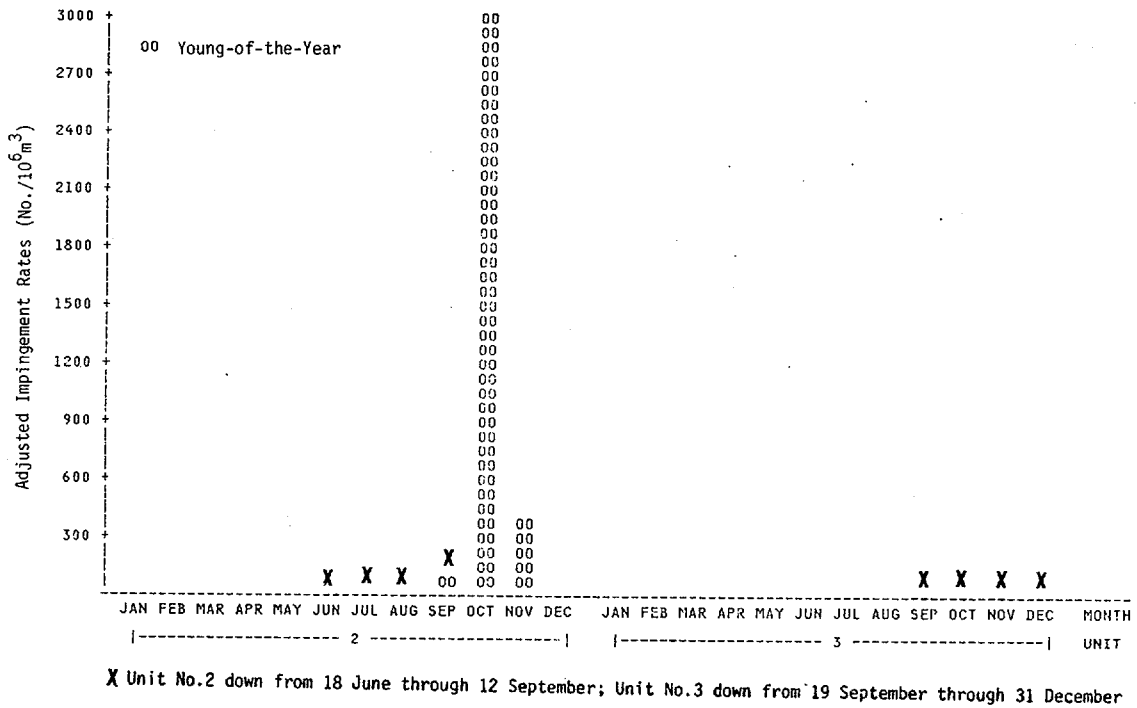


Figure III-16. Monthly Adjusted Impingement Rates for Blueback Herring (young-of-the-year) at Indian Point Units No. 2 and No. 3 during 1979

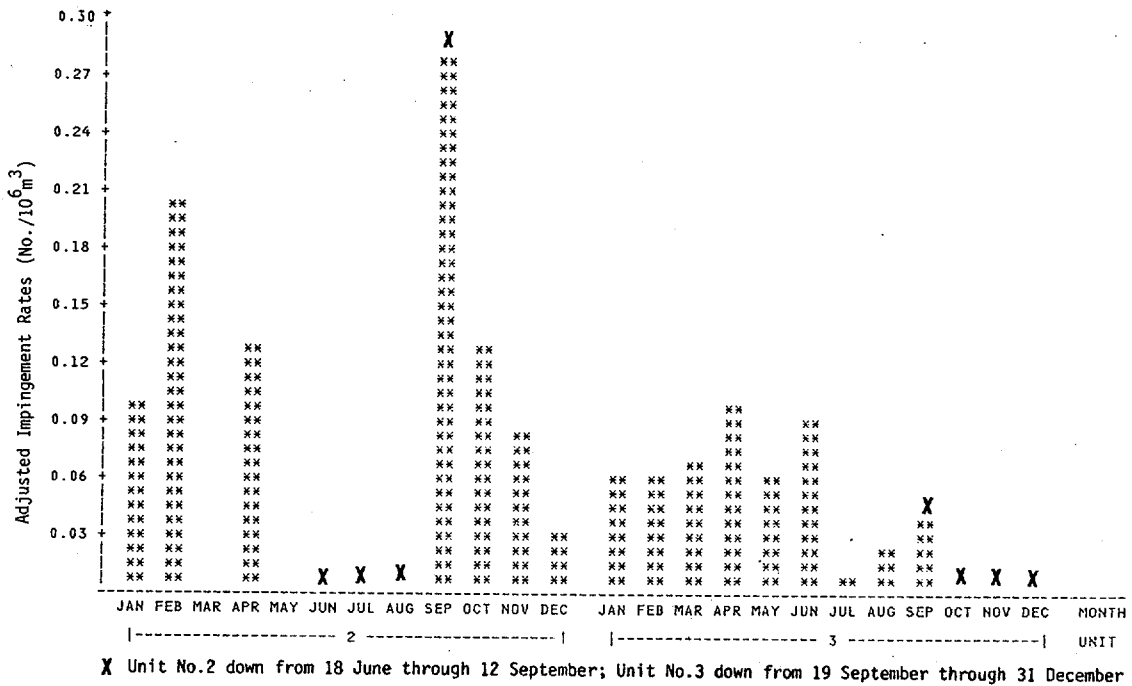


Figure III-17. Monthly Adjusted Impingement Rates for Atlantic Sturgeon (all ages) at Indian Point Units No. 2 and No. 3 during 1979

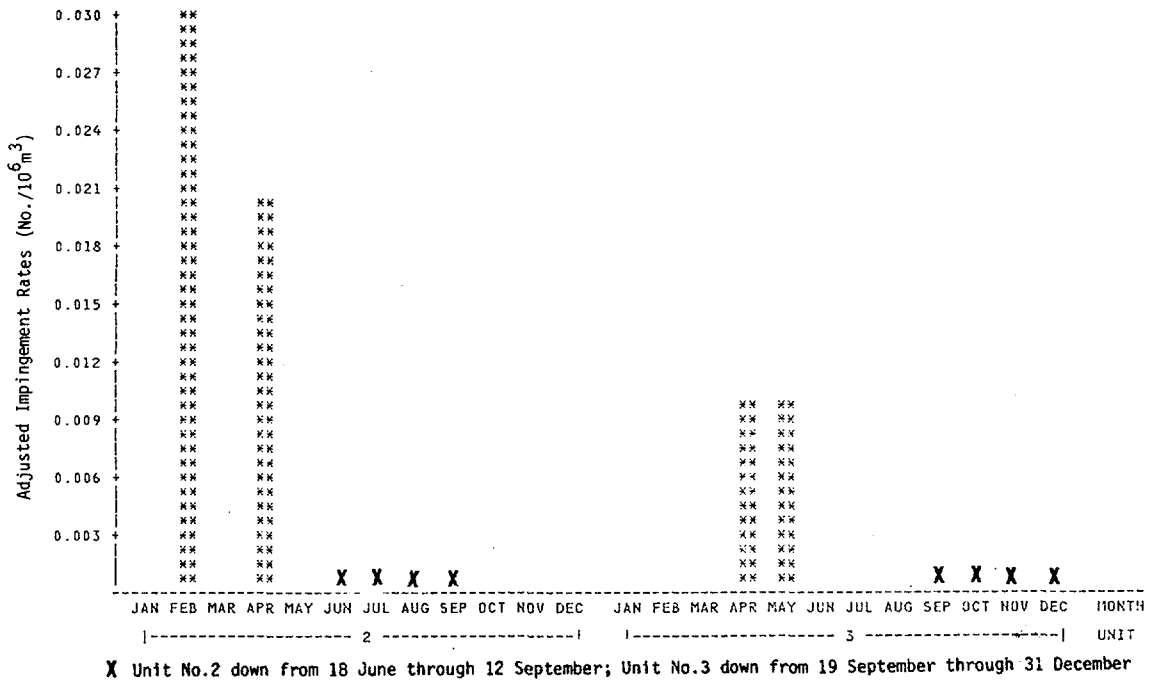


Figure III-18. Monthly Adjusted Impingement Rates for Shortnose Sturgeon (all ages) at Indian Point Units No. 2 and No. 3 during 1979

In summary, overall impingement rates (all species combined) at the Indian Point Generating Station in 1979 were highest during the fall and winter. White perch, striped bass, spottail shiner, and white catfish exhibited a unimodal impingement pattern with a peak in late fall, winter, or early spring. A unimodal pattern with peak impingement occurring during the summer was noted for bay anchovy, bluefish, and weakfish, while the clupeids, rainbow smelt, Atlantic tomcod, and hogchoker had bimodal patterns which were somewhat obscured by unit outages. Of the major species impinged, the majority of the impinged individuals were less than 12 months old.

#### D. SPECIES COMPOSITION OF IMPINGEMENT AND NEARFIELD COLLECTIONS

##### 1. Number of Species

##### a. Impingement

Seventy-four species of fish were impinged at the Indian Point





Generating Station during 1979 (Appendix Table B-1), only two more than impinged during 1977 and 1978 (TI 1980a). Three of these species [American sand lance (Ammodytes americanus), striped anchovy (Anchoa hepsetus), and Atlantic mackerel (Scomber scombrus)] were not previously collected in the Indian Point region (Appendix Table B-1).

b. Nearfield

Forty-two species were collected in the Indian Point nearfield region during 1979 (Appendix Table B-1). Thirty-eight species were collected by beach seine, 25 by bottom trawl, and 11 by surface trawl. These values are consistent with previous years (1972 through 1978) (TI 1980a) when the number of species collected in the nearfield has ranged from 38 to 50. No species new to the estuary were collected by nearfield sampling during 1979. Except for the absence of emerald shiner, all species present every year during 1974 through 1978 were collected in 1979.

2. Species Composition

a. Impingement

White perch, blueback herring, Atlantic tomcod, and bay anchovy were the predominant fish species impinged at the Indian Point Generating Station during 1979. These species comprised 91.3% of the total unadjusted impingement collection for 1979 and have comprised over 85% of impingement since 1975 (Appendix Table A-21).

b. Nearfield

As in impingement collections, nearfield catches were numerically dominated by a small number of species. During 1979, 10 species comprised 86% of beach seine collections, 7 species comprised 93% of lined and unlined bottom trawl collections, and only 3 species comprised 99% of surface trawl collections. These results are similar to previous years (Appendix Tables B-2 through B-5).

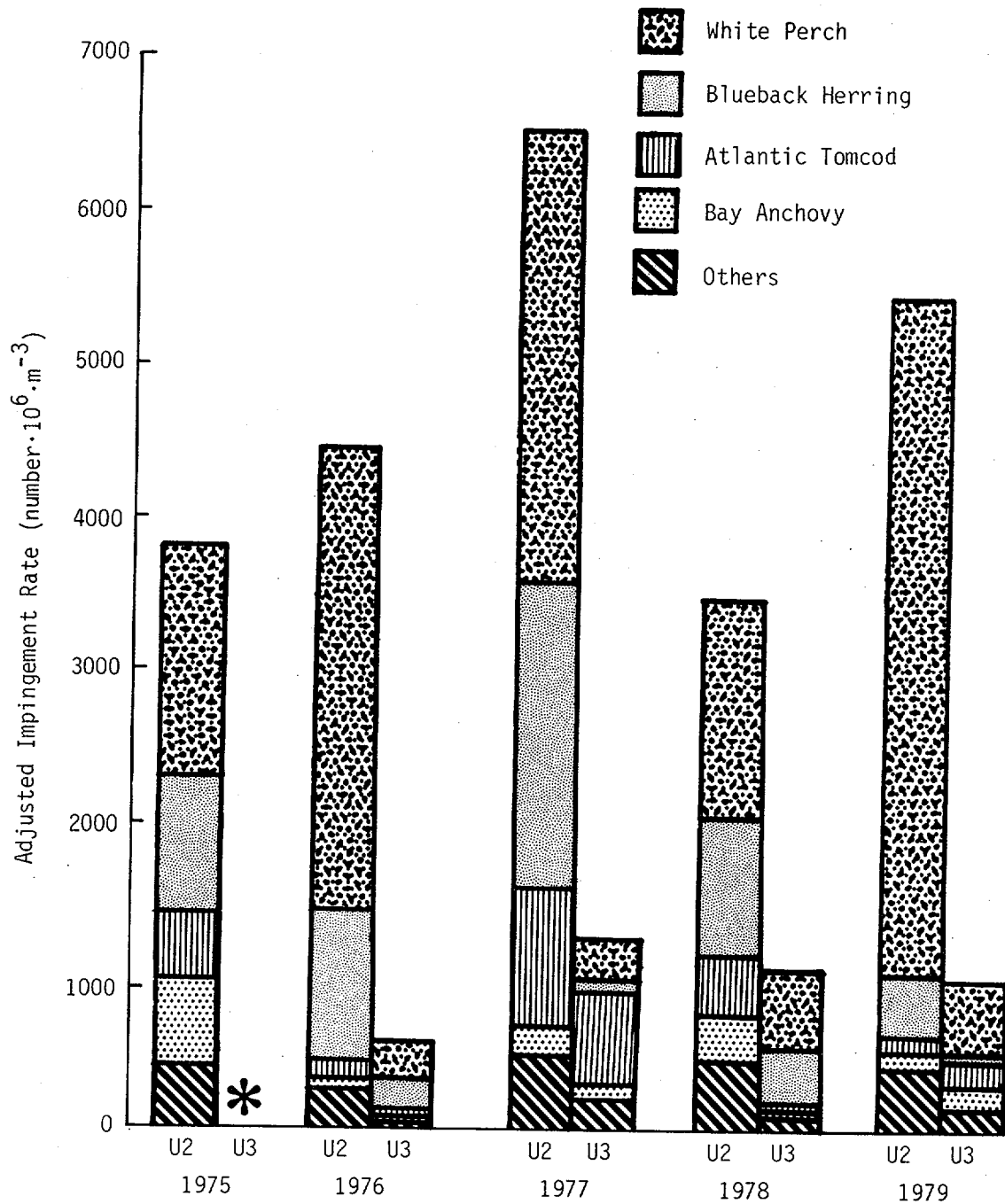


### 3. Relative Abundance

#### a. Impingement

There was a major change in the relative contribution of white perch and blueback herring to impingement during 1979 with respect to their relative contribution in previous years (1975 through 1978). The proportion of white perch increased dramatically while the proportion of blueback herring decreased (Figure III-19). The drastic decrease in proportion of blueback herring at Unit No. 3 was partly due to lack of Unit No. 3 operation during the fall blueback migration period. However, these changes in proportion did reflect an actual increase in the number of white perch impinged as well as an actual decline in the number of blueback herring impinged. The changes in impingement of these two species were apparently due to changes in their abundance rather than changes in environmental parameters which affect their impingement or changes in plant operation (Appendix Tables A-16, B-1, B-2). This conclusion is based on a decrease in 1979 from previous years in nearfield blueback herring collections (Subsection III.D.3.b). An increase in white perch nearfield catch was not noted; however, the majority of white perch impingement occurred during the winter (Subsection III.C) when nearfield collections were not made. White perch abundance indices for 1979 do however indicate that the 1979 year class, which represents the fall 1979 portion of the 1979 impingement bar in Figure III-19, was higher than in the years 1975 through 1979 [TI 1980c (in preparation)].

Differences in the relative contribution of other species to impingement in 1979 were minimal compared to previous years. The proportion of Atlantic tomcod in impingement collections during 1979 was similar to that seen in 1975, 1976, and 1978 and lower than the 1977 contribution (Figure III-19). Bay anchovy impingement was low during 1976 corresponding to high levels of summer freshwater flow, which kept conductivity near Indian Point low [Appendix Figure B-1 (a and b)]. Bay anchovy impingement has remained rather consistent during 1975, and 1977 through 1979. The lower proportion of bay anchovy at Unit No. 3 in 1978, and Unit No. 2 in 1979 reflect reduced operation of those units (Appendix Table A-16) during the summer when bay anchovy are most susceptible to impingement. The contributions of other



\* Unit No. 3 was not operational in 1975

† Annual Adjustments used on all years (Unit No. 2 - 3.5, Unit No. 3 - 1.4)

Figure III-19. Adjusted<sup>†</sup> Impingement Rates and Relative Proportions of Abundant Species at Indian Point Generating Station, Units No. 2 (U2) and No. 3 (U3), 1975 through 1979



major species impinged (Appendix Table A-21), hogchoker, striped bass, and rainbow smelt, have changed little over the five year period (1975 through 1979). The relative contribution of striped bass to impingement, although low, (0.8% to 2.4%) has increased steadily from 1975 through 1979. The increase in proportion has been accompanied by an increase in actual number impinged from 5,977 in 1975 to 50,511 in 1979 (Appendix Table A-21).

The increase in number of striped bass collected from impingement during 1975 through 1979 appears to have been caused by increases in water withdrawal and also by increases in striped bass abundance. The volume of water withdrawn by Unit No. 2 and Unit No. 3 (represented by total unit discharge) was much larger during 1977, 1978, and 1979 than during 1975 and 1976. Impingement of striped bass (and many other species) was also much greater during 1977 through 1979 than during 1975 and 1976 (Table III-7). Half of the increase in numbers impinged are accounted for when the affect of differences in water withdrawal are removed by dividing number of striped bass collected by the volume withdrawn. The remaining increase in number impinged can be at least partially explained by changes in abundance. Trends in impingement rate and young-of-the-year abundance indexes are similar but do not correspond exactly (Table III-7). The discrepancy is due to the fact that impingement of striped bass occurs primarily during the fall (October through December) and winter (January through March) (Appendix Table A-9 and TI 1980a Appendix Table A-13); therefore, a large year class will cause high impingement rates during the fall of one year (as young-of-the-year) and during the winter of the next year (as yearlings). For example, the large 1978 year class caused high impingement rates during the fall of 1978 and the winter of 1979. Thus, impingement during 1979 was high as a result of the 1978 year class although the 1979 year class was small.

#### b. Nearfield

During 1979, total catch-per-effort in the nearfield by beach seine and unlined bottom trawl were lower than during any year from 1974 through 1978 (Figure III-20 and III-21), total catch-per-effort by lined bottom trawl and surface trawl (Figures III-22 and III-23) were lower during 1979 than all other years but one (total catch-per-effort was lowest during



Table III-7

Number of Striped Bass Collected during Impingement Sampling at Indian Point Generating Station and Rate of Impingement (Number/Volume) Compared to Water Withdrawal (total unit discharge) and Abundance, Hudson River Estuary, 1975 through 1979

Year	Number Collected	Total Unit Discharge (in million m <sup>3</sup> )	Rate Number/Volume	Abundance Indices	
				Beach Seine Survey CPUA*	Combined Standing Crop <sup>†</sup>
1975	5,977	1118.9	5.34	21.3	20
1976	6,130	1329.1	4.61	15.5	18
1977	27,677	2158.6	12.82	22.8	34
1978	42,282	2030.4	20.82	31.4	33
1979	50,511	1934.9	26.11	13.0	12

\*CPUA = catch-per-unit-area; 1975 through 1978 values from TI 1980b

<sup>†</sup>from TI 1980c

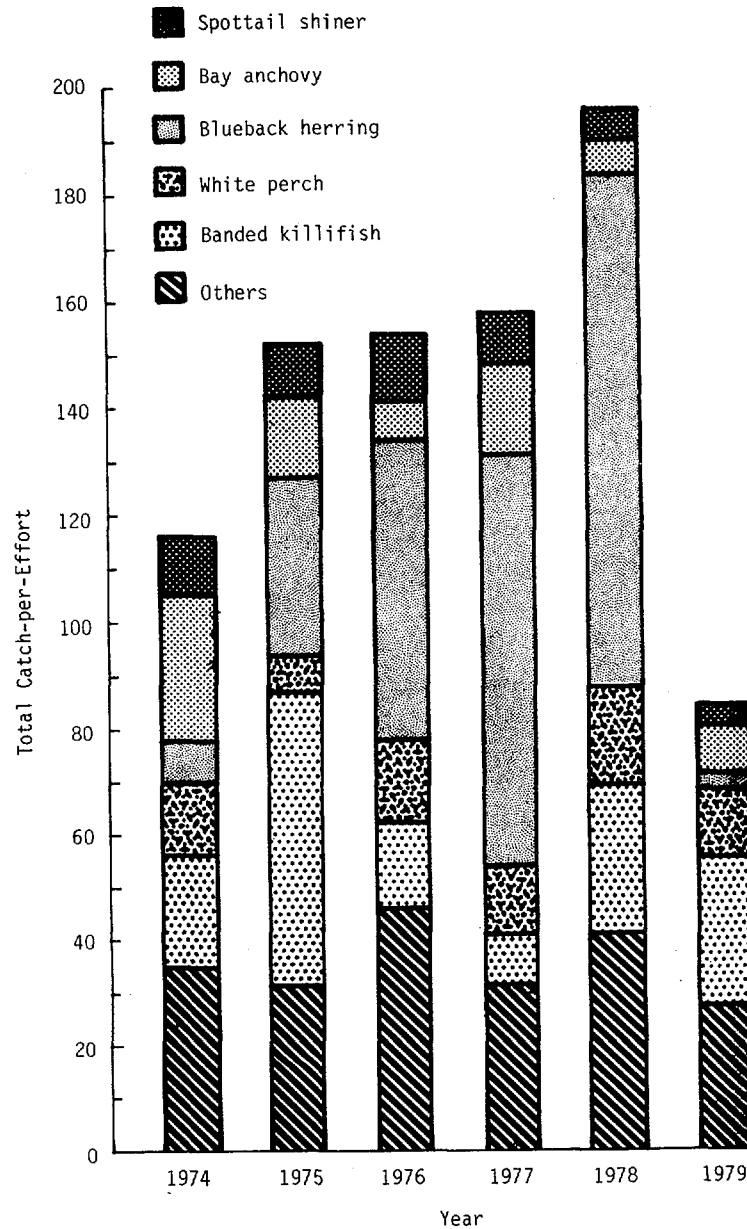


Figure III-20. Total Catch-per-Effort and Relative Proportions of Abundant Species Collected in Beach Seines, Indian Point Nearfield Region, 1974 through 1979

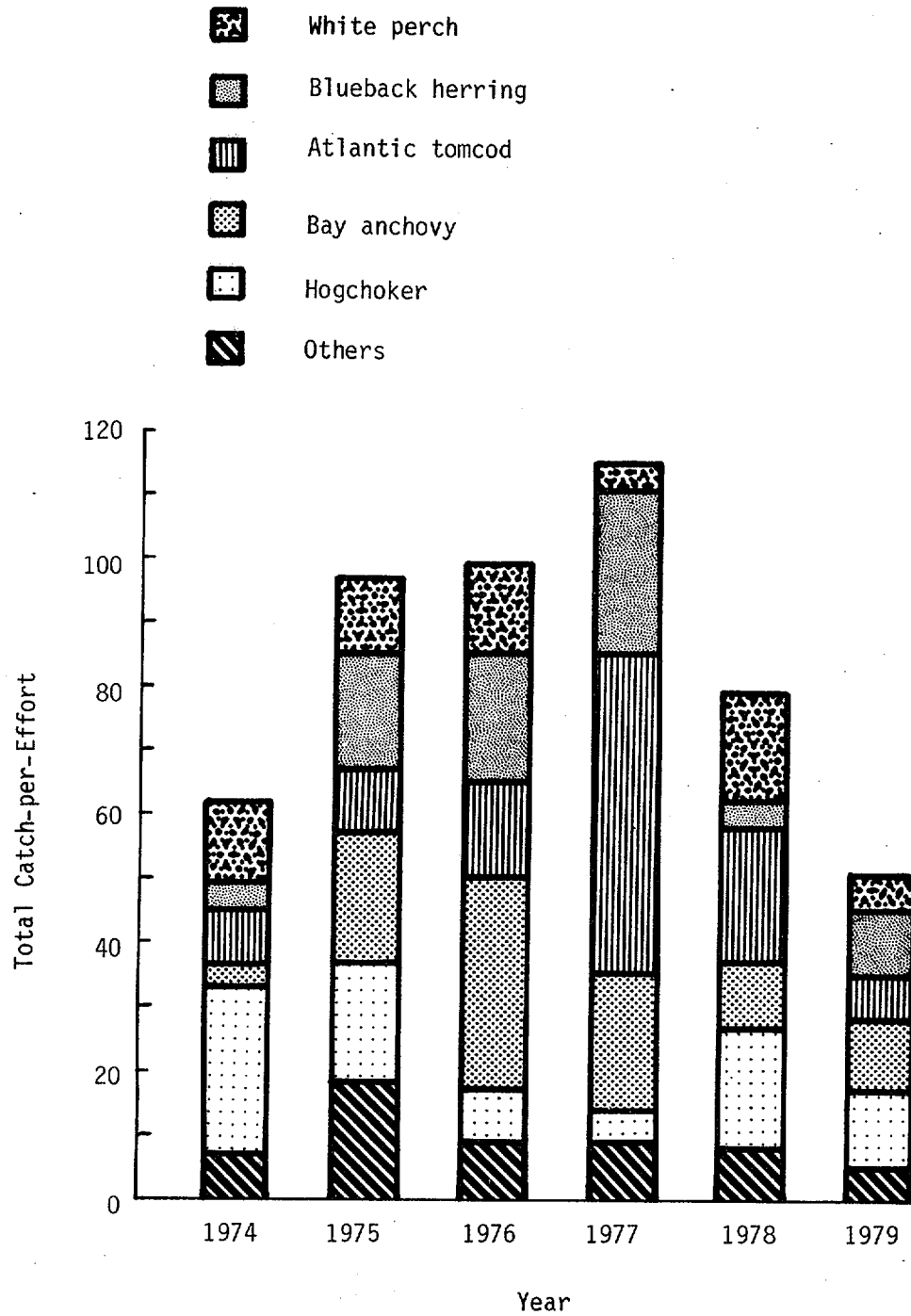


Figure III-21. Total Catch-per-Effort and Relative Proportions of Species Collected with Unlined Bottom Trawl, Indian Point Nearfield Region, 1974 through 1979

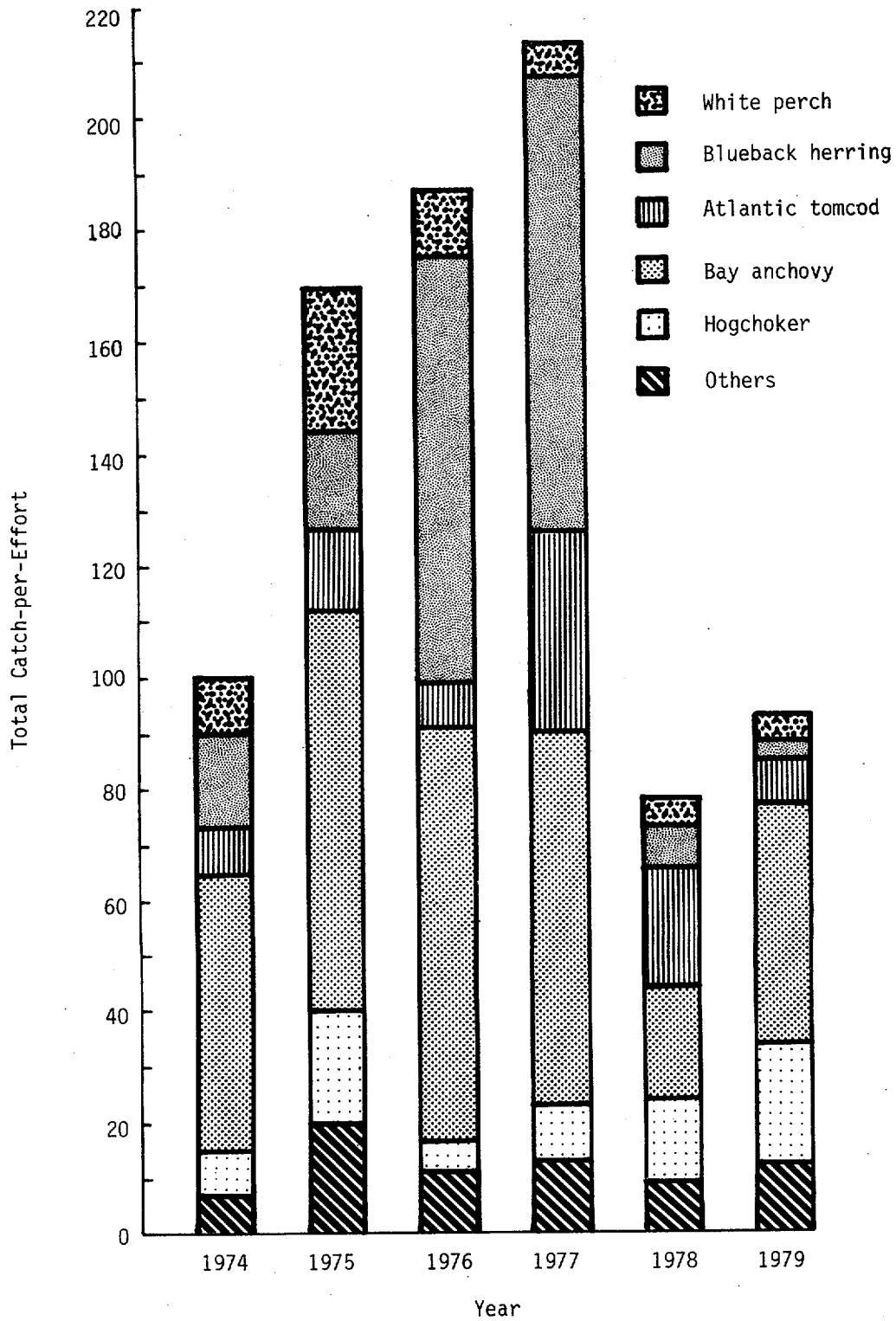


Figure III-22. Total Catch-per-Effort and Relative Proportions of Species Collected with Lined Bottom Trawl, Indian Point Nearfield Region, 1974 through 1979



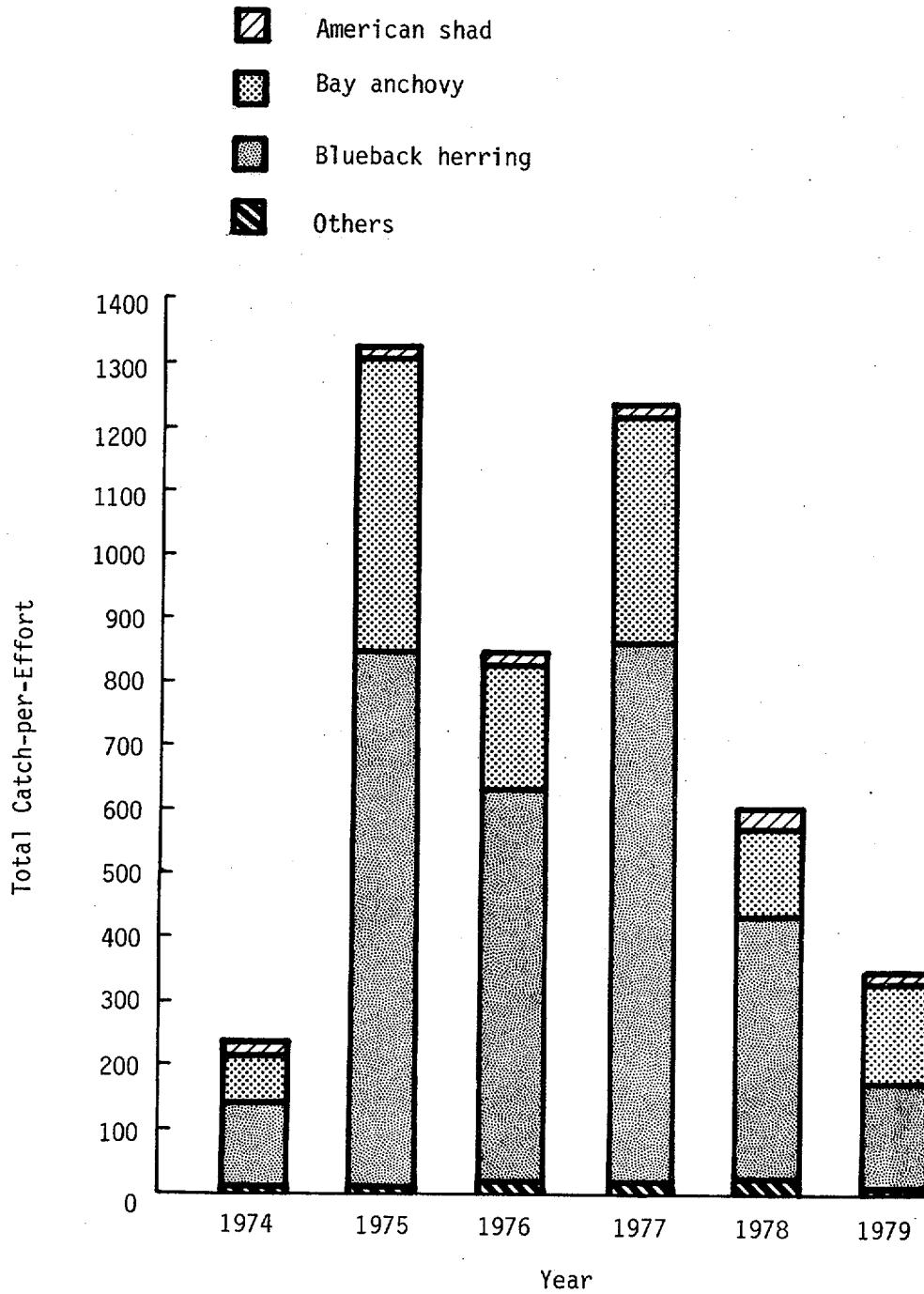


Figure III-23. Total Catch-per-Effort and Relative Proportions of Species Collected with Surface Trawl, Indian Point Nearfield Region, 1974 through 1979



1978 for lined bottom trawl and during 1974 for surface trawl). The lower catches during 1979 were due to greatly reduced numbers of blueback herring in beach seine, lined bottom trawl, and surface trawl collections and smaller catches of Atlantic tomcod by unlined bottom trawl.

Rankings of species contributing a large percentage of the total catch-per-effort of each gear, as presented in Figures III-20 through III-23 were tested using Kendall's coefficient of concordance (Siegel 1956). In this analysis, the category "others" were considered as one species. The proportional abundance of species in beach seine and surface trawl collections exhibited a consistent pattern across years while species in lined and unlined bottom trawl collections did not (Appendix Table B-8).

#### E. RECAPTURES OF HATCHERY-REARED STRIPED BASS

##### 1. Description of Hatchery Program

During 1973 through 1975, TI investigated the feasibility of artificially hatching, rearing, and stocking young-of-the-year striped bass. The hatchery program was designed to mitigate losses of wild striped bass due to power plant operation along the Hudson River. Such a study was stipulated as a condition of the license issued by the Federal Energy Regulatory Commission to Consolidated Edison Company of New York, Inc. in 1970 to construct and operate a pumped storage hydroelectric plant at Cornwall, New York.

During the three years (1973 through 1975) that stockable size fingerlings (50 through 150 mm TL) were reared, a total of more than 318,000 striped bass were released into the Hudson River between RM 24 and RM 62 with the intent of monitoring their survival through a recapture effort. These fish were hatched at a pilot facility operated by TI at Verplanck, New York, using induced spawning techniques on wild brood fish captured each spring from the Hudson River. Positive identifica-



tion of hatchery-reared fish has been assured by marking each individual with a finclip and magnetic nose tag prior to stocking.

As of 30 June 1980, 1,925 hatchery-reared striped bass have been recaptured from the Hudson River and adjacent waters (Table III-8). Short-term (three to nine months) survival of hatchery-reared striped bass was assessed by comparing the change in rate of recapture of marked wild fingerlings versus marked hatchery-reared fingerlings through time, and has been shown to be similar to that of wild fish (TI 1977a). Analysis of stomach contents, growth, and movements have provided evidence that hatchery-reared and wild striped bass behave and grow similarly (TI 1977c, 1979b). The present goal is to confirm that long-term survival occurs and to determine whether hatchery-reared striped bass participate in the spring spawning run. Data on distribution of all recaptured hatchery-reared fish since 1973 are presented. Also, data on size and maturity of those fish recaptured from 1977 through June 1980 are presented and compared with similar data for wild striped bass.

## 2. Distribution

Hatchery-reared striped bass, stocked between river mile (RM) 24 and RM 62, have dispersed over the entire Hudson River estuary (Figure III-24) within a year after release, as far upriver as Albany (RM 149) and as far downriver as the lowest portions of the estuary in the vicinity of Staten Island, N.Y. and Manhasset Bay on Long Island (TI 1979b). Most wild striped bass appear to emigrate from the river before Age I (TI 1977b) and, since so few hatchery-reared two and three year olds were recaptured during 1976 and 1977 (Table III-8), it appears the hatchery-reared and wild fish emigrate similarly (TI 1979b). Recent collections (1978 through June 1980) indicate hatchery-reared striped bass return to the river as three to six year olds during the spring spawning run.

## 3. Growth

The mean lengths and weights of hatchery-reared striped bass



Table III-8  
Summary of Recaptures of Hatchery-Reared Striped Bass  
during Year of Release and Subsequent Years

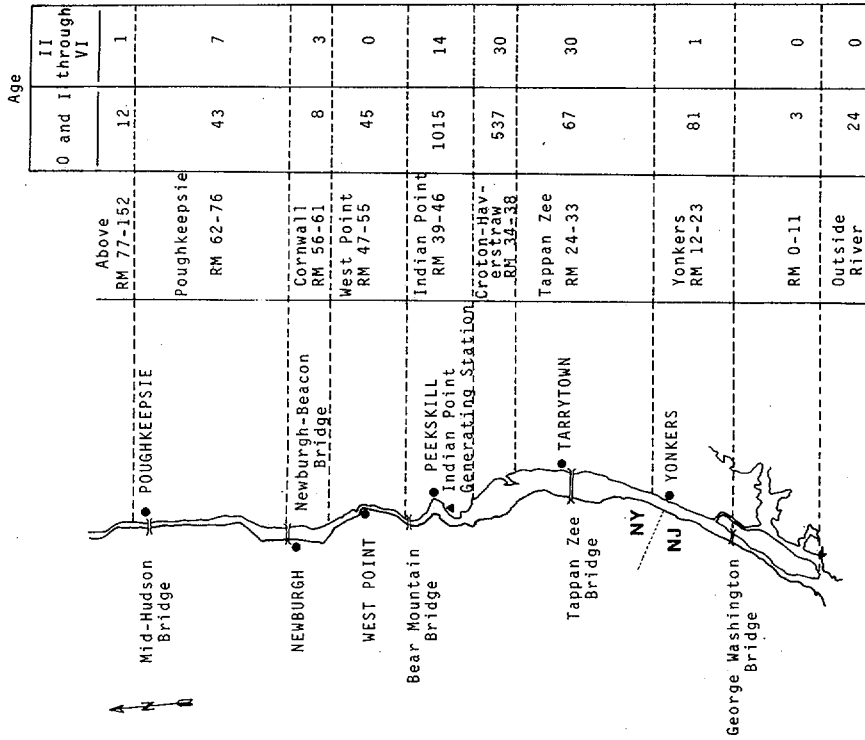
Stocked		Recaptured	
Year	Number	Year	Number
1973*	28,674	1973	46
		1974	3
1974	101,524	1974	164
		1975	442
		1976	6
		1977	6
		1978	21
		1979 <sup>†</sup>	12
		1980 <sup>†</sup>	5
1975	188,387	1975	925
		1976	259
		1977	10
		1978	11
		1979 <sup>†</sup>	13
		1980 <sup>†</sup>	2
All Years Combined	318,585	All Years Combined	1,925

\*All fish stocked in 1973 were marked by clipping the second dorsal fin, which has since been observed to be capable of rapid regeneration. Fin regeneration, combined with nose-tag insertion/retention rate of only 17% in 1973 (TI 1974a), may explain why more recaptures from the first year of stocking have not been identified

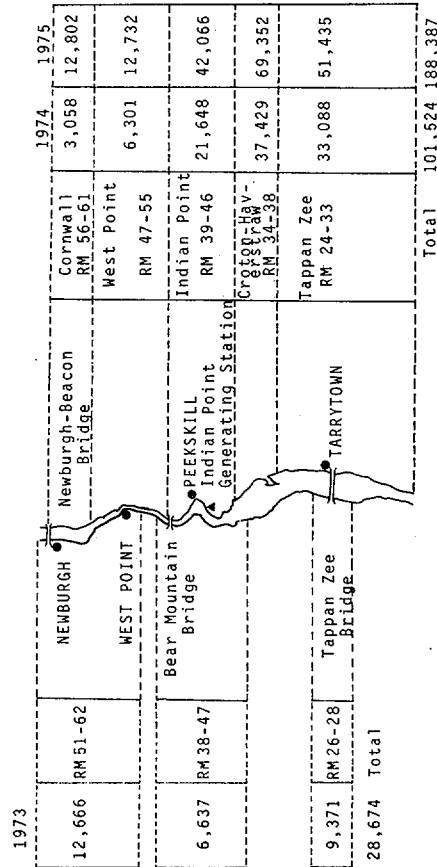
<sup>†</sup>through 30 June 1980



Number Recaptured



Number Stocked



\* Four fish lacked recapture location information and are not shown on map.

Figure III-24. Number of Hatchery-Reared Striped Bass Fingerlings Stocked in Hudson River by Geographical Area during 1973, 1974, and 1975 and Number and Location of Individuals (ages 0 and I, and II through VI) Recaptured through 30 June 1980\*



caught during 1977 and 1978 were less than those of wild striped bass of the same age and sex (Tables III-9 and III-10). The differences in means (length and weight) may not, however, reflect actual growth differences between hatchery and wild fish, since many of the fish were collected by size selective gear such as gill nets. The smallest mesh (10.1 cm stretch) gill net used is selective for fish  $>350$  mm TL (see Figure B-51 in TI 1980b). Therefore, length and weight data for wild fish, obtained predominantly from gill nets, may be biased high, especially for age groups with lengths  $\leq 350$  mm TL (ages II and III). Data for hatchery-reared fish were obtained from several gear types (Table III-11 and TI 1980a) and thus may not be as strongly affected by size selectivity of the capture gear.

#### 4. Sexual Maturity

The presence of mature hatchery-reared striped bass among wild striped bass collected prior to and during the spawning period provides evidence that hatchery-reared striped bass contribute to the Hudson River spawning stock. Sexual maturity has been determined for hatchery-reared fish (for methodology see TI 1980b) recaptured from 1977 through 30 June 1980. Similar to wild striped bass, [most of which are mature at Age IV through VI (TI 1980b)] most four, five, and six year old hatchery males were mature (Table III-12). Female striped bass mature more slowly than males (TI 1980b), therefore it was not unusual that mature hatchery-reared females were not recaptured until 1979 as five year old fish. During the 1979 and 1980 spring spawning seasons, 20% (3 of 16) of the females recaptured were mature (Table III-12).

#### 5. Conclusion

These findings support the position that the stocking program may provide a viable alternative to cooling towers for mitigation of striped bass losses resulting from power plant operations along the Hudson River. The collection of mature hatchery-reared striped bass in the river during the spawning run with characteristics similar to those of wild fish provides evidence that hatchery-reared fish contribute to the Hudson River spawning stock.



Table III-9

Mean Total Length [ $\bar{X}$ TL(mm)] of Hatchery-Reared and Wild Striped Bass Collected during 1977 through 1980 in Hudson River Estuary during March through June Sampling Period

Collection Year	Sex	Hatchery-Reared Striped Bass						Wild Striped Bass					
		1974 Stocking			1975 Stocking			1974 Year Class			1975 Year Class		
		$\bar{X}$ TL (mm)	SE	N	$\bar{X}$ TL (mm)	SE	N	$\bar{X}$ TL (mm)	SE	N	$\bar{X}$ TL (mm)	SE	N
1977	Male	344	26	6	227	13	5	369	5	150	239	6	56
	Female	ND	ND	ND	237	10	3	377	8	98	230	6	54
1978	Male	417	16	16	373	24	4	456	4	295	384	5	134
	Female	424	44	2	393	21	7	473	5	187	419	6	99
1979	Male	496	32	6	443	36	5	492	4	423	459	3	357
	Female	558	44	5	425	15	7	533	5	244	476	4	209
1980	Male	574	61	3	ND	ND	ND	--	--	--	--	--	--
	Female	609	161	2	570	100	2	--	--	--	--	--	--

SE = Standard Error

N = Sample Size

ND = No Data

Dashes indicate data not yet available



Table III-10  
 Mean Weight [ $\bar{XWT}(g)$ ] of Hatchery-Reared and Wild Striped Bass Collected during 1977 through 1980 in Hudson River Estuary during March through June Sampling Period

Collection Year	Sex	Hatchery-Reared Striped Bass						Wild Striped Bass					
		1974 Stocking			1975 Stocking			1974 Year Class			1975 Year Class		
		$\bar{XWT}(g)$	SE	N	$\bar{XWT}(g)$	SE	N	$\bar{XWT}(g)$	SE	N	$\bar{XWT}(g)$	SE	N
1977	Male	434	80	6	133	22	5	559	29	93	175	16	30
	Female	ND	ND	ND	176	7	3	549	42	53	152	14	32
1978	Male	868	110	16	548	90	4	984	38	186	614	29	97
	Female	834	266	2	731	125	7	1114	55	115	790	40	79
1979	Male	1530	372	5*	1032	342	5	1317	48	235	926	31	174
	Female	2080	420	5	688	33	6*	1646	92	109	1043	38	107
1980	Male	2567	858	3	ND	ND	ND	--	--	--	--	--	--
	Female	3300	2400	2	2175	975	2	--	--	--	--	--	--

\*Two fish were in such poor condition at time of recapture that weight data were not taken

SE = Standard Error

N = Sample Size

ND = No Data

Dashes indicate data not yet available





Table III-11  
Hatchery-Reared Striped Bass Recaptured from Hudson River Estuary, July 1979 through June 1980

Date Recaptured	RM	KM	Site	Gear*	Finclip	Stocking Season (Fall)	Reference Tag Number	Length (mm)	Weight (g)	Nose Tag	Sex	Body Weight/ Gonad Weight	Visible Sexual Condition
20 Sep 1979	59	94	East	61.0 m BS	1st Dorsal	1974	JT 9481	494	1178	No	Male	-- †	Immature
21 Mar 1980	34	54	East	10.1 cm GN	1st Dorsal	1975	**	670	3150	No	Female	237	Developing
02 Apr 1980	34	54	East	12.7 cm GN	1st Dorsal	1975	**	470	1200	No	Female	190	Immature
07 Apr 1980	34	54	East	15.2 cm GN	1st Dorsal	1974	**	626	3400	No	Male	17	Ripe
24 Apr 1980	36	58	East	12.7 cm GN	1st Dorsal	1974	**	448	900	No	Female	145	Immature
30 Apr 1980	46	74	West	15.2 cm GN	1st Dorsal	1974	**	643	3450	No	Male	13	Ripe
30 Apr 1980	35	56	East	17.8 cm GN	1st Dorsal	1974	**	770	5700	No	Female	23	Mature
12 May 1980	36	58	East	10.1 cm GN	Both Pelvic	1974	**	452	850	Yes	Male	654	Developing

\*BS = Beach Seine; measurement denotes length  
GN = Gill Net; measurement denotes stretch mesh size; all gill nets 91.4 m x 2.4 m

†Body weight/gonad weight data were not available for this fish since it was not in spawning condition during September

\*\*Beginning in 1980, hatchery-recaptured striped bass were uniquely identified with a sample number and individual fish identification number. Therefore, reference tag numbers were no longer used in 1980



Table III-12  
Maturity by Age of Hatchery-Reared and Wild Striped Bass  
from Hudson River during 1977 through 30 June 1980

Year Stocked	Year Recaptured	Age (years)	Sex	Hatchery-Reared				Wild	
				Number Mature*	Number Immature	Others <sup>†</sup>	Number Mature*	Number Immature	
1974	1977	III	Male	5	1	0	12	22	
			Female	0	0	0	0	27	
	1978	IV	Male	14	2	3	72	10	
			Female	0	2	0	1	58	
	1979	V	Male	6	0	1	55	11	
			Female	2	3	0	12	38	
1980**	VI	Male	2	1	0	--	--		
		Female	1	1	0	--	--		
1975	1977	II	Male	0	3	3	3	22	
			Female	0	3	0	0	24	
	1978	III	Male	1	3	0	15	22	
			Female	0	7	0	0	43	
	1979	IV	Male	1	4	0	54	17	
			Female	0	7	0	0	51	
1980**	V	Male	0	0	0	--	--		
		Female	0	2	0	--	--		

\*Includes fish with body weight:gonad weight less than 70:1 for females; 235:1 for males or fish visually classified as mature  
<sup>†</sup>Number of fish collected outside of spawning season, or fish for which sexual condition not determined  
 \*\*through 30 June 1980  
 Dashes indicate data not yet available



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SECTION IV  
ANALYSIS OF DAILY IMPINGEMENT VARIATION

A. INTRODUCTION

Data collected at the Indian Point Generating Station has provided one of the most complete records of fish impingement for any power plant (Stupka and Sharma 1977). Regulatory technical specifications require continuous collection and sampling from intake structures at 24 hour intervals to provide daily counts by species of the number of fish impinged (NRC 1975); however, this daily sampling regime may be more than adequate to reliably estimate impingement rates. Recent studies by Johnston (1976), Kumar and Griffith (1977), Murarka and Bodeau (1977), Murarka et al. (1977), and El-Shamy (1979) have each suggested that precise estimates of mean daily and annual total counts of fish impinged may be obtained with a less than daily sampling schedule. If a program of less frequent sampling could be instituted, fish could be returned to the river on non-sample days as is presently done at many other generating stations (Freeman and Sharma 1977), thus allowing a portion of those released to survive.

The sampling effort (number of days) required to obtain a specified level of precision is related primarily to the timing and magnitude of variation in daily impingement counts. Those specific times of the year with high variation among daily impingement counts may require daily sampling while low variation periods may require less frequent sampling to obtain the same degree of precision. This analysis 1) describes the temporal variability among daily impingement total counts at Indian Point, 2) uses estimates of daily variability as a basis for selecting a reduced sampling design, and 3) evaluates the accuracy and precision of annual total impingement estimates using three reduced sampling designs.



## B. ANALYSIS OF DAILY IMPINGEMENT VARIATION

### 1. Selection of a Nonbiased Measure of Daily Impingement

A daily count of the total number of fish impinged has been used to quantify impingement at Indian Point Units No. 2 and No. 3. Impingement counts, however, have not completely reflected underlying natural variation because they were influenced by variation in volume of cooling water pumped. Therefore, "raw" impingement counts (actual numbers collected from screen washings prior to any adjustments for efficiency) were scaled to reflect the estimated number of fish which could have been impinged if the unit was pumping at maximum capacity. This estimated maximum daily (EMD) impingement count was the product of selected (Appendix Subsection C.1.c) daily impingement rate (numbers $\cdot 10^6\text{m}^{-3}$ ) and maximum pumping capacity of all six circulator pumps. Two maximum volume constants were used: one for the 100% pumping capacity period from 1 April through 31 December ( $4.58 \cdot 10^6\text{m}^3\cdot\text{day}^{-1}$ ) and one for the 60% period from 1 January through 31 March of each year ( $2.75 \cdot 10^6\text{m}^3\cdot\text{day}^{-1}$ ). Dates for the winter period were selected to encompass the time when all circulator pumps at each unit were continuously operated at 60% pumping capacity. The earliest date all 6 circulators were continuously operating at 60% was 20 Dec 1978 at Unit No. 3. The earliest date a 100% pumping rate began was 3 April 1979 for Unit No. 3. Thus, 1 January to 31 March was selected to encompass the period of 60% pumping capacity. All analyses in this section used EMD counts and were performed separately on Indian Point Units No. 2 and No. 3 for the period 1976 through 1979.

### 2. Analysis of Impingement Variability

Tukey's 3RSSH smoothing technique (Tukey 1977), which classifies raw data into "smooth" and "rough" components, was applied to EMD counts to empirically separate the variation from the temporal pattern of impingement and to aid in identification of periods of high and low daily variation. This procedure also served to smooth across gaps in the impingement data that were due to plant outages. Impingement data for the period from June 1978 through May 1979 for Indian Point Unit No. 2 was selected to demonstrate this smoothing technique (Figure IV-1)

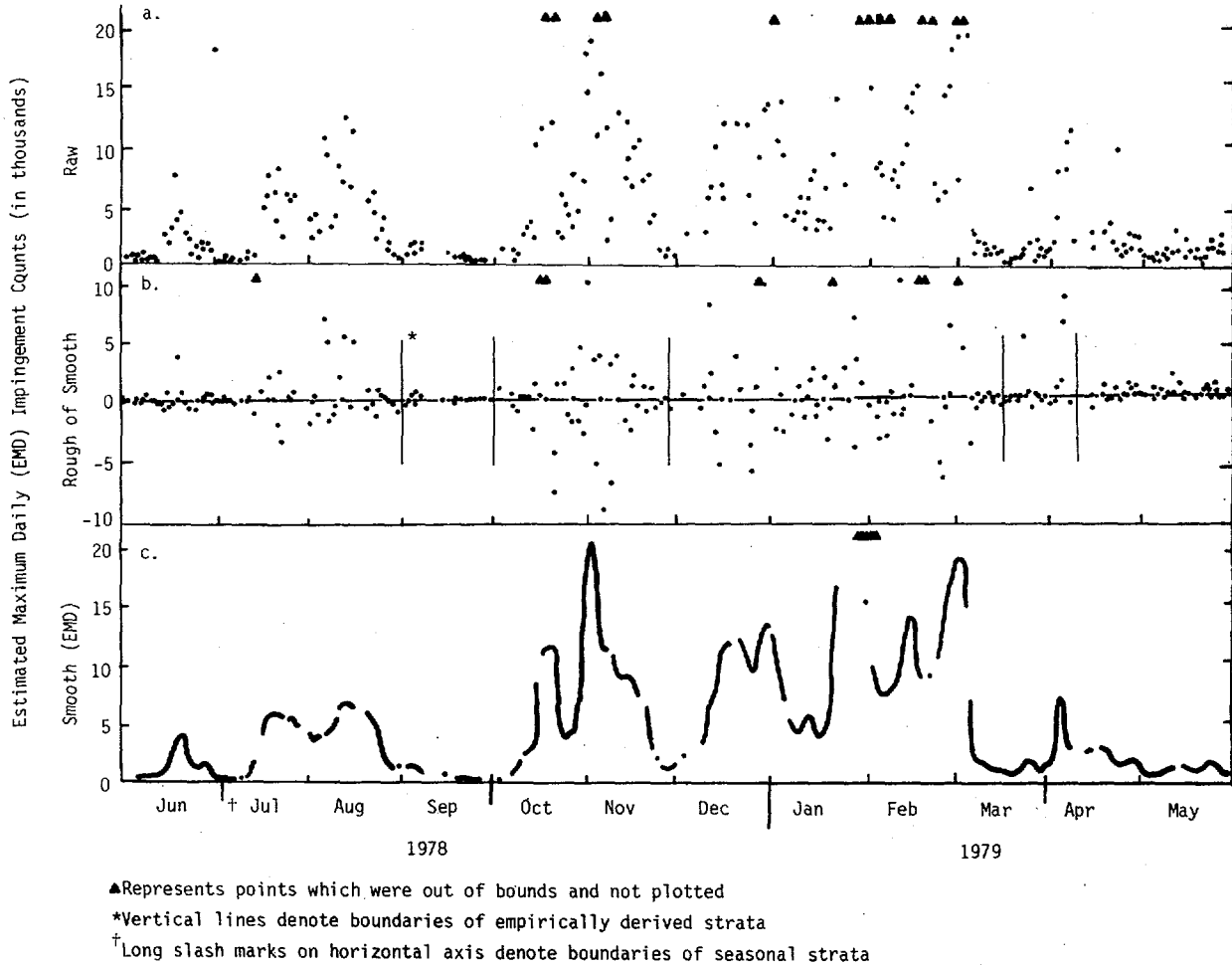


Figure IV-1. Comparison between "Raw" or Actual Estimated Maximum Daily (EMD) Counts and "Smooth" and "Rough" Values Obtained after Application of Tukey's 3RSSH Smoothing Technique to Indian Point Unit No. 2 Impingement Data, 1 June 1978 through 31 May 1979



because it represented a period of nearly continuous operation and typified annual impingement patterns. The degree of scatter in the "rough" component directly reflected the variation which was removed from the raw data to draw the "smooth" curve. "Raw" and "smooth" EMD counts were nearly identical in periods of low variation but differed in high variation periods. In periods when "smooth" EMD counts were small, "rough" values were low and close to zero [e.g., Figure IV-1(b), June 1978, September 1978, and May 1979]. In periods when "smooth" EMD counts were large and variable, "rough" values deviated considerably from the zero base line [e.g., Figure IV-1(b), October 1978 through February 1979].

Visual examination of the scatter presented in "rough" plots and patterns presented in "smooth" plots (Figures IV-2 and IV-3) permitted identification of periods of high and low variation which were relatively distinct in timing and duration across years. The following empirically determined temporal strata were selected for Unit No. 2, and Unit No. 3:

<u>Unit No. 2</u>	<u>Unit No. 3</u>
01 Jun through 31 Aug	01 Jun through 31 Aug
01 Sep through 30 Sep	01 Sep through 30 Sep
01 Oct through 27 Nov	01 Oct through 10 Dec
28 Nov through 15 Mar	11 Dec through 31 Jan
16 Mar through 07 Apr	01 Feb through 25 Mar
08 Apr through 31 May	26 Mar through 15 Apr
	16 Apr through 31 May

C. EVALUATION OF THE EFFECT OF VARIATION ON ESTIMATES OF NUMBER OF FISH IMPINGED

Partitioning of the year into nonoverlapping time intervals, or strata, and differential allocation of sampling effort among these strata provide a means of adjusting effort relative to differences in natural variation and length of the time period. Thus, relatively consistent levels of precision and accuracy are maintained. Using 1976 through 1979 impingement data, two potential stratification schemes were examined for their applicability to reduced sampling designs. One of



these, the empirical stratification described above, was based on the natural variability observed in the pooled 1976 through 1979 impingement data; the second, a seasonal stratification, consisted of four, 3 month seasons (January through March, April through June, etc.). A third design, simple random allocation of days throughout the year, was used for reference. Stratification, with random allocation of days within strata, should allow impingement counts to be estimated more precisely than if days were randomly allocated over an entire year (Cochran 1977, Murarka and Bodeau 1977).

1. Statistical Methods for Testing Effects of Variation on Sample Designs

For each of the three sample designs; empirical, seasonal, and simple random, data was pooled across 1976 through 1979 and analyzed separately for Unit No. 2 and No. 3. Precision of the empirical and seasonal stratified designs and the simple random design was compared by plotting the "exact" standard error of the mean EMD counts (Figures IV-4 and IV-5) for each sampling fraction (fraction of the year sampled). Each of the 12 sampling fractions tested, any of which could be chosen as the desired level of impingement sampling, represented a given percentage (5, 10, 20, 25, 30, 40, 50, 60, 70, 75, 80, and 90%) of days within a year on which impingement counts could be made using a reduced sampling plan. The "exact" standard error of the mean for each sampling fraction was mathematically derived from the entire set of available EMD counts using modifications of formulae by Cochran (1977) described below. The standard error is exact in this situation since the total population of EMD counts is known for 1976 through 1979. If the total population of EMD counts were not known, i.e., impingement counts had not been made on each day of operation, the standard error could only have been approximated.

- a. Calculation of Exact Standard Error for the Simple Random Sampling Design

$$\text{S.E. } \bar{y} = \frac{S}{\sqrt{n}} \sqrt{\frac{N-n}{N}} \quad (1)$$



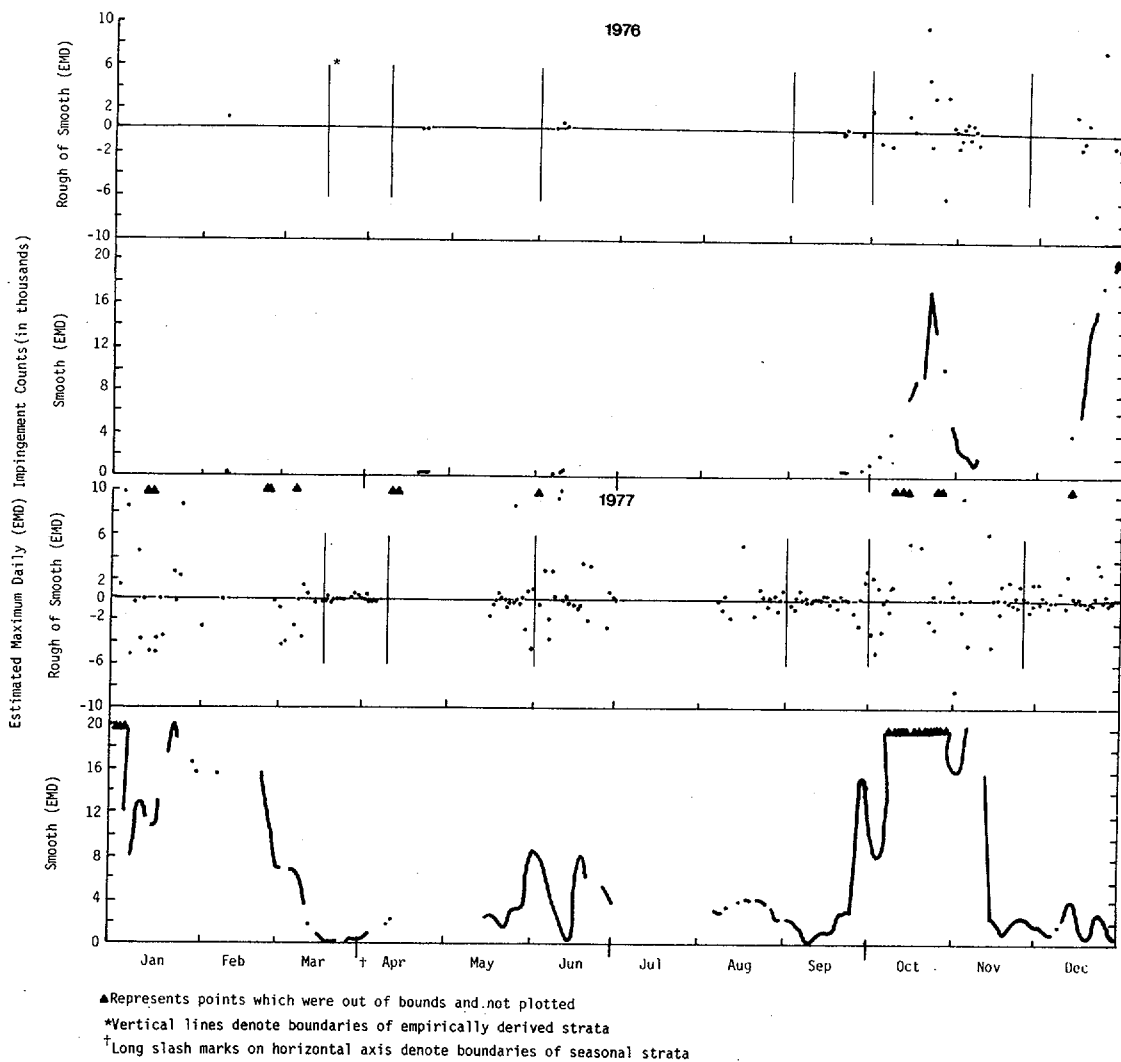


Figure IV-2. Tukey's 3RSSH "Smooth" and "Rough" Plots of Estimated Maximum Daily (EMD) Impingement Counts (all species combined) for Indian Point Unit No. 2, 1976 through 1979 ["Smooth" plots represent curves fitted through scatter plots of the "raw" data; "Rough" plots represent residue scatter (variation) removed from "raw" data in the smoothing procedure]

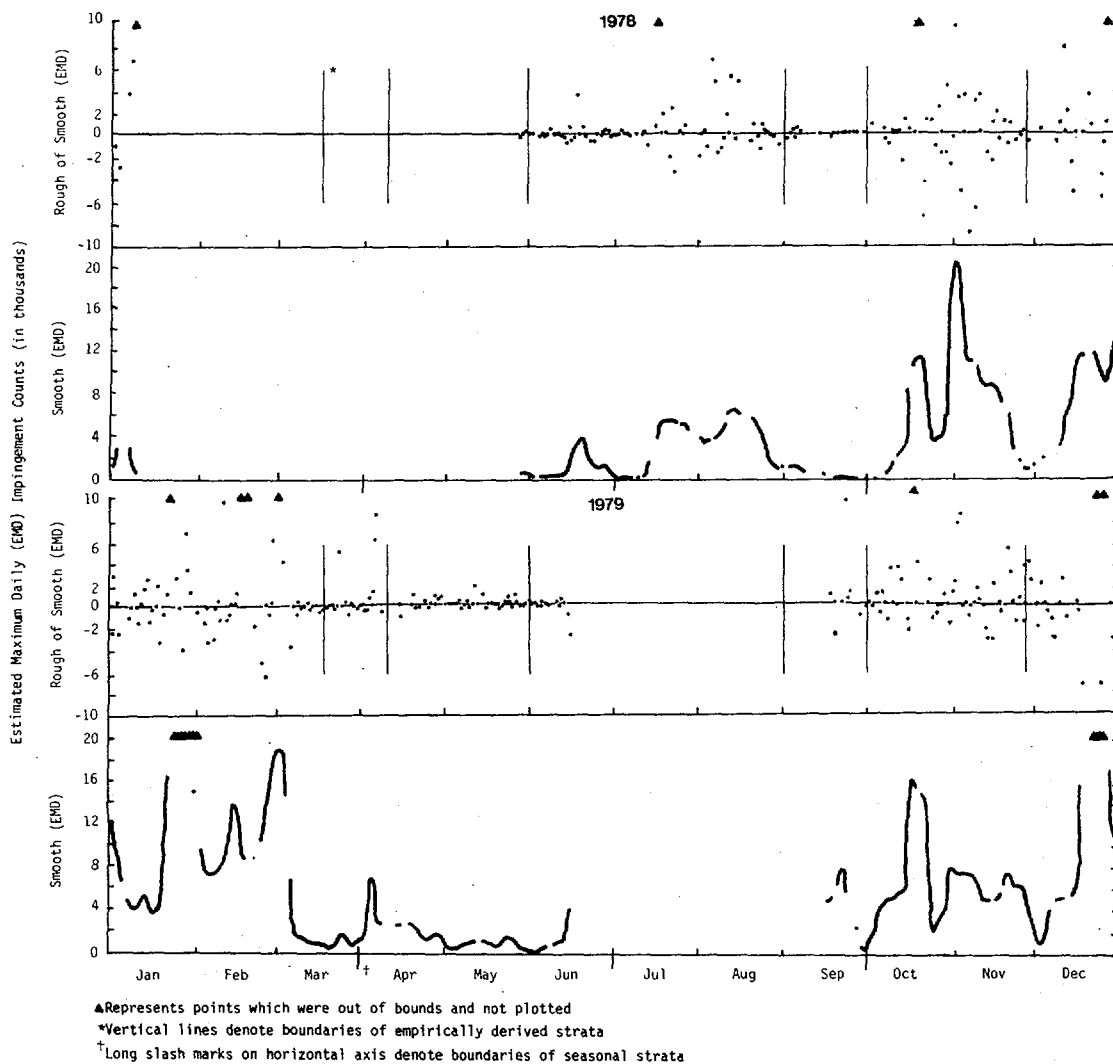


Figure IV-2 (Contd)

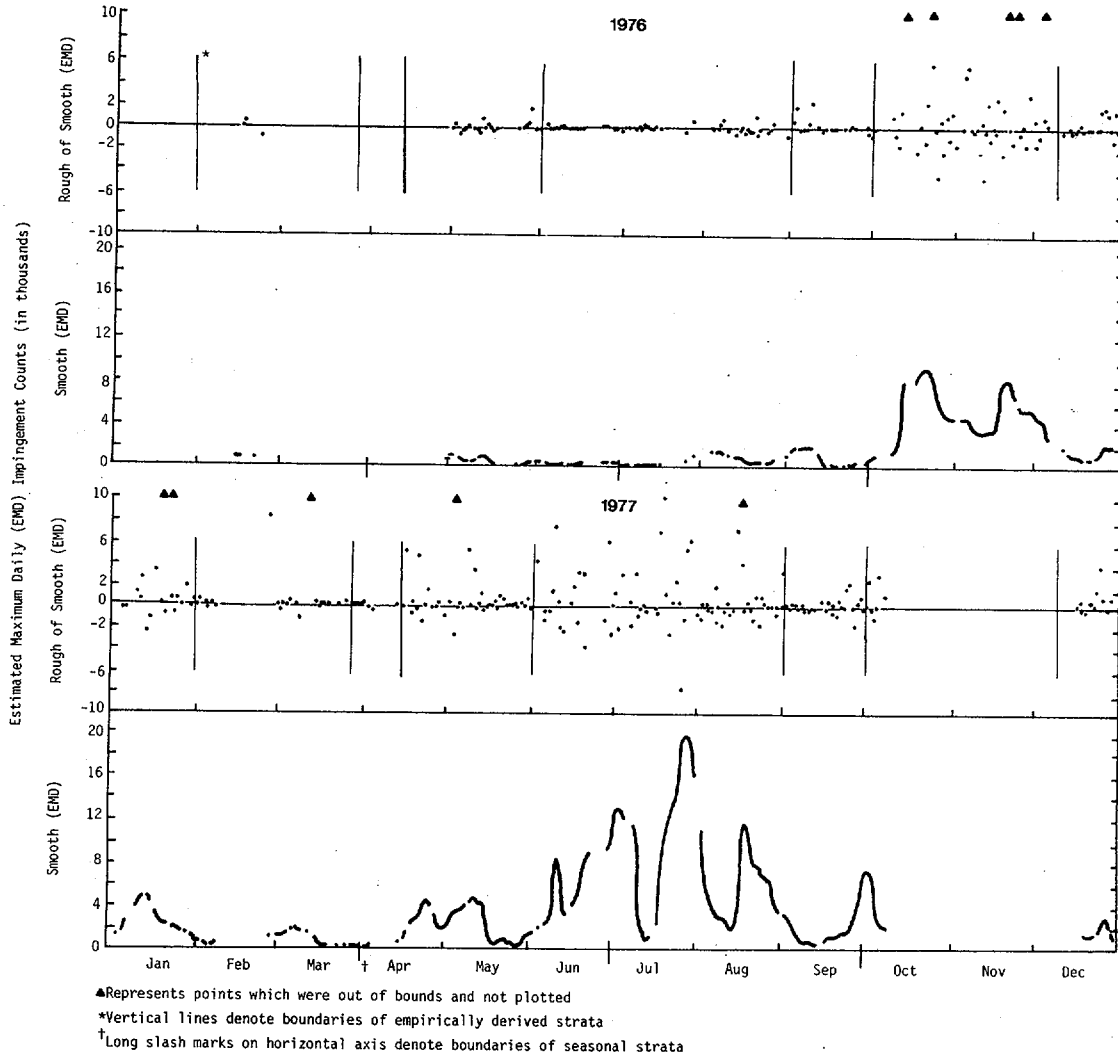


Figure IV-3. Tukey's 3RSSH "Smooth" and "Rough" Plots of Estimated Maximum Daily (EMD) Impingement Counts (all species combined) for Indian Point Unit No. 3, 1976 through 1979 ["Smooth" plots represent curves fitted through scatter plots of the "raw" data; "rough" plots represent residual scatter (variation) removed from "raw" data in the smoothing procedure]

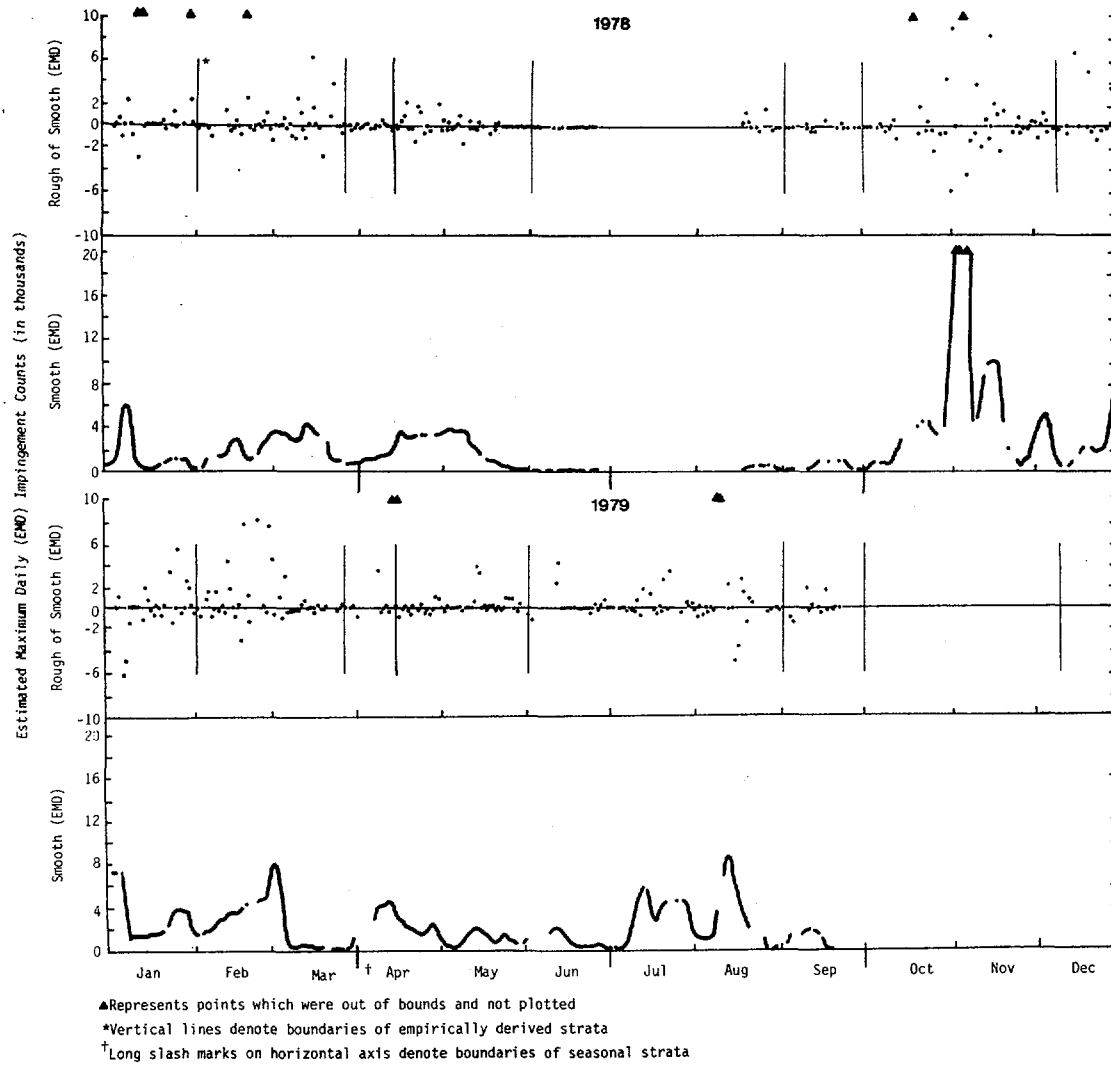


Figure IV-3 (Contd)

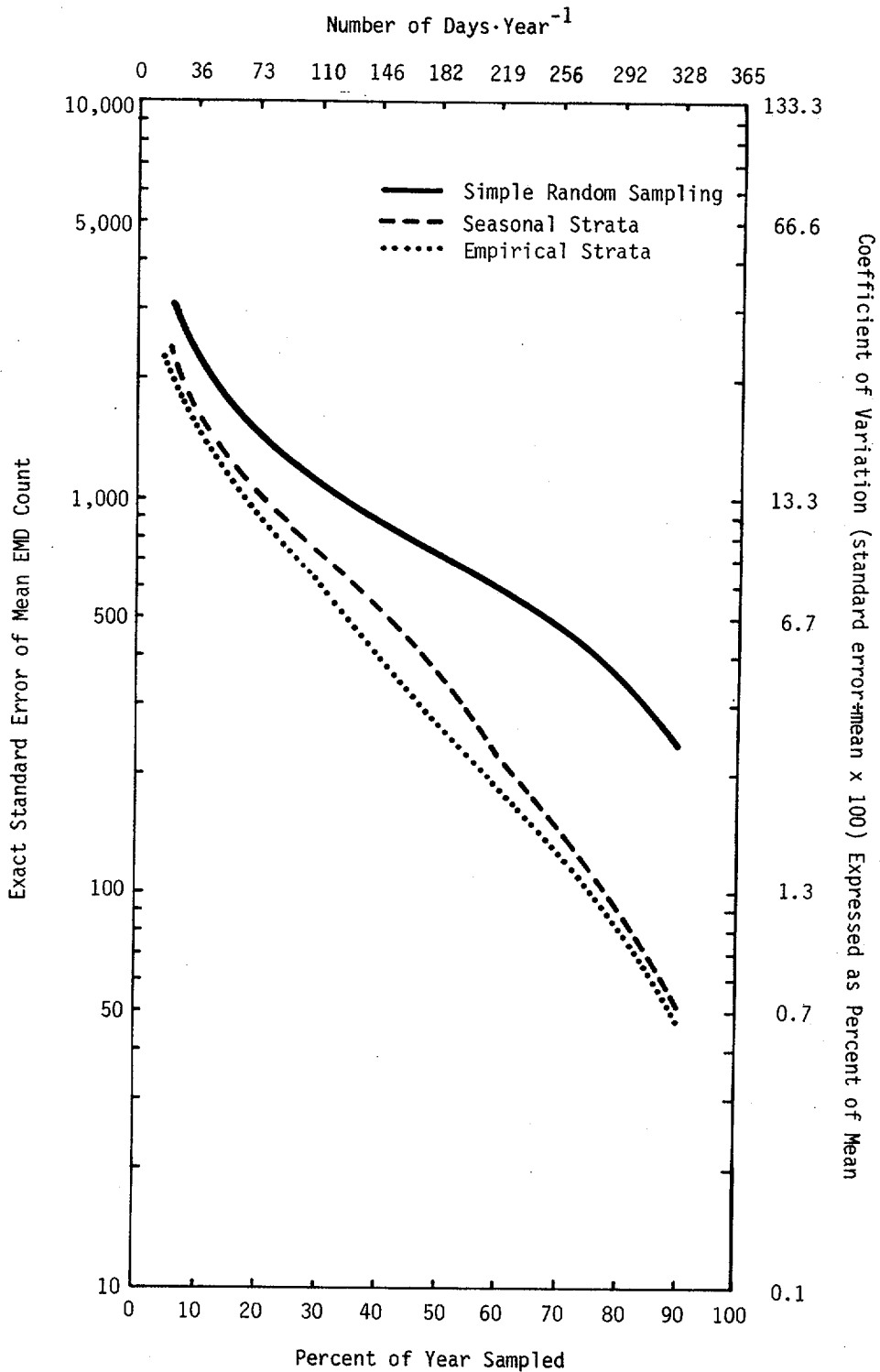


Figure IV-4. Relationship between Precision (standard error or coefficient of variation) of Mean Estimated Maximum Daily (EMD) Impingement at Indian Point Unit No. 2 and Percent of Year Sampled by Three Sampling Designs

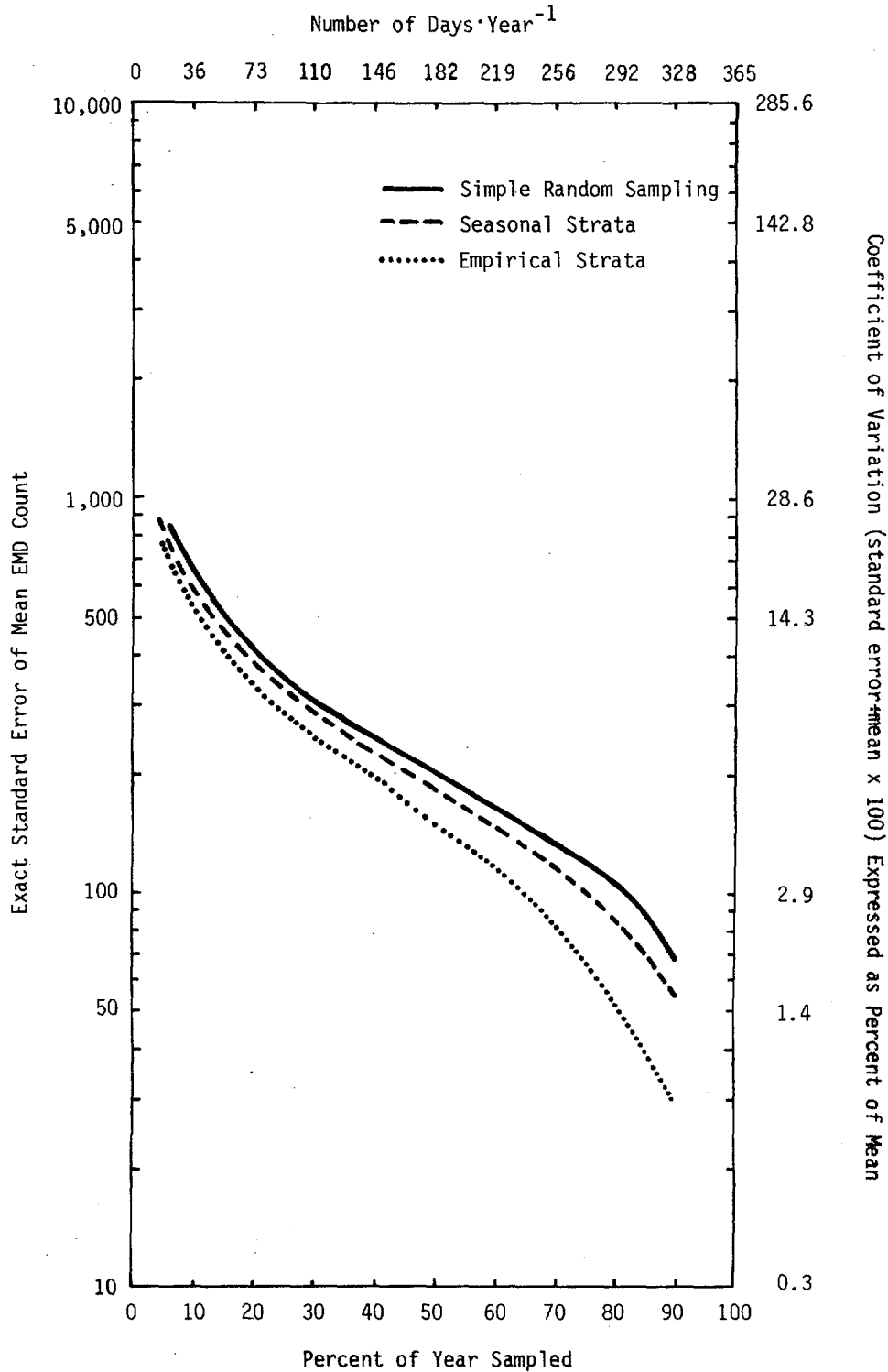


Figure IV-5. Relationship between Precision (standard error or coefficient of variation) of Mean Estimated Maximum Daily (EMD) Impingement at Indian Point Unit No. 3 and Percent of Year Sampled by Three Sampling Designs



where

S.E. $\bar{y}$  = standard error of the mean EMD count ( $\bar{y}$ )

S = standard deviation for "parent" population

n = number of days (EMD counts) in the sampling fraction

N = total number of days (EMD countd) in the "parent" population

This formula permitted calculation of the relationship between each sampling fraction and precision (S.E. $\bar{y}$ ) of simple random sampling. A second measure of precision, the coefficient of variation, was calculated at each sampling fraction by expressing the standard error as a percent of the mean (S.E. $\bar{y} \div \bar{y} \times 100\%$ ).

b. Calculation of Exact Standard Error for Seasonal and Empirical Stratified Random Sampling Designs

The relationship between each sampling fraction and the standard error of the stratified mean EMD count (S.E. $\bar{y}_{st}$ ) was determined using estimates of the within-stratum variation for both empirical and seasonal stratification schemes. The following formula was used in both computations [modified from Cochran 1977 (formula 5.12)]:

$$S.E.\bar{y}_{st} = \frac{1}{N} \sqrt{\sum_{h=1}^L N_h (N_h - n_h) \frac{S_h^2}{n_h}} \quad (2)$$

where

S.E. $\bar{y}_{st}$  = standard error of the stratified mean EMD count ( $\bar{y}_{st}$ )

N = total number of days (EMD counts) in the "parent" population

L = total number of strata

$N_h$  = total number of days in the  $h^{th}$  stratum of the "parent" population

$n_h$  = number of days (EMD counts) in the sampling fraction from the  $h^{th}$  stratum



$S_h^2$  = variance for the  $h^{\text{th}}$  stratum in the "parent" population

The coefficient of variation for stratified sampling was calculated as it was for simple random sampling ( $S.E.\bar{y}_{st} \div \bar{y}_{st} \times 100\%$ ). The actual number of days (EMD counts) for each sampling fraction was allocated to each temporal stratum using a Neyman allocation scheme (Cochran 1977). This method selected EMD counts (days) in direct proportion to both the number of days and the variance in each stratum. High variance and long time periods received proportionally more samples than low variance or short time periods.

c. Estimates of Mean EMD Counts and Annual Total Impingement Counts

Most inferences made in subsequent analyses pertain to the mean EMD count ( $\bar{y}$  for simple random sampling and  $\bar{y}_{st}$  for stratified random sampling) and standard error of the mean EMD count ( $S.E.\bar{y}$  and  $S.E.\bar{y}_{st}$ ). These inferences can likewise be made about annual total impingement counts using the following relationships (Cochran 1977):

$$T_1 = N_1 \bar{y} \quad \text{or} \quad N_1 \bar{y}_{st} \quad (3)$$

$$S.E.T_1 = N_1 S.E.\bar{y} \quad \text{or} \quad N_1 S.E.\bar{y}_{st}$$

where

$T_1$  = annual total impingement count

$S.E.T_1$  = standard error of annual total impingement count

$\bar{y}$  or  $\bar{y}_{st}$  = mean as in formula (1) or (2), respectively

$S.E.\bar{y}$  or  $S.E.\bar{y}_{st}$  = standard error of the mean as in formula (1) or (2), respectively

$N_1$  = number of days in a year (365 or 366 in leap year)





For example, if the mean EMD count and standard error of the mean were  $1000 \pm 100$  fish the annual total and standard error of the total would be  $365,000 \pm 36,500$  fish. In both cases, the coefficient of variation would be 10%.

## 2. Effect of Daily Impingement Variation on Precision with Reduced Sampling Effort

Precision increased logarithmically with increasing sampling fraction for all three sampling designs at both Indian Point Units No. 2 (Figure IV-4) and No. 3 (Figure IV-5). Simple random sampling was the least precise, stratified random sampling using four seasonal strata was intermediate in precision, and stratified random sampling using empirical strata was the most precise design at both Units No. 2 and No. 3. However, the relationship between sampling design, precision, and sampling fraction differed between Units No. 2 and No. 3. At Unit No. 2 (Figure IV-4), both stratified designs were considerably more precise than the simple random design, particularly at large sampling fractions. The two stratified designs responded similarly to increased sampling fractions (lines nearly parallel) except at intermediate fractions when the precision of empirical stratification was disproportionately higher than for the seasonal design. In contrast, at Unit No. 3 (Figure IV-5), curves for the relationship between precision and sampling fractions were not as widely separated as at Unit No. 2, and the precision of sampling in seasonal strata more closely resembled that of simple random than of empirical; otherwise, the patterns of precision were very similar for both units.

Standard error of the mean EMD count was higher at Indian Point Unit No. 2 than at Unit No. 3 (Figures IV-4 and IV-5). For the two stratified designs, standard error of the mean EMD count at Unit No. 2 ranged between 2339 at a 5% sampling fraction to 47 at a 90% fraction (Figure IV-4). At Unit No. 3, standard error ranged between 828 at a 5% fraction to 28 at a 90% fraction. These differences were primarily due to higher mean daily impingement (EMD) counts at Unit No. 2 than at Unit



No. 3 and were greatly reduced when precision was expressed as a coefficient of variation (Figures IV-4 and IV-5). For example, with empirical stratification and a 50% sampling fraction, the mean EMD count and standard error at Unit No. 2 were  $7502 \pm 264$  fish and at Unit No. 3 were  $3443 \pm 149$  fish; the coefficient of variation was 3.5% and 4.3%, respectively. For annual impingement based on EMD counts the total and standard error of the total were  $2.738 \times 10^6 \pm 0.096 \times 10^6$  at Unit No. 2 and  $1.257 \times 10^6 \pm 0.054 \times 10^6$  at Unit No. 3.

### 3. Effects of Daily Impingement Variation on Accuracy with Reduced Sampling Effort

The 1976 through 1979 impingement data from Indian Point Units No. 2 and No. 3 differed from the normal distribution used in sampling theory (these data were positively skewed), and no exact formula exists for computing the degree of "bias" due to this nonnormality. Simulated sampling was used to determine the effects of nonnormality on the accuracy of 95% confidence limits for estimating yearly mean EMD impingement counts. This approach is recommended when data are suspected of violating the assumptions of classical theory (i.e., normality) and can be used to determine the sensitivity of a statistic to these violations (Barrett and Goldsmith 1976, Cochran 1977, and Green 1979). The simulation involved repeated application of each of the two stratified designs for each sampling fraction to determine the number of times the actual 95% confidence interval about the estimated yearly mean EMD enclosed the true mean EMD count. The true mean was obtained from daily sampling (1976 through 1979) at Indian Point Unit No. 2 and Unit No. 3, and simulations were repeated 1000 times for each sampling fraction at each unit (No. 2 and No. 3). If a 95% confidence level was achieved by the design, 95% of the confidence intervals calculated for each simulated mean EMD count should "catch" or enclose the true mean.

As an example of how simulated sampling was conducted, assume that an empirical stratification scheme was used for a 20% sampling fraction at Indian Point Unit No. 2. The first step in the simulation



was to determine the number of days in a 20% fraction and allocate those days to each of six empirical strata by the Neyman allocation scheme (Cochran 1977). If the 1 June through 31 August stratum received an allocation of 28 days, those 28 days would be randomly selected from the 1976 through 1979 data base of EMD counts for that period. When all six strata were sampled, a stratified mean EMD count with 95% confidence limits was computed. This sample confidence interval was examined to determine if it enclosed the true mean (the mean of all EMD counts for Unit No. 2 in the 1976 through 1979 period). This entire sampling procedure was repeated 1000 times for the 20% fraction at Unit No. 2 for empirical stratification.

Results from simulated sampling indicated that a 95% confidence interval was nearly achieved at any sampling fraction greater than 20% to 30% (Figure IV-6). Differences between empirical and seasonal stratified designs were not apparent. At Unit No. 2, confidence intervals for means from sampling fractions above 30% caught the true mean approximately 94% to 95% of the time. At Unit No. 3, confidence intervals for means of sampling fractions above 20% caught the true mean approximately 93% to 94% of the time. For the small percentage of cases when the true mean was not caught by the 95% confidence interval, the estimated mean was generally lower than the true mean (Table IV-1). Therefore, for sampling intensities above 20% to 30%, a 95% confidence limit about the mean EMD count was accurate 93% to 95% of the time. When it failed, the sample mean EMD count tended to underestimate the true mean.

#### D. AN APPROACH FOR SELECTING A REDUCED SAMPLING PROGRAM

Selection and implementation of any reduced impingement sampling program at Indian Point requires two types of information: 1) desired and attainable levels of precision and accuracy and 2) an acceptable sampling plan for the goals of the study. Table IV-2 presents the actual sampling allocations for the stratified designs used in the above analysis. To illustrate the selection of a reduced sampling design using the results of this analysis, assume that a seasonal

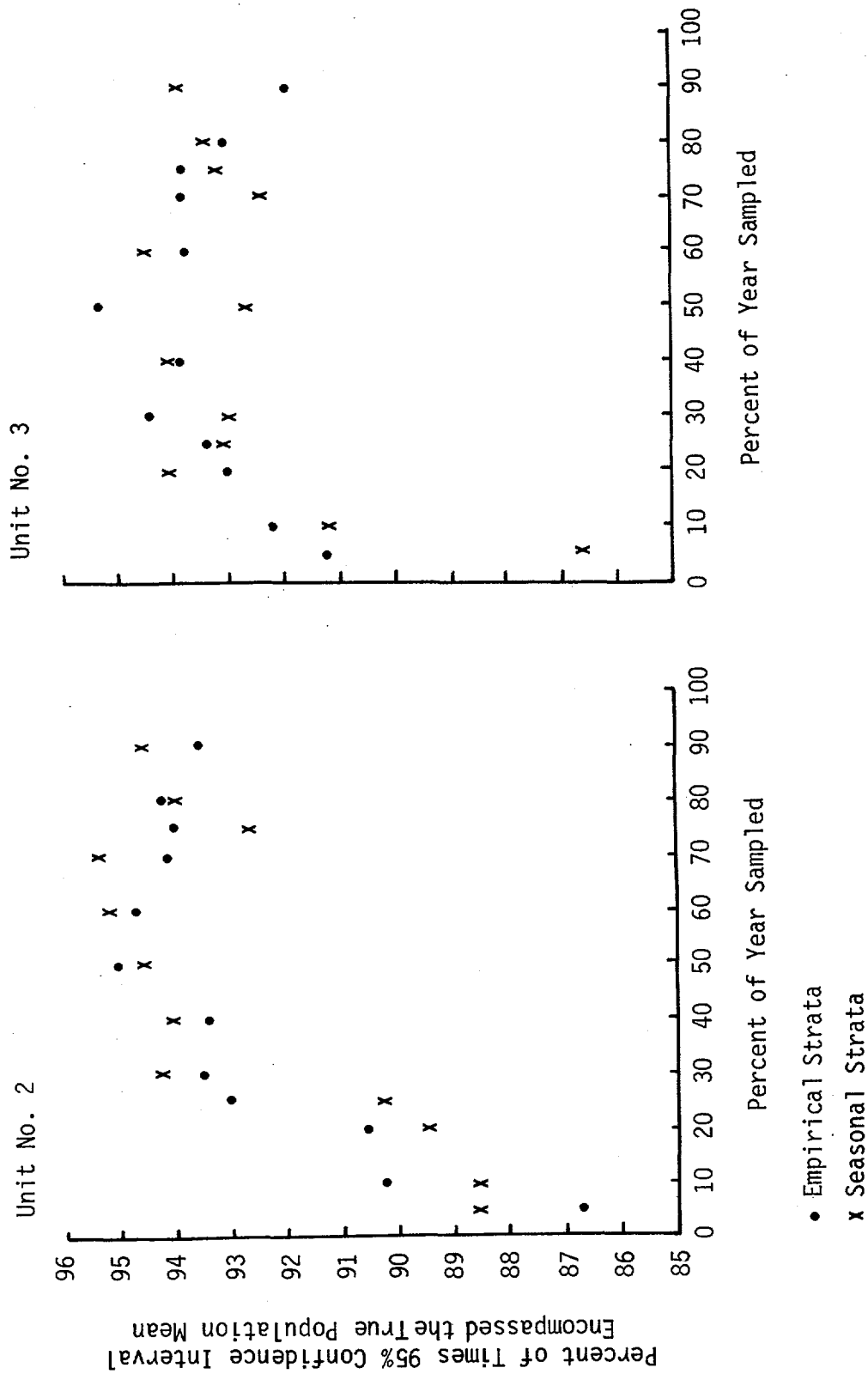


Figure IV-6. Accuracy of Two Stratified Random Sampling Designs for Calculating Mean Estimated Maximum Daily (EMD) Impingement at Various Intensities of Sampling at Indian Point Units No. 2 and No. 3 (accuracy measured as percent of times estimated mean EMD count with a 95% confidence interval enclosed true population mean for 1000 simulations)



Table IV-1

Accuracy and Relative Bias for Two Stratified Random Sampling Designs,  
Expressed as Percent of Times Calculated Mean Estimated Maximum Daily  
(EMD) Impingement with 95% Confidence Limits was Higher or Lower  
than True Mean\*

	Sampling Fraction (percent)	Seasonal			Empirical		
		Percent Missing Low	Percent Missing High	Total Percent Missing	Percent Missing Low	Percent Missing High	Total Percent Missing
Unit No. 2	05	11.4	0.0	11.4	12.9	0.4	13.3
	10	11.2	0.2	11.4	9.6	0.2	9.8
	20	10.0	0.5	10.5	9.1	0.4	9.5
	25	8.8	0.9	9.7	6.5	0.5	7.0
	30	5.2	0.5	5.7	5.5	1.0	6.5
	40	5.2	0.7	5.9	5.3	1.3	6.6
	50	4.3	1.1	5.4	4.2	0.8	5.0
	60	4.1	0.7	4.8	3.7	1.6	5.3
	70	3.4	1.2	4.6	4.1	1.7	5.8
	75	5.7	1.6	7.3	5.1	0.9	6.0
	80	4.6	1.3	5.9	4.4	1.4	5.8
	90	4.3	1.1	5.4	5.2	1.2	6.4
Unit No. 3	05	13.1	0.3	13.4	8.7	0.1	8.8
	10	8.5	0.3	8.8	6.8	1.0	7.8
	20	5.2	0.7	5.9	5.9	1.1	7.0
	25	6.2	0.7	6.9	5.1	1.5	6.6
	30	6.7	0.3	7.0	4.8	0.8	5.6
	40	4.7	1.3	6.0	4.9	1.2	6.1
	50	5.6	1.7	7.3	3.6	1.1	4.7
	60	4.7	0.8	5.5	4.9	1.3	6.2
	70	5.7	1.9	7.6	5.0	1.2	6.2
	75	5.3	1.5	6.8	5.0	1.2	6.2
	80	5.9	0.7	6.6	5.4	1.5	6.9
	90	5.8	0.3	6.1	6.8	1.2	8.0

\*Results were based on 1000 simulations for each design at each sampling fraction



**Table IV-2**  
**Sample Allocations\* for Stratified Random Sampling Using Empirical or Seasonal Strata**

Stratified Sampling Design	Stratum Dates	Percent of Year Sampled												
		5	10	20	25	30	40	50	60	70	75	80	90	100
Unit No. 2 Seasonal Stratification	01 Jan - 31 Mar	4	8	16	20	24	32	52	73	92	92	92	92	92
	01 Apr - 30 Jun	2	3	6	8	9	13	20	28	38	47	57	76	90
	01 Jul - 30 Sep	2	3	6	7	9	11	19	26	34	43	51	69	91
	01 Oct - 31 Dec	11	23	45	57	68	90	92	92	92	92	92	92	92
	Total per year	19	37	73	92	110	146	183	219	256	274	292	329	365
Empirical Stratification	01 Jun - 31 Aug	2	3	7	9	11	18	25	32	44	52	61	79	92
	01 Sep - 30 Sep	2	2	2	3	3	5	8	10	13	16	18	24	30
	01 Oct - 27 Nov	7	18	38	47	57	58	58	58	58	58	58	58	58
	28 Nov - 15 Mar	4	10	20	26	31	52	73	95	108	108	108	108	108
	16 Mar - 07 Apr	2	2	2	2	2	3	4	5	7	9	10	13	23
08 Apr - 31 May	2	2	4	5	6	10	15	19	26	31	37	47	54	
Total per year	19	37	73	92	110	146	183	219	256	274	292	329	365	
Unit No. 3 Seasonal Stratification	01 Jan - 31 Mar	4	7	15	18	22	28	37	44	53	58	64	76	92
	01 Apr - 30 Jun	4	7	14	18	22	29	35	41	50	56	62	73	90
	01 Jul - 30 Sep	4	9	17	21	25	34	42	51	61	68	74	88	91
	01 Oct - 31 Dec	7	14	27	35	41	55	69	83	92	92	92	92	92
	Total per year	19	37	73	92	110	146	183	219	256	274	292	329	365
Empirical Stratification	01 Jun - 31 Aug	4	9	18	23	28	37	47	58	75	83	92	92	92
	01 Sep - 30 Sep	2	2	2	3	3	4	4	6	8	8	9	13	30
	01 Oct - 10 Dec	5	12	25	32	37	50	64	71	71	71	71	71	71
	11 Dec - 31 Jan	2	6	10	12	15	20	24	31	39	44	48	52	52
	01 Feb - 25 Mar	2	3	7	8	10	13	16	20	26	29	32	50	53
26 Mar - 15 Apr	2	3	7	9	11	14	18	21	21	21	21	21	21	
16 Apr - 31 May	2	2	4	5	6	8	10	12	16	18	19	30	46	
Total per year	19	37	73	92	110	146	183	219	256	274	292	329	365	

\*Values represent the number of days to be randomly selected from each temporal stratum for various sampling fractions (percent of year sampled) at Indian Point Units No. 2 or No. 3



stratification scheme and a 50% reduction in sampling was desired for Indian Point Unit No. 2. A 50% reduction in effort would require 183 days of sampling per year. Figure IV-4 indicates that for a seasonal stratified design the mean daily impingement count for one year's data would have an expected precision level of  $\pm 4.6$  percent (the coefficient of variation) of the mean daily collection size. Given the size of impingement collection in the 1976 through 1979 period, this precision would allow estimation of the annual mean daily collection size to within  $\pm 354$  fish (the standard error of the 1976 through 1979 mean EMD count). Using Equation (3), this would allow a precision of  $\pm 129,000$  fish when estimating annual total impingement. The 95% confidence interval about the yearly mean daily impingement count would catch the true yearly mean better than 94% of the time (Figure IV-6). If this level of precision and accuracy was desirable and acceptable, the design could be implemented by randomly taking daily impingement samples according to the scheme in Table IV-2. A 50% reduction in sampling effort at Unit No. 2 using seasonal stratification would require that impingement collections be made on the following number of randomly selected days in each season.

01 Jan through 31 Mar = 52  
01 Apr through 30 Jun = 20  
01 Jul through 30 Sep = 19  
01 Oct through 31 Dec = 92

Periods of the year with high and variable daily impingement counts require intensive sampling (e.g., October through December where sampling was every day), while few days need be sampled in low variation periods (e.g., April through September); the object being to achieve a low probability of not sampling days with high impingement counts. This is accomplished by sampling every day during periods of high variation. Low variation periods naturally have a low probability of missing days with high impingement counts since these periods contain few or no high impingement days. For strata with intermediate variability (e.g., January through March), selecting additional days, up to all days, would insure that all days with high impingement counts were selected. It



would also be possible, during intermediate periods, to institute a system wherein once high impingement was encountered in a "less-than-daily" sampling mode, sampling could revert to a daily schedule until daily counts decreased.

#### E. SUMMARY

Daily variation in impingement counts was analyzed to determine its effect on precision and accuracy of reduced sampling plans for Indian Point Unit No. 2 and Unit No. 3. Precision increased logarithmically as more days in the year were sampled. Simple random sampling was the least precise and stratified random sampling was the most precise design at all reduced sampling levels. For stratified sampling, an empirical stratification scheme based on sampling during periods of high and low variation among daily impingement counts was only slightly more precise than seasonal stratification, primarily because of the tendency for periods of natural variation to be seasonal. Sampling more than 30% of the year at Unit No. 2 and 20% of the year at Unit No. 3 achieved an accuracy of approximately 93% to 95% in estimating mean daily or annual total impingement counts. Finally, information was presented which illustrated the use of these results to select a reduced impingement sampling design at Indian Point Units No. 2 and No. 3.





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SECTION V  
IMPINGEMENT AS AN INDEX OF FISH ABUNDANCE

A. INTRODUCTION

The Indian Point Generating Station can be viewed as a year-round shoreline fish sampler due to the continuous withdrawal of water from the Hudson River for cooling and the resultant impingement of fish on water intake screens. Thus, it may provide a means of detecting major changes in the abundance of the impingeable life stages of the more common species in impingement collections. For example, studies of North Carolina's Cape Fear estuary in relation to impingement at the Brunswick Steam Electric Generating Station revealed that the relative abundance of impinged organisms generally reflected that organism's relative abundance in the estuary (Carolina Power and Light Company 1980). Claridge and Gardner (1978) assumed impingement provided a reliable sample and monitored growth and movements of the twait shad (Alosa fallix) by collecting samples from the cooling water intake screens of three power stations along the Severn Estuary and Bristol Channel in western England. To investigate the possibility of using impingement to monitor fish abundance in the Hudson River estuary, annual changes in riverwide abundance of white perch, striped bass, and Atlantic tomcod as estimated from fisheries collections made during 1973 through 1978 were compared to annual variations in impingement of these species at the Indian Point Generating Station only. Since annual changes in distribution of fish within the river may in itself result in variation in annual impingement magnitude at Indian Point or any other fixed location, impingement at five generating stations along the Hudson River (Bowline, Lovett, Roseton, Danskammer, and Indian Point) was combined and also compared to the riverwide abundances of these three species.

B. DERIVATION OF INDICES AND ANALYTICAL APPROACH

Previous analyses indicated that the major variables affecting impingement at the Indian Point Generating Station were the volume of cooling water circulated through the plant and changes in water



temperature and salt front position in the estuary. Changes in salt front position cause changes in fish distribution and thus alter vulnerability to impingement. The primary factor influencing water temperature and salt front position is the volume of fresh water entering the estuary (TI 1976). Therefore, impingement counts were adjusted by covariance analysis (Helwig and Council 1979) to remove variation due to changes both in volume of cooling water circulated and freshwater flow. The remaining annual differences in impingement counts should then be due primarily to changes in the abundance of fish species impinged or to random error. The annual counts (unadjusted for collection efficiency) were used to rank each year in order of greatest to least impingement.

In the course of the Hudson River Ecological Study several indices have been developed to evaluate annual abundance changes of the key species (white perch, striped bass, and Atlantic tomcod) in the estuary (TI 1980b). Abundance indices selected for comparison with impingement counts in this analysis were those which provided an estimate of the life stages impinged. The juvenile abundance index derived from beach seine collections in late summer and fall were used for white perch and striped bass. The summer-fall abundance index for juvenile Atlantic tomcod, however, was not used since an unknown proportion of the juvenile population appears to emigrate from the sampling area during some years. This movement would lead to erroneously low abundance indices for those years that the tomcod left the sampling area. Therefore, the winter spawning population estimate was selected as the most reliable estimate of annual abundance for Atlantic tomcod.

Comparisons between adjusted annual impingement and annual abundance were then made for each species for the Indian Point Generating Station alone and the five stations combined. Two sets of ranks for the years 1973 through 1978 were developed, one based on annual impingement counts adjusted for freshwater flow and volume of water circulated and a second based on selected annual abundance indices. The two rankings were then compared using Kendall's Rank



Correlation Coefficient,  $\tau$  (Siegel 1956). Significantly similar rankings indicated that impingement reflected annual changes in riverwide abundance of the life stage represented by the selected abundance index. Also, to the extent that the index reflected year class strength, a similar ranking would be indicative that impingement could be useful as a measure of year class strength.

The effect of adjusting impingement counts for freshwater flow was tested by performing the same analyses described above without this adjustment. This evaluation was not done for volume circulated since it has been shown in previous analyses to account for a significant amount of variation in impingement (TI 1980a).

## C. RESULTS

### 1. White Perch

The rankings of white perch based on annual impingement at the Indian Point Generating Station from July 1973 through June 1979 and the rankings based on the riverwide juvenile abundance index for these years were similar; however, the relationship was not significant ( $p = 0.85$ ). The ranking of annual impingement for the five stations combined, however, was significantly similar ( $p = 0.01$ ) to rankings based on the riverwide juvenile abundance index (Table V-1). Removal of the freshwater flow adjustment did not change the white perch impingement ranking.

### 2. Atlantic Tomcod

Adjusted impingement values for Atlantic tomcod at the Indian Point Generating Station in the months September through March were compared to the ranking of annual adult spawning population estimates made during corresponding time periods for the years 1974 through 1979. The rankings were not significantly similar ( $p = 0.14$ ) (Table V-2). Adjusted impingement at the five power plants combined was also not significantly similar ( $p = 0.14$ ) to adult population size (Table V-2). Ranking Atlantic tomcod without a freshwater flow adjustment changed the



Table V-1

Comparison of Annual Ranking of White Perch Abundance from Adjusted Impingement Collections at Indian Point Alone, and at Indian Point, Bowline, Lovett, Roseton, and Danskammer Generating Stations Combined to Selected Riverwide Abundance Indices for July 1973 through June 1979 Using Kendall's Rank Correlation Coefficient ( $\tau$ ) and Associated Probabilities of Independence ( $p$ )

Annual Abundance Ranking*		
Indian Point Impingement	Juvenile Abundance	Combined Impingement
1976	1973	1973
1978	1975	1976
1977	1976	1975
1975	1978	1978
1974	1977	1977
1973	1974	1974
$\tau = -0.07$		$\tau = 0.87$
$p^\dagger = 0.85$		$p^\dagger = 0.01$

\*Ranked high to low from top to bottom  
 $\dagger p < 0.05$  indicates significantly similar rankings

Table V-2

Comparison of Annual Ranking of Atlantic Tomcod Abundance from Adjusted Impingement Collections at Indian Point Alone and at Indian Point, Bowline, Lovett, Roseton, and Danskammer Generating Stations Combined to Riverwide Spawning Population Estimates for September 1974 through March 1979 Using Kendall's Rank Correlation Coefficient ( $\tau$ ) and Associated Probabilities of Independence ( $p$ )

Annual Abundance Ranking*		
Indian Point Impingement	Spawning Population Estimate	Combined Impingement
1974	1976	1976
1976	1978	1974
1978	1974	1978
1975	1975	1977
1977	1977	1975
$\tau = 0.60$		$\tau = 0.60$
$p^\dagger = 0.14$		$p^\dagger = 0.14$

\*Ranked high to low from top to bottom  
 $\dagger p < 0.05$  indicates significantly similar rankings



probability for plants combined and Indian Point to  $p = 0.33$  which also is not significant.

### 3. Striped Bass

Rankings based on impingement collections of striped bass at the Indian Point Generating Station were not significantly similar ( $p = 0.85$ ) to the juvenile abundance index ranking from July 1973 through June 1979 (Table V-3). The same comparison for adjusted impingement at the five generating stations combined was also not significantly similar ( $p = 0.85$ ). Removal of the freshwater flow adjustment to impingement did not change the striped bass impingement ranking.

Table V-3

Comparison of Annual Ranking of Striped Bass Abundance from Adjusted Impingement Collections at Indian Point Alone and at Indian Point, Bowline, Lovett, Roseton, and Danskammer Generation Stations Combined to Selected Riverwide Abundance Indices for July 1973 through June 1979 Using Kendall's Rank Correlation Coefficient ( $\tau$ ) and Associated Probabilities of Independence ( $p$ )

Annual Abundance Ranking*		
Indian Point Impingement	Juvenile Abundance	Combined Impingement
1977	1973	1973
1978	1978	1974
1976	1977	1975
1974	1975	1977
1975	1976	1978
1973	1974	1976
$\tau = -0.07$ $p^\dagger = 0.85$	$\tau = 0.07$ $p^\dagger = 0.85$	

\*Ranked high to low from top to bottom

$^\dagger p < 0.05$  indicates significantly similar rankings



#### D. SUMMARY OF IMPINGEMENT TO RIVER ABUNDANCE INDICES COMPARISONS

To evaluate the usefulness of impingement collections for monitoring year class strength, annual impingement counts (adjusted for variation due to changes in volume circulated through the plant and freshwater flow into the estuary) at the Indian Point Generating Station and at Bowline, Lovett, Roseton, Danskammer, and Indian Point generating stations combined were compared to selected annual abundance indices for white perch, Atlantic tomcod, and striped bass. The abundance indices were developed from riverwide fisheries gear collections and selected for these comparisons based on previous evaluations of their representation of year class strength (TI 1980b) for the life stages impinged.

Impingement collections at the five stations combined can be used to obtain a general indication of juvenile abundance for white perch. However, white perch juvenile abundance has not been shown to reflect relative abundance of the year class in later years (TI 1980b), thus changes in annual impingement may not indicate relative year class strength. VanWinkle et al. (1980) performed a similar comparison for white perch using a portion of the data set (1972 through 1976) used in this report. They selected portions of each year's impingement, used abundance indices based on a shorter sampling period, and reported a nonsignificant correlation between annual rankings of impingement and juvenile abundance indices.

Impingement collections cannot be used to obtain a general indication of abundance of the other two key species (i.e., striped bass and Atlantic tomcod). For Atlantic tomcod, the annual ranking of the spawning population size did not match the annual ranking of impingement collections; thus, year class strength of this species was not reflected by impingement either. Although impingement collections of striped bass did not reflect annual abundance of juvenile striped bass, the years included in this analysis covered a time span with only one large year class (1973). The low degree of variation in the juvenile abundance index during 1974 through 1978 may have been smaller than the sampling error. In other words, impingement collections could reflect large



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differences in juvenile striped bass abundance but appear not to be sensitive enough to reflect small changes.





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## SECTION VI

### EVALUATION OF INFERENCES DRAWN FROM STANDARD STATIONS DATA

#### A. INTRODUCTION

The objective of this section is to determine if similar inferences concerning fish populations in the Indian Point area can be drawn from the two separate but overlapping sampling programs currently being performed. Since 1973, TI has sampled the Hudson River estuary in the vicinity of the Indian Point Generating Station (RM 42) with two distinct beach seine programs: the "Standard Stations" Program in which fixed sites from RM 39 through RM 43 are sampled, and the "Long River" Beach Seine Survey in which a subset of sites is randomly chosen for sampling from all available sites in each of 12 river regions (Yonkers through Albany, RM 12 through RM 152), one of which is the Indian Point region (RM 39 through RM 46). This section seeks to answer the question: "Will standard stations sampling reveal the same trends in relative abundance and species composition as long river sampling conducted in the Indian Point region?"

The origin and development of the Standard Stations Program and the subsequent development of the more extensive Long River Surveys will be reviewed. The gear and sampling designs will be compared to determine the redundancy of the two sampling programs. Past comparisons of standard station and long river data will be reviewed. Species composition and relative abundance, as indicated by standard stations and long river beach seining in the Indian Point region, will be compared statistically to determine if the same inferences can be derived from both surveys. Finally, an assessment will be made to determine which type of sampling would be more worthwhile if only one survey was continued.



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## B. ORIGIN AND DEVELOPMENT OF STANDARD STATIONS AND LONG RIVER SAMPLING

An intensive study of the Hudson River estuary in the area of Indian Point was begun in June 1969 to provide information necessary for the evaluation of the ecological impact of the Indian Point Nuclear Generating Station. Raytheon Company (1971) conducted an initial baseline study during which fish, invertebrate, and water chemistry samples were collected at a number of fixed stations between Croton Point (RM 34) and the Bear Mountain Bridge (RM 46). Based on the results of the baseline survey which ended in October 1970, an expanded study was initiated in early 1972 to permit assessment and mathematical modeling of plant impact. This expanded study included the present Standard Stations Program (TI 1973). Some changes have occurred since the inception of standard stations sampling, but the overall program has remained essentially the same (TI 1980a). The objectives of standard stations sampling were: 1) to determine the relative abundance and species composition of juvenile and older fishes in the Indian Point area and 2) to provide biocharacteristic data to determine the age structure, growth rates, and fecundity of the Hudson River populations of striped bass, white perch, and Atlantic tomcod (identified as the key species). Standard station sampling also continued the data base established by the initial baseline study.

As new electric generating plants came on line and proposals for new sites along the Hudson River were presented, the need for an environmental study of the entire estuary became apparent. Beginning in 1973, more extensive surveys were conducted in addition to standard stations sampling (TI 1975a). Beach seine samples were collected weekly from the George Washington Bridge (RM 12) to the Troy Dam (RM 153) using a stratified random design to select sample sites. Also, bottom trawl samples were collected biweekly at fixed stations between the Tappan Zee (RM 27) and Newburgh-Beacon (RM 62) bridges. These Long River Surveys were designed to gather information on the spatiotemporal distribution of the estuarine fishes and provide additional effort for the ongoing Mark-Recapture Program.



Thus, since 1973, TI has been sampling juvenile and older fishes of the Indian Point area using two separate but similar programs: 1) the Long River Program including Beach Seine and Interregional Bottom Trawl Surveys and 2) Standard Stations Program including beach seine, bottom trawl, and surface trawl sampling (Table IV-1). The same types of data (i.e., fish collections with concurrent water quality data) have been collected by both surveys, and to this extent the two sampling programs have overlapped and duplicated effort.

Although beach seines used by the two programs have been identical, the programs have differed in sampling design. The sites sampled in the Standard Stations Program have been fixed (i.e., the same sites have been sampled consistently and always at low tide) while those sampled in the Long River Survey are randomly chosen from all available sites and are sampled without regard for tidal stage. However, neither of the two beach seine sampling programs has had a truly random or totally fixed design. Because beach seine sampling is restricted to areas suitable for seining (i.e., unobstructed beaches), the Long River Survey has sampled a randomly selected subset of fixed stations. Furthermore, because estuaries are highly variable (e.g., fluctuations in salinity, freshwater flow, etc.), fixed location sampling is not as consistent in the lower Hudson as it would be in systems where the environment is more constant (e.g., terrestrial ecosystems or small lakes). Thus, long river and standard station beach seining designs have differed only minimally and therefore might provide similar results.

Bottom trawls, used by the two programs have not been the same. The Standard Stations Program has used a trawl equipped with smaller trawl doors and both a trawl with a fine-mesh liner and a trawl without the liner in the cod end. The Long River Survey has used only one trawl equipped with larger trawl doors and a fine-mesh cod-end cover. These gear differences would confound any differences due to sampling design that exist between Standard Station and Long River Bottom Trawl Programs. Differences between programs in trends in abundance for juvenile Atlantic tomcod during 1965 through 1977 have been attributed to gear differences (TI 1979b). Therefore, only beach seine data have been used in the new analyses presented in this section.



Table VI-1  
 Comparison of Standard Stations and Long River Fisheries Sampling  
 in Indian Point Region, Hudson River Estuary

Gear*	Standard Stations	Long River in Indian Point Region
30.5-m Beach Seine	Stations: 7 fixed sites Frequency: weekly Time: day, 2 hr before low tide Season: April through December	Stations: Chosen randomly from all recognized available beaches Frequency: one or more days/week until regional allocation filled Time: day, no regard to tidal stage Season: April through December
13.5-m Bottom Trawl	Stations: 7 fixed sites Frequency: biweekly (2 sets of samples) a. one using unlined net b. one using fine mesh liner Time: day Season: April through December Tow Duration: 10 min. Gear: trawl doors, 0.38 m x 0.76 m	Stations: 11 fixed sites Frequency: biweekly (alternate weeks from Standard Stations) Time: day Season: April through December Tow Duration: 5 min. Gear: trawl doors, 0.76 m x 1.22 m fine mesh cod-end cover
15.0-m Surface Trawl	Stations: 7 fixed sites Frequency: biweekly Time: day Season: July through December	Not Used

\*For complete gear descriptions see TI 1980a and TI 1980b



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## C. COMPARISONS OF STANDARD STATIONS AND LONG RIVER DATA

### 1. Previous Comparisons of Species Composition and Abundance

Previous analyses of standard stations and long river beach seine data have focused on the degree to which nearfield (standard stations) data represented the species composition of the estuary and patterns of abundance in the estuary for selected species examined individually. Qualitative comparison of species composition during 1974 through 1978 revealed that the same 10 species contributed from 91% to 97% of the beach seine catches of both surveys (TI 1980a). Comparisons of juvenile blueback herring and bay anchovy abundance during 1975 through 1977 indicated that standard stations and long river data each yielded the same inferences concerning yearly patterns and magnitude (TI 1979b).

### 2. New Analyses: Community Comparison within Indian Point Area

#### a. Species Composition

To determine if standard stations and long river beach seining in the Indian Point region produced the same representations of species composition, rankings based on percentages of the combined catch-per-effort (C/f) of the 10 most abundant species (Appendix Table B-6) were compared for each year, 1976 through 1979\*, and across years using Kendall's  $\tau$  (a non-parametric rank correlation test, Siegel 1956). The rankings were significantly correlated for each year except 1979 and for the across years comparison (Table VI-2). Thus, standard stations and long river beach seining in the Indian Point region usually reflected the same species composition for the Indian Point region.

The lack of a significant correlation during 1979 was due to a difference in the proportions of blueback herring collected in the two surveys. During 1976 through 1978, blueback herring was the most abundant species in both surveys comprising 34% to 60% of the combined

\*Although data have been collected from 1973 through 1979, at the time of this writing the 1973 through 1975 beach seine data from long river sampling were in a format that was incompatible with this analysis.



Table VI-2  
 Comparison of Catch/Effort Rankings of Ten Most Abundant Fish Species Collected by  
 Standard Stations and Long River Beach Seining in Indian Point Region,  
 Hudson River Estuary, during 1976 through 1979

Species	Catch/Effort Rankings									
	Standard Stations Survey					Long River Survey (Indian Point Region)				
	1976	1977	1978	1979	1976-1979	1976	1977	1978	1979	1976-1979
Blueback herring	1	1	1	8	1	1	1	1	1	1
White perch	2	3	4	2	3	2	3	3	4	4
Banded killifish	3	4	2	1	2	4	8	4	2	5
American shad	4	7	3	7	4	5	4	2	5	3
Spottail shiner	5	5	6	5	6	6	5	8	6	6
Tessellated darter	6	8	8	4	8	8	9	9	9	9
Bay anchovy	7	2	7	3	5	3	2	6	3	2
Alewife	8	9	9	10	9	7	6	5	10	7
Striped bass	9	6	5	6	7	10	7	7	8	8
Pumpkinseed	10	10	10	9	10	9	10	10	7	10

Kendall's $\tau$	0.73	0.64	0.64	0.33	0.64
Probability Level	<0.005	<0.005	<0.005	0.10	<0.005



C/f of the 10 species (Appendix Table B-6). However, in 1979, blueback herring contributed only 5% of the standard stations combined C/f while continuing to contribute the majority of the long river C/f. Apparently, blueback herring migrated through the Indian Point region quickly in 1979 and were "missed" by standard stations sampling. This interpretation is based upon the fact that 78.2% of the blueback herring collected during long river beach seine sampling came from only one tow made on 18 October (Appendix Table B-9). Standard stations were sampled on the previous day when 21.8% of the total blueback herring catch by the Standard Stations Program was collected in one sample. Standard stations were not sampled again for a week, a period during which the blueback herring migration through the Indian Point area probably peaked. Standard stations sampling may have missed the peak of the migration in 1979 because of a rapid movement through the Indian Point region. Examination of biweekly catch-per-effort values for young-of-the-year blueback herring from 1976, which is thought to have been a smaller year class than that of 1979, revealed that blueback were present in the Indian Point region for an extended period (July through November) and were reasonably well represented in nearfield catches (TI 1977c). Thus, the duration of the period in which blueback herring occupy the Indian Point region appears to be more important than year class size in determining catch sizes of standard stations samples.

#### b. Trends in Community Abundance

Trends in abundance of the major species comprising the Indian Point fish community were compared between programs using a multivariate analysis of variance (MANOV), (Morrison 1976). Catch data from each sample was transformed to reduce problems of nonnormality and variance heterogeneity. The common transformation  $\ln(x+1)$  was used (Gnanadesikan 1977), where  $x$  was the number caught, for each of the 10 most abundant species (all life stages combined). Mean annual C/f's were calculated from the transformed data for each program. For each species, the mean transformed C/f was subtracted from that of the previous year for each pair of years: 1976-1977, 1977-1978, 1978-1979. The standard stations differences were then subtracted from the long river differences and the





results compared to zero (zero would indicate that exactly the same changes were occurring in both programs) using MANOV (Figure VI-1). This technique tested the "community" of major species rather than each species individually and avoided the problem of multiple species comparisons and inflated  $\alpha$  levels. Because station 11 was not sampled

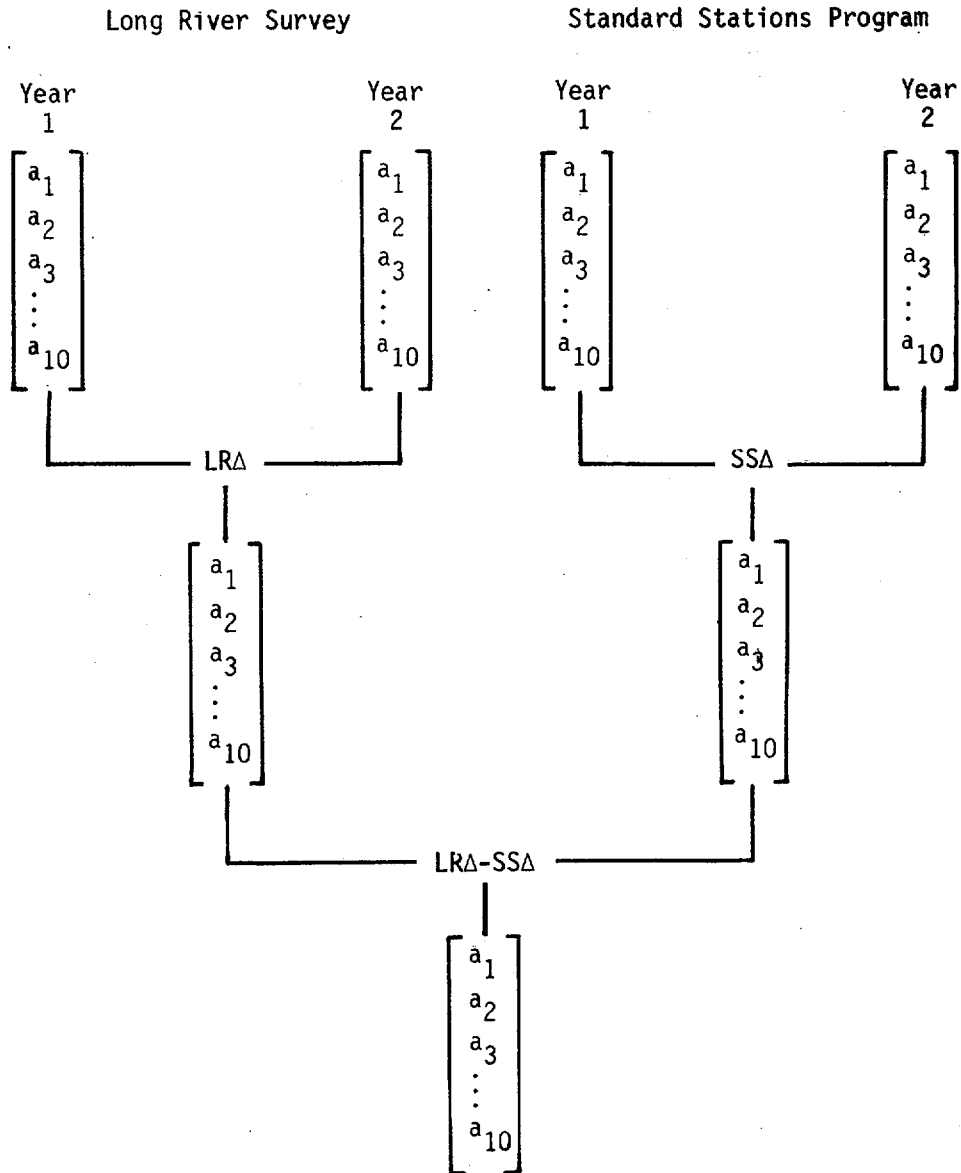


Figure VI-1. Diagrammatic Origin of Values Used in Multivariate Analysis of Variance (MANOV) for Comparing Trends in Abundance in Standard Stations (SS) versus Long River (LR) Beach Seine Collections in Indian Point Region, Hudson River Estuary, during 1976 through 1979 (values  $a_1$  through  $a_{10}$  = annual transformed C/f's or  $\Delta C/f$ 's)



after September during 1979 (Appendix Section C.2), the analysis was performed both with and without the data for that station during that year to determine if the loss of that station half way through the sampling year affected the results.

The trends in abundance were not significantly different between programs from 1977 to 1978 and 1978 to 1979, but were significantly different from 1976 to 1977 (Table VI-3). The deletion of data from station 11 for 1979 did not affect the results. The discordance between programs for the 1976 to 1977 comparison was produced primarily by differences for certain species in the magnitude of the change in abundance from 1976 to 1977 (Figure VI-2). For example, while abundance of tessellated darter declined from 1976 to 1977 in both programs, the decrease was much larger in the Standard Stations Program. Banded killifish, pumpkinseed, alewife, and bay anchovy also exhibited differences in the magnitude of the change in abundance from 1976 to 1977. However, the change in abundance from 1976 to 1977 was quite similar between programs for striped bass, American shad, white perch, spottail shiner, and blueback herring.

Table VI-3

Results of Multivariate Analysis of Variance of Trends in Abundance as Determined from Standard Stations Sampling Program versus Long River Beach Seine Sampling in Indian Point Region, Hudson River Estuary, 1976 through 1979

	Comparison			
	1976 to 1977	1977 to 1978	1978 to 1979	1978 to 1979*
$T^2$	25.65	15.98	4.93	6.72
Probability Level	0.01	0.15	0.91	0.79

\*Excluding station 11

#### c. Discussion

The two programs exhibited similar trends in species composition and community abundance. The differences that occurred may have been related to sampling intensity. During 1976 through 1978 when samples were allocated to each region based on the distribution of

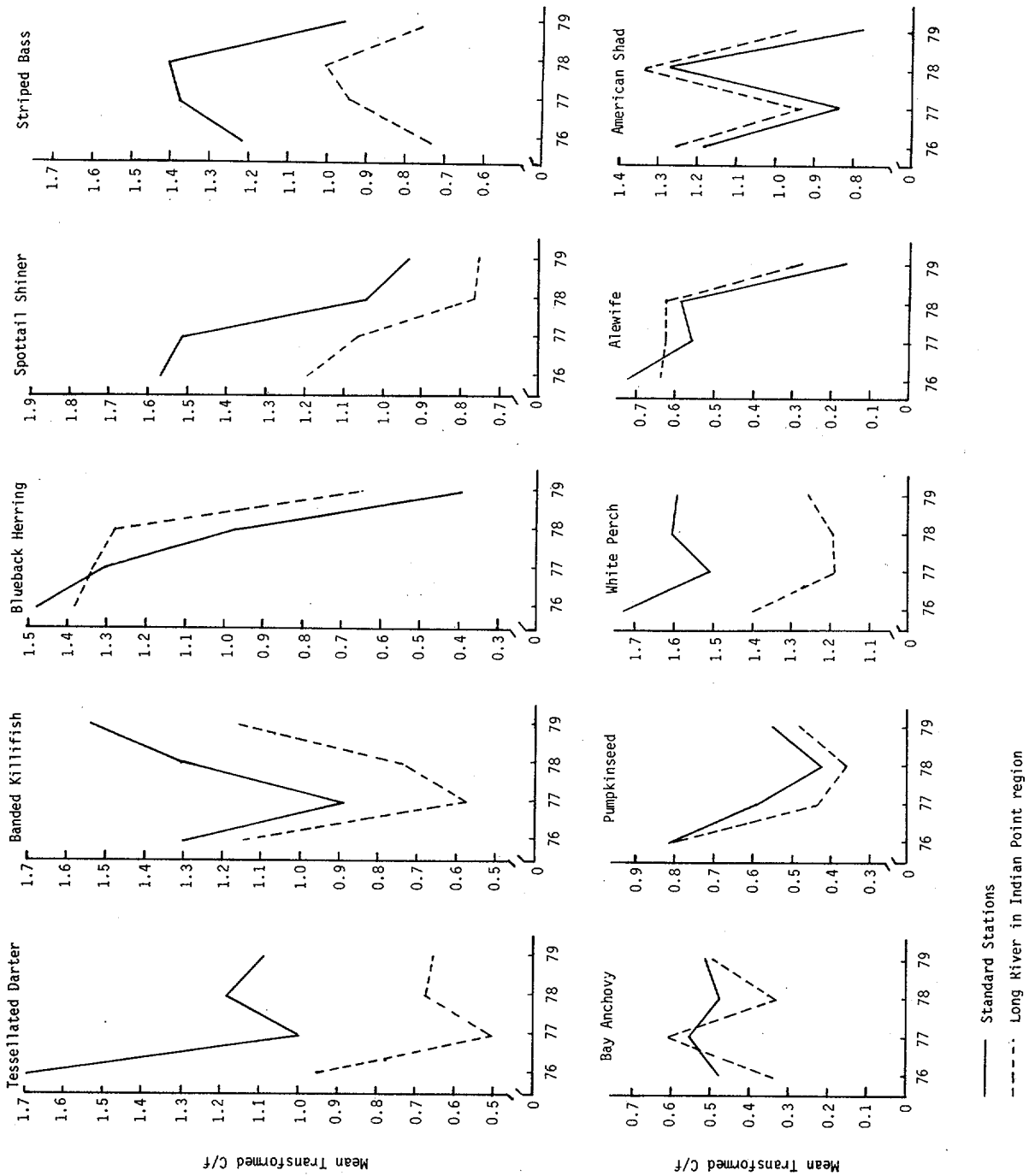


Figure VI-2. Comparison of Year-to-Year Changes in Abundance of Ten Most Abundant Fish Species as Determined during Standard Stations and Long River Beach Seine Survey in Indian Point Region, Hudson River Estuary, 1976 through 1979



juvenile striped bass, the number of long river beach seine tows in the Indian Point region was more than twice that of standard stations tows (Table VI-4). Beginning in 1979, long river samples were allocated to each region based on shore zone surface area, and the sampling efforts of the two programs were almost equal.

Table VI-4  
Number of Beach Seine Samples Collected during Standard Stations  
and Long River Sampling in Indian Point Region,  
Hudson River Estuary, 1976 through 1979

Year	Standard Stations Program	Long River Survey
1976	251	712
1977	271	703
1978	267	584
1979	242	226

Because of the greater sampling effort, relative abundance was probably more accurately depicted by the Long River Survey during 1976 through 1978. While the allocation scheme adopted in 1979 has removed this advantage of long river sampling, other features of the long river sampling design make it the better program.

The fixed station design of standard stations increases the danger of bias due to confounding with natural features within the Indian Point region. One such confounding natural feature is the tendency for the catches of some species to be larger at low tides than at other tidal stages (TI 1973). This may result from increased density due to a reduction in available habitat. Larger catch at low tide explains the greater abundance of most species in standard station beach seine collections than in long river collections (Figure VI-2), because standard stations are always sampled immediately prior to low tide while long river beach seining is scheduled without regard to tidal condition.



However, abundance was not greater in standard station collections for all species. Therefore, if comparisons of relative abundance among species are made, standard station data would include a bias not present in long river beach seine data. Additionally, cluster analysis of standard stations beaches indicated that each beach appeared to have its own unique species composition (TI 1980a). Therefore, the Long River Survey which selects sites from all available beaches in the region would give a better representation of the overall fish community.

The Long River Survey also has more beaches available for sampling; thus, the loss of one station would not threaten to disrupt the program as it did for standard stations in 1979 when one of the seven stations became unavailable for sampling. Furthermore, the Long River Survey has a greater frequency of sampling days during each week. All standard stations beaches are usually sampled on the same day each week while long river samples are generally taken over several days. Therefore, a species such as blueback herring which migrates through the Indian Point area would have a lesser chance of being "missed" by long river sampling.

#### D. SUMMARY AND CONCLUSIONS

Fishes in the Indian Point area have been sampled by two distinct but similar programs since 1973: Standard Stations and Long River. The programs originated for different purposes, but both are capable of gathering the same types of information. Gear differences confound comparisons of standard stations and long river bottom trawls; however, the beach seines are identical and have been shown to yield similar results. Past comparisons focused on the degree to which the Indian Point area reflected trends in fish abundance and species composition of the estuary in general. New analyses presented in this report compared standard stations and long river beach seine sampling in the Indian Point region to determine if the same inferences concerning the Indian Point fish community could be drawn from both surveys. Results indicated that species composition is usually the same for both surveys and that trends in abundance are usually, but not always, the



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same. The design of the Long River Survey has several advantages over the Standard Stations Program and may give a better representation of the Indian Point fish community.



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## SECTION VII

### GLOSSARY

- Age Composition (age structure):** The quantitative make-up of a group or population of fish based on age classes (e.g., age I, II, III, etc.); usually expressed as the proportion or percentage of individuals of a given age in the population.
- Brood Fish:** Fish used for spawning in a hatchery.
- Catch-Per-Effort (C/f):** The catch of fish, in number or weight, collected using a specified gear for a defined amount of time or effort, e.g., catch per tow, catch per volume.
- Conductivity (specific conductance):** A measure of the total concentration of the solutes in water (i.e., a measure of salinity) determined by a solution's capacity to conduct an electrical current. Since conductivity increases 2% to 3% for each degree centigrade, it is reported at a standard temperature of 25°C in millisiemens per centimeter (mS/cm).
- Con Edison:** Consolidated Edison Company of New York, Inc.
- Dissolved Oxygen:** Oxygen dissolved in water; derived from photosynthesis and diffusion of atmospheric oxygen. Expressed in milligrams per liter (mg/l).
- Estimated Maximum Daily (EMD) Impingement:** The number of fish which would have been impinged on the collection screens at Indian Point Unit No. 2 or No. 3 if the unit was pumping cooling water at maximum capacity at all six intake structures per unit. EMD impingement counts are obtained from the product of the daily impingement rate (numbers  $\cdot 10^6 m^{-3}$ ) and maximum pumping capacity ( $10^6 m^3$ ).
- Entrainment:** The passage of small organisms along with water through a power plant cooling system. Entrained organisms are organisms too small to be impinged (see Impingement).
- Estuary:** A semi-enclosed coastal body of water which has free access to the sea and which has salinity that is measurably diluted below the salinity of open ocean water by freshwater tributaries and surface drainage. For the Hudson system, the estuary is that portion of the Hudson River downstream from the Troy Dam at RM 153.
- Finclip:** A method for marking fish by excising one or more of the fins; this method is used on fish that are too small to be tagged effectively.
- Fingerling:** Juvenile fish approximately 50-150 mm total length.



**Impingement:** The process whereby the force of water being withdrawn through an intake screen forces organisms to come in contact with and be held against that screen.

**Indian Point Region:** An area of the Hudson River near the Indian Point Electric Generating Station (RM 39 through RM 46).

**Juvenile (Young-of-the-Year):** The lifestage beginning when a fish acquires the full complement of adult fin characteristics and extending to Age I (i.e., through 31 December of the year spawned).

**Long River (surveys):** Sampling programs that include several or all river regions (e.g., Interregional Bottom Trawl and Beach Seine Surveys).

**Lower Estuary:** As used in this report, includes the Yonkers (RM 12 through RM 23) and Tappan Zee (RM 24 through RM 33) river regions (characterized by variable but usually salt or brackish water).

**Magnetic Nose Tag:** Small piece of fine gauge wire magnetized for electronic detection and inserted into nasal cartilage of fish.

**Nearfield:** Area of the Hudson River estuary in the vicinity of a power plant. In this report, it refers to the area near the Indian Point Generating Station (RM 39 through RM 43).

**NRC:** Nuclear Regulatory Commission.

**Parent Population (sampling statistics):** Synonym for population, but used in connection with computer sampling routines which select subsets of data from a data base. The parent population is a data set containing all possible observations, e.g., the parent population of days in a year contains all 365 days.

**pH:** The measure of the hydrogen ion activity of a solution, i.e., its acidity or alkalinity. Neutral pH is 7, with increasing acidity from pH 7 to pH 1 and increasing alkalinity from pH 7 to pH 14.

**Population (sampling statistics):** Any collection of things (living or nonliving) about which information is required. For example, one can sample a population of days, fish, or rivers.

**Relative Abundance:** A measure of the number of organisms in a given time period or area relative to another time period or area.

**Riverwide:** As used in this report, refers to the "long river" study area encompassed by river miles 12 through 152.

**Salt Front:** The leading gradient area of a mass of seawater intruding into the estuary. Salt front is defined as the area associated with a conductivity of 0.3 mS/cm or equivalent to a salinity of about 0.1 part per thousand (‰).





**Size Selectivity:** Differential probability of capture of fish of varying sizes due to avoidance by the fish or to size of net mesh.

**Species Composition:** The assemblage of species found in an area. Also, the proportion of individuals of a given species making up the total number of individuals represented by all species (i.e., relative species composition).

**Standard Stations:** Standard sampling areas in the nearfield (RM 39 through RM 43) of the Indian Point Generating Station.

**Stratum (sampling statistics):** A subpopulation or subset of data. For example, the months in a year would represent 12 strata.

**TI:** Texas Instruments Incorporated.

**Turbidity:** The opacity of water caused by the presence of suspended particulate matter (such as clay, silt, microorganisms, or organic and inorganic detritus).

**Year Class:** A cohort of fish spawned or hatched during a given calendar year.

**Year Class Abundance:** The number or relative number of fish of a given species spawned or hatched during a given calendar year.

**Year Class Strength:** The abundance of each year class relative to other year classes.

**Yearling:** The age of fish during the calendar year following the year in which they were spawned.

**Young-of-the-Year:** See Juvenile.



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SECTION VIII

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IMPINGEMENT STUDIES

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.APPENDIX A.1

Total Counts of Each Species Impinged



Table A-1  
Total Monthly Actual Count of Each Species Collected from Intake Screens  
at Indian Point Unit No. 2 during 1979

TAXON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR_TOTAL
ALEWIFE	10	39	7	4	57	26	0	0	210	276	288	10	929
ANCHOVY	157	303	0	0	1634	167	0	0	17129	11546	238	64	31067
AMERICAN SHAD	6	0	0	0	0	0	0	0	419	1675	242	24	4743
BLUEFISH	21	5	0	0	5	17	0	0	11	7	0	0	43
BROWN BULLHEAD	325	179	23	7	43	20	0	0	37	265	173	107	233
PUMPKINSEED	2	3	3	0	2	10	0	0	0	0	77	109	165
BLACK CRAPPIE	2	4	0	0	0	0	0	0	0	0	0	3	3019
CARP	319	44	0	0	0	0	0	0	0	0	0	0	211
AMERICAN EEL	49	59	0	0	227	97	0	0	22	54	101	111	233
GOLDEN SHINER	12	11	168	129	22	0	0	0	0	11	1	14	370
HOGCHOKER	176	111	320	113	7	219	0	0	0	222	227	551	13107
LESSESLATED DARTER	69	113	20	438	4825	0	0	0	1737	222	227	551	13107
BANDED KILLIFISH	104	151	9	22	14	20	0	0	20	102	101	510	1005
EMERALD SHINER	1	1	0	0	0	0	0	0	0	0	0	0	844
LARGEMOUTH BASS	18	34	11	0	2	0	0	0	0	0	0	5	23
MUMMICHOG	200	0	0	0	0	0	0	0	0	0	0	0	840
ATLANTIC MENHADEN	0	0	0	0	0	0	0	0	0	0	0	0	20
ATLANTIC UNIDENTIFIED	41	11	0	14	176	65	0	0	997	95200	18937	111	115571
MINNOW UNIDENTIFIED	0	0	0	0	0	0	0	0	0	0	0	0	11
BLUEBACK HERRING	0	0	0	0	0	0	0	0	0	0	0	0	0
WHITE SUCKER	0	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC SILVERSIDE	0	0	0	0	0	0	0	0	0	0	0	0	0
RAINBOW SMELT	2657	3362	1175	1309	2624	211	0	0	453	1459	1444	1548	16263
SHORTNOSE STURGEON	782	368	774	634	59	0	0	0	16	164	310	850	3945
SPOTTAIL SHINER	4	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC STURGEON	19522	9669	4366	443	166	63	0	0	621	594	366	2426	38282
4-SPINE STICKLEBACK	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC TOMCOD	2515	891	434	496	678	8521	0	0	592	758	33	2817	29503
WHITE CATFISH	329	202	113	67	80	14	0	0	23	14	21	208	2040
WHITE PERCH	315681	286928	122391	64074	15865	30657	0	0	24203	60524	126019	210181	1238093
YELLOW PERCH	130	2	1	5	13	0	0	0	1	0	22	0	426
ROCK BASS	1	0	0	0	0	0	0	0	0	0	0	0	10
NOPTHERN PIPEFISH	0	0	0	0	0	0	0	0	0	0	0	0	0
REDBREAST SUNFISH	0	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC NEEDLEFISH	0	0	0	0	0	0	0	0	0	0	0	0	0
CPEVALLE JACK	0	0	0	0	0	0	0	0	0	0	0	0	0
WEAVERFISH	0	0	0	0	0	0	0	0	0	0	0	0	0
UNIDENTIFIED	0	0	0	0	0	0	0	0	0	0	0	0	0
SPOT	0	0	0	0	0	0	0	0	0	0	0	0	0
WINTER FLOUNDER	1	0	0	0	0	0	0	0	0	0	0	0	0
WATER SILVERSIDE	12	120	50	2	0	0	0	0	0	0	0	0	14
TIDEM LAMPREY	0	0	0	0	0	0	0	0	0	0	0	0	0
SEA LAMPREY	0	0	0	0	0	0	0	0	0	0	0	0	0
GIZZARD SHAD	573	1	0	0	0	0	0	0	0	0	0	0	574
SILVER HAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STRIPED MULLET	0	0	0	0	0	0	0	0	0	0	0	0	0
3-SPINE STICKLEBACK	32	148	107	15	0	0	0	0	0	0	0	0	641
BUTTE CRAPPIE	0	0	0	0	0	0	0	0	0	0	0	0	0
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0	0	0	0	0
SILVER PERCH	0	0	0	0	0	0	0	0	0	0	0	0	0
CENTRARCHID UNID	21	37	92	37	30	2	0	0	651	1373	2325	1408	5922
SQUIREL OR RED HAKE	14	0	0	0	0	0	0	0	0	0	0	0	0
GRASSY MUDMINNOW	0	0	0	0	0	0	0	0	0	0	0	0	0
EAST BASS	0	0	0	0	0	0	0	0	0	0	0	0	0
ROUGH SILVERSIDE	0	0	0	0	0	0	0	0	0	0	0	0	0
SUMMER FLOUNDER	0	0	0	0	0	0	0	0	0	0	0	0	0
STRIPED SEAPOB	0	0	0	0	0	0	0	0	0	0	0	0	0
NORTHERN SEAPOB	0	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC CROAKER	0	0	0	0	0	0	0	0	0	0	0	0	0
LONGHORN SCULPIN	0	0	0	0	0	0	0	0	0	0	0	0	0
HICKORY SHAD	0	0	0	0	0	0	0	0	0	0	0	0	0
STRIPE ANCHOVY	0	0	0	0	0	0	0	0	0	0	0	0	0
WINDOOPANE	0	0	0	0	0	0	0	0	0	0	0	0	0
SEABOIN	0	0	0	0	0	0	0	0	0	0	0	0	0
BLACK SEA BASS	0	0	0	0	0	0	0	0	0	0	0	0	0
SAND LANCE	0	0	0	0	0	0	0	0	0	0	0	0	0
COLUMN TOTAL	343453	312154	130052	69036	32505	12562	0	0	54873	181517	157859	222924	1516335







Table A-3  
Total Monthly Actual Count of Each Species Collected from Intake Screens  
at Indian Point Units No. 2 and No. 3 Combined during 1979

TAXON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR_TOTAL
ALEMITE	15	77	16	50	580	27	5252	1429	439	274	293	10	8225
BALANCE	13	0	0	16	9785	367	5220	26066	20759	1156	213	19	129275
BLUESHAD	0	0	0	11	33	9	11354	1423	1423	1855	2422	42	25030
BUEGILL	0	0	0	0	0	38	3119	446	622	1855	0	0	11000
BROWN BULLHEAD	0	0	0	17	42	23	1	15	23	14	18	107	150
BUMPKINSEED	26	37	34	17	44	23	1	82	42	28	17	30	150
BLACK CRAPPIE	51	265	37	167	24	101	57	82	80	28	77	107	407
CARP	12	0	0	0	0	4	0	0	0	0	0	0	12
TOCAN EEL	0	0	0	0	0	0	0	0	0	0	0	0	0
GOLDEN SHINER	625	135	13	392	465	34	191	125	54	0	0	11	2327
WALLE	13	161	12	124	59	12	191	125	54	54	11	11	2102
GOLDEN SHINER	14	12	0	124	59	12	191	125	54	54	11	11	2102
HOGCHOKER	14	26	0	2915	5	42	671	2072	2370	2288	2273	521	23234
TESSELLATED DARTER	18	16	0	915	9570	11	229	27	23	18	101	370	1804
BANDED KILLIFISH	157	17	18	915	128	11	0	27	23	18	101	370	1804
EMERALD SHINER	1	0	0	0	0	0	0	0	0	0	0	0	0
MUSKELSHAD	12	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC MENHADEN	0	0	0	0	0	0	0	0	0	0	0	0	0
UNIDENTIFIED	0	0	0	0	0	0	0	0	0	0	0	0	0
MANNON PICKEREL	0	0	0	0	0	0	0	0	0	0	0	0	0
MAIN PICKEREL	0	0	0	0	0	0	0	0	0	0	0	0	0
BLUEBACK HERPING	58	20	0	232	1283	768	571	3036	1767	95200	18930	111	122000
WHITE SUCKER	1	0	0	0	0	0	0	0	0	0	0	0	0
WALLE	1	424	188	3888	10522	232	882	402	533	145	1444	1546	32277
SMALLMOUTH BASS	0	0	0	0	0	0	0	0	0	0	0	0	0
SHORNOSE STURGEON	0	0	0	0	0	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	107	570	120	2538	13	28	61	254	42	164	310	837	780
ATLANTIC STURGEON	2411	18962	583	1423	684	122	283	622	1014	54	36	2463	5051
STRIPED BASS	33	107	48	824	829	185	2813	84369	10704	75	329	2317	159633
ATLANTIC TOMCOD	33	107	48	824	829	185	2813	84369	10704	75	329	2317	159633
WHITE CATFISH	38552	36038	1579	149251	3317	147	462	2632	34428	6034	126012	21040	157198
YELLOW PERCH	1	0	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SHORNOSE STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC TOMCOD	1	0	0	0	0	0	0	0	0	0	0	0	0
WHITE CATFISH	1	0	0	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	1	0	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SHORNOSE STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC TOMCOD	1	0	0	0	0	0	0	0	0	0	0	0	0
WHITE CATFISH	1	0	0	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	1	0	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SHORNOSE STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC TOMCOD	1	0	0	0	0	0	0	0	0	0	0	0	0
WHITE CATFISH	1	0	0	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	1	0	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SHORNOSE STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC TOMCOD	1	0	0	0	0	0	0	0	0	0	0	0	0
WHITE CATFISH	1	0	0	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	1	0	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SHORNOSE STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC TOMCOD	1	0	0	0	0	0	0	0	0	0	0	0	0
WHITE CATFISH	1	0	0	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	1	0	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SHORNOSE STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC TOMCOD	1	0	0	0	0	0	0	0	0	0	0	0	0
WHITE CATFISH	1	0	0	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	1	0	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SHORNOSE STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC TOMCOD	1	0	0	0	0	0	0	0	0	0	0	0	0
WHITE CATFISH	1	0	0	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	1	0	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SHORNOSE STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC TOMCOD	1	0	0	0	0	0	0	0	0	0	0	0	0
WHITE CATFISH	1	0	0	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	1	0	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SHORNOSE STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC TOMCOD	1	0	0	0	0	0	0	0	0	0	0	0	0
WHITE CATFISH	1	0	0	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	1	0	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SHORNOSE STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
SPOTTAIL SHINER	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC STURGEON	1	0	0	0	0	0	0	0	0	0	0	0	0
STRIPED BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
ATLANTIC TOMCOD	1	0	0	0	0	0	0	0	0	0	0	0	0
WHITE CATFISH	1	0	0	0	0	0	0	0	0	0	0	0	0
YELLOW PERCH	1	0	0	0	0	0	0	0	0	0	0	0	0
ROCK BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SMALLMOUTH BASS	1	0	0	0	0	0	0	0	0	0	0	0	0
SHORNOSE STURGEON	1	0	0	0	0	0							





Table A-5  
 Total Estimated Count of Each Species Impinged Monthly at Indian Point Unit No. 3 during 1979  
 (adjusted to account for collection efficiency)

TAXON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR_TOTAL
ALEMITE													
ALY	125	44	10	54	791	414	7687	2150	347				11702
ANCHOVY	0	0	0	19	11930	5233	6587	39154	5453				143399
ARCTIC SHAD	0	0	0	1	54	16	17039	11920	1497				33600
BULLHEAD	255	0	0	10	0	563	4685	676	14				6002
BROWN TULLHEAD	22	129	13	310	63	35	6	27	56				217
BUMPY SEED	22	129	204	133	317	128	93	1251	74				1392
BLACK CRAPPIE	37	0	0	6	0	6	0	129	0				1465
AMERICAN EEL	366	113	100	313	0	372	0	2	0				211
COLDEN SHINER	12	110	309	125	77	19	294	168	54				2166
ROCKBASS	160	19	63	81	78	3	4	0	4				2778
PERSED LATER DARTER	12	19	170	2121	7079	313	1015	3063	955				169
FINNED KILLIFISH	22	25	46	575	103	14	42	39	29				14662
LEAKED SHINER	4	0	0	36	22	18	17	35	60				847
AMERICAN BASS	4	0	13	0	22	0	4	0	0				3212
MOHAWK	10	10	10	10	22	0	4	4	0				30
ATLANTIC MENHADEN	10	10	10	10	32	53	261	273	47				666
SHINER	19	10	0	10	10	1035	874	4561	1168				9628
SMITHY	10	10	0	264	169	2	2	2	123				2265
ATLANTIC SHELLFISH	654	1032	647	3097	11916	3039	1334	611	123				4179
SMALLMOUTH BASS	0	0	10	0	2	0	0	0	0				42
SCOTTISH STURGEON	362	282	519	2263	20	33	99	390	42				1527
ATLANTIC STURGEON	5304	3933	1795	1169	787	95	432	941	594				19486
STRIPED BASS	995	0	0	393	231	15045	42209	124564	7082				1599
ATLANTIC CATFISH	332	16	235	366	211	65	119	119	119				43064
WHITE PERCH	8311	10016	42274	9618	2647	17416	7025	33356	15532				20142
WELLS PERCH	2	7	2	114	13	0	4	2	33				22
ROCK BASS	0	0	0	10	4	0	0	0	0				29
NORTHERN PIPEFISH	0	0	0	30	0	0	0	0	0				676
REDFIN	0	0	0	0	2	0	0	0	0				111
NORTHERN SUNFISH	0	0	0	0	0	0	0	0	0				2
ATLANTIC NEEDLEFISH	0	0	0	0	0	0	0	0	0				2
CREVALLE	0	0	0	0	0	0	0	0	0				2
WEAK FISH	0	0	0	0	0	0	0	0	0				676
LOOKDOWN	0	0	0	0	0	0	0	0	0				111
LOUPEE	0	0	0	0	0	0	0	0	0				2
4-BEARD UNIDENTIFIED	0	0	0	0	0	0	0	0	0				2
MOONFISH	100	0	0	0	0	0	0	0	0				2
NORTHERN POOPY OR SCUP	20	0	0	0	0	0	0	0	0				4
WINTER FLOUNDER	0	0	0	0	0	0	0	0	0				4
SEA LAMP	20	14	0	15	0	0	0	0	0				4
GIZZARD	0	19	0	0	20	0	0	0	0				4
SPINE	44	5	4	28	6	0	0	0	0				45
BROWN TROUT	0	0	0	0	0	0	0	0	0				14
BULLHEAD	0	0	0	0	0	0	0	0	0				2
WHITE CRAPPIE	0	0	0	0	0	0	0	0	0				2
SILVER CRAPPIE	0	0	0	0	0	0	0	0	0				2
GENIVAR UNID	10	0	0	0	0	0	0	0	0				2
SCUPEL OP RED HAKE	6	30	20	27	39	60	60	22	26				231
CENTRAL MUDMINNOW	0	0	0	0	0	0	0	0	0				2
GRUBBY MUDMINNOW	0	0	0	0	0	0	0	0	0				2
EAST MUDMINNOW	0	0	0	0	0	0	0	0	0				2
WHOLE SILVERSIDE	0	0	0	0	0	0	0	0	0				2
ROUGH SILVERSIDE	0	0	0	0	0	0	0	0	0				2
SUMNER FLOUNDER	0	0	0	0	0	0	0	0	0				2
ATLANTIC CRAPPIE	0	0	0	0	0	0	0	0	0				2
HICKORY SHAD	0	0	0	0	0	0	0	0	0				2
AMERICAN SANDLANCE	0	0	0	0	0	0	0	0	0				2
ATLANTIC MACKEREL	0	0	0	0	0	0	0	0	0				2
MUDMINNOW UNIDENTIFIED	0	0	0	0	0	0	0	0	0				2
MACKEREL SCAD	0	0	0	0	0	0	0	0	0				2
COLUMN TOTAL	93130	106392	46668	109924	64537	43966	170483	239086	35458				909644





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## APPENDIX A.2

### Number and Weights of Major Impinged Species

Total counts and total weights of 15 species predominant in impingement collections (adjusted for collection efficiency) are summarized in the following tables by week, month, season, and year. The following codes denote the 15 species presented.

AL	Alewife
AS	American Shad
BH	Blueback Herring
SNS	Shortnose Sturgeon
ATS	Atlantic Sturgeon
SB	Striped Bass
TC	Atlantic Tomcod
WP	White Perch
BA	Bay Anchovy
BF	Bluefish
HC	Hogchoker
RS	Rainbow Smelt
SS	Spottail Shiner
WC	White Catfish
WKF	Weakfish



Table A-7

Total Estimated Count of Fifteen Major Species and All Species Combined Impinged at Indian Point Unit No. 2 Intake Screens during 1979 (summarized by week, month, season, and year and adjusted for collection efficiency)

PERIOD	AL	AS	BH	SNS	ATS	SB	TC	MP	BA	BF	HC	RS	SS	WC	WKF	ALL SPEC
JAN	20	16	24	0	0	12	11	47	120	0	16	263	42	14	0	28
FEB	14	10	20	0	0	10	12	47	0	0	4	15	14	0	0	14
MAR	20	10	20	0	0	10	12	47	0	0	4	15	14	0	0	14
APR	20	10	20	0	0	10	12	47	0	0	4	15	14	0	0	14
MAY	20	10	20	0	0	10	12	47	0	0	4	15	14	0	0	14
JUN	20	10	20	0	0	10	12	47	0	0	4	15	14	0	0	14
JUL	20	10	20	0	0	10	12	47	0	0	4	15	14	0	0	14
AUG	20	10	20	0	0	10	12	47	0	0	4	15	14	0	0	14
SEP	20	10	20	0	0	10	12	47	0	0	4	15	14	0	0	14
OCT	20	10	20	0	0	10	12	47	0	0	4	15	14	0	0	14
NOV	20	10	20	0	0	10	12	47	0	0	4	15	14	0	0	14
DEC	20	10	20	0	0	10	12	47	0	0	4	15	14	0	0	14
SEASON	200	160	240	0	0	120	110	470	1200	0	60	2630	420	140	0	280
YEAR	2016	13015	40677	4	62	6881	9806	21720	11743	100	2297	42229	6716	475	646	36673



Table A-8

Total Estimated Count of Fifteen Major Species and All Species Combined Impinged at Indian Point Unit No. 3 Intake Screens during 1979 (summarized by week, month, season, and year and adjusted for collection efficiency)

PERIOD	AL	AS	BH	SMS	ATS	SB	TC	MP	BA	BF	MC	PS	SS	WC	WVF	ALL SPEC
JAN	11	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
FEB	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAR	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
APR	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAY	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUN	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SEP	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OCT	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOV	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEC	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SEASON	11	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
YEAR	11	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0





Table A-9  
 Total Estimated Count of Fifteen Major Species and All Species Combined  
 Impinged at Indian Point Units No. 2 and No. 3 Intake Screens Combined during 1979  
 (summarized by week, month, season, and year and adjusted for collection efficiency)

PERIOD	AL	AS	BH	SNS	ATS	SB	TC	UD	BA	BF	MC	RS	SS	WC	MKF	ALL SPEC
JAN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
FEB	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MAR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
APR	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MAY	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
JUN	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
JULY	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
AUG	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SEPT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
OCT	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
NOV	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
DEC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
YEAR	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14



Table A-10

Total Estimated Weight (g) of Fifteen Major Species and All Species Combined Impinged at Indian Point Unit No. 2 Intake Screens during 1979 (summarized by week, month, season, and year and adjusted for collection efficiency)

PERIOD	AL	AS	BS	SNS	ATS	SB	TC	MP	BA	BF	MC	RS	SS	WC	MKF	ALL SPEC.
JAN	210	60	50	0	57	0	0	56	0	0	150	0	0	100	0	0
FEB	1277	60	101	0	22	118	0	40	0	0	10	1	0	200	0	0
MAR	500	60	0	0	3	0	0	0	0	0	0	0	0	0	0	0
APR	50	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAY	65	0	0	1191	0	0	0	0	0	0	0	0	0	0	0	0
JUN	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SEP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OCT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SEASON	2099	200	200	1191	22	118	0	170	0	0	150	0	0	1000	0	0
YEAR	2099	200	200	1191	22	118	0	170	0	0	150	0	0	1000	0	0





Table A-12

Total Estimated Weight (g) of Fifteen Major Species and All Species Combined Impinged at Indian Point Units No. 2 and No. 3 Intake Screens Combined during 1979 (summarized by week, month, season, and year and adjusted for collection efficiency)

PERIOD	AL	AS	BH	SNS	ATS	SB	TC	UP	BA	BF	UC	RC	SS	UC	WK	ALL SPEC
WEEK	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
MONTH	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
SEASON	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01
YEAR	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01	01



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### APPENDIX A.3

#### Adjusted Impingement Rates

Impingement rates of 15 species predominant in impingement collections (adjusted for collection efficiency) are summarized in the following tables by week, month, season, and year. The following codes denote the 15 species presented.

AL	Alewife
AS	American Shad
BH	Blueback Herring
SNS	Shortnose Sturgeon
ATS	Atlantic Sturgeon
SB	Striped Bass
TC	Atlantic Tomcod
WP	White Perch
BA	Bay Anchovy
BF	Bluefish
HC	Hogchoker
RS	Rainbow Smelt
SS	Spottail Shiner
WC	White Catfish
WKF	Weakfish





Table A-14

Adjusted Impingement Rates (No./10<sup>6</sup>m<sup>3</sup>) for Fifteen Major Species and All Species Combined Impinged at Indian Point Unit No. 3 during 1979 (summarized by week, month, season, and year)

PERIOD	AL	AS	BH	SNS	ATS	SB	TC	WP	BA	BF	MC	PS	SS	MC	WFF	ALL SPEC
JAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FEB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
JUN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
JUL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AUG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OCT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	0.07	0.07	0.16	0.00	0.06	0.11	0.15	0.22	0.16	0.00	0.10	0.57	0.28	0.13	0.00	0.44
SEASON	0.07	0.07	0.16	0.00	0.06	0.11	0.15	0.22	0.16	0.00	0.10	0.57	0.28	0.13	0.00	0.44
YEAR	12.03	23.73	10.43	0.00	0.66	14.67	15.31	35.60	143.64	6.63	16.20	25.03	6.62	1.77	9.99	104.27



APPENDIX A.4

Volumes Circulated and Days of Operation  
at Indian Point





Table A-15  
 Number of Days of Operation at Indian Point Units No. 2 and No. 3  
 and Number of Days Selected for Computation of Impingement Rates, 1976 through 1979

Year	Month	Number of Days							
		Unit No. 2		Unit No. 3		Unit No. 3			
		Operation*	Selected	Operation*	Selected	Operation*	Selected		
1976	Jan	31	0	0	0	31	5	31	28
	Feb	29	1	24	3	17	0	28	23
	Mar	31	0	31	0	0	0	31	28
	Apr	4	2	30	0	0	0	30	28
	May	0	0	30	20	12	3	31	29
	Jun	14	3	30	19	30	28	25	21
	Jul	0	0	31	14	31	23	0	0
	Aug	0	0	31	18	31	24	19	11
	Sep	16	3	30	19	30	17	30	14
	Oct	31	13	31	21	31	24	31	20
	Nov	13	9	30	27	30	24	30	23
	Dec	24	10	31	23	31	18	31	23
Total		193	41	329	164	274	166	317	248
1977	Jan	31	20	31	22	31	27	31	28
	Feb	27	5	28	6	28	22	28	23
	Mar	31	22	31	18	31	28	31	25
	Apr	14	6	30	17	30	22	30	24
	May	18	16	31	30	31	30	31	29
	Jun	30	23	30	19	17	14	30	22
	Jul	3	1	31	25	0	0	31	25
	Aug	28	15	31	30	0	0	31	22
	Sep	30	27	30	28	19	9	19	12
	Oct	31	26	12	7	31	29	0	0
	Nov	30	24	0	0	30	29	0	0
	Dec	31	29	18	11	30	20	0	0
Total		303	214	303	213	278	230	262	210

\*Data obtained from Con Edison plant performance records



Table A-16  
 Total Unit Discharge\* (10<sup>6</sup>m<sup>3</sup>) at Indian Point Units No. 2 and No. 3, 1976 through 1979

	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1976	Unit 2	462.4	79.9	75.1	81.9	4.3	0	12.9	0	0	32.3	107.1	17.6	51.3
	Unit 3	866.7	0	30.6	25.5	53.7	85.9	93.7	107.0	113.1	80.1	104.9	98.1	74.1
	Combined	1329.1	79.9	105.7	107.4	58.0	85.9	106.6	107.0	113.1	112.4	212.0	115.7	125.4
1977	Unit 2	1016.5	58.8	56.5	71.8	39.9	88.1	133.3	13.0	106.8	140.9	123.3	95.4	88.7
	Unit 3	1142.1	73.0	63.9	82.3	100.5	139.5	135.7	139.8	146.0	141.0	53.7	0	66.7
	Combined	2158.6	131.8	120.4	154.1	140.0	227.6	269.0	152.8	252.8	281.9	177.0	95.4	155.4
1978	Unit 2	1015.2	79.0	34.0	0	1.6	40.2	141.5	144.1	145.6	82.6	129.5	107.4	109.7
	Unit 3	1015.2	88.1	71.4	86.1	76.0	122.0	47.2	2.1	38.7	121.7	140.8	133.6	87.5
	Combined	2030.4	167.1	105.4	86.1	77.6	162.2	188.7	146.2	184.3	204.3	270.3	241.0	197.2
1979	Unit 2	976.0	88.2	74.8	87.8	113.8	145.2	77.1	3.8	4.0	78.1	123.1	97.4	82.7
	Unit 3	958.8	75.1	66.6	66.0	136.5	145.2	136.7	144.8	130.9	53.6	1.7	0.9	0.9
	Combined	1934.9	163.2	141.4	153.8	250.3	290.4	213.9	148.6	134.9	131.7	124.8	98.2	83.6

\*Including service water



APPENDIX A.5

Collection Efficiency Test Results



Table A-17

Collection Efficiency Test Results for Dyed Fish Released at  
Indian Point Unit No. 2 during 1979

Test Date	Number Released	Number Recovered	Percent Recovered
05 Jan	180	119	66.1
01 Feb	180	122	67.8
15 Feb	180	105	58.3
13 Mar	180	57	31.7
27 Mar	180	74	41.1
19 Apr	180	100	55.6
26 Apr	180	126	70.0
05 May	180	24	13.3
10 May	180	56	31.1
24 May	180	33	18.3
07 Jun	180	10	5.6
20 Sep	180	75	41.7
04 Oct	120	29	24.2
06 Oct	120	43	35.8
20 Oct	180	56	31.1
25 Oct	180	47	26.1
31 Oct	180	84	46.7
08 Nov	180	100	55.5
15 Nov	180	65	36.1
20 Nov	180	85	47.2
11 Dec	180	99	55.0
20 Dec	180	83	46.1
28 Dec	180	74	41.1
Total	4,020	1,666	41.4



Table A-18

Collection Efficiency Test Results for Dyed Fish Released at  
Indian Point Unit No. 3 during 1979

Test Date	Number Released	Number Recovered	Percent Recovered
10 Jan	180	164	91.1
26 Jan	180	130	72.2
07 Feb	180	168	93.3
21 Feb	180	166	92.2
06 Mar	180	143	79.4
05 Apr	180	167	92.8
11 Apr	180	160	88.9
03 May	180	108	60.0
17 May	180	112	62.2
31 May	180	99	55.0
14 Jun	180	152	84.4
21 Jun	180	117	65.0
28 Jun	180	95	52.8
04 Jul	180	106	58.9
12 Jul	120	55	45.8
19 Jul	180	161	89.4
26 Jul	120	14	11.7
27 Jul	180	143	79.4
02 Aug	180	122	67.8
09 Aug	180	163	90.6
16 Aug	180	148	82.2
Total	3,660	2,693	73.6



Table A-19

Collection Efficiency Test Results for Tagged Fish Released at  
Indian Point Unit No. 2 during 1979

Test Date	Number Released	Number of Tagged Fish Recovered	Number of Tags Only Recovered	Percent of Tagged Fish Recovered
15 Jan	180	87	4	48.3
19 Apr	180	120	2	66.7
26 Apr	180	136	4	75.6
05 May	180	31	41	17.2
10 May	180	44	32	24.4
24 May	180	27	21	15.0
20 Sep	180	116	24	64.4
04 Oct	120	46	22	38.3
06 Oct	120	67	10	55.8
13 Oct*	180	65	26	36.1
20 Oct	180	69	21	38.3
25 Oct	180	55	31	30.6
31 Oct	180	78	24	43.3
08 Nov	180	125	12	69.4
15 Nov	180	77	19	42.8
20 Nov	180	99	11	55.0
11 Dec	180	126	13	70.0
20 Dec	180	81	22	45.0
28 Dec	180	102	1	56.7
Total	3,300	1,551	340	47.0

\*Indicates a multiple screen test as described in Appendix C



Table A-20

Collection Efficiency Test Results for Tagged Fish Released at  
Indian Point Unit No. 3 during 1979

Test Date	Number Released	Number of Tagged Fish Recovered	Number of Tags Only Recovered	Percent of Tagged Fish Recovered
05 Apr	180	169	1	93.9
11 Apr	180	155	2	86.1
03 May	180	108	5	60.0
17 May	180	120	11	66.7
31 May	180	137	4	76.1
14 Jun	180	144	9	80.0
21 Jun	180	121	11	67.2
28 Jun	180	110	13	61.1
04 Jul	180	97	14	53.9
12 Jul	120	75	13	62.5
19 Jul	180	136	13	75.6
26 Jul	120	44	35	36.7
27 Jul	180	83	22	46.1
02 Aug	180	110	20	61.1
09 Aug	180	145	7	80.6
16 Aug	180	147	6	81.7
23 Aug*	180	44	39	24.4
Total	2,940	1,945	225	66.2

\*Indicates a multiple screen test as described in Appendix C



APPENDIX A.6

Number, Percent, and Rank of Major Impinged  
Species at Indian Point





Table A-21

Number of Individuals (unadjusted for collection efficiency), Percent, and Rank of Seventeen Fish Species Impinged at Indian Point Generating Station during 1975 through 1979

Species †	1975*			1976*			1977			1978			1979		
	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank	Number	Percent	Rank
White perch	299,325	43.0	1	440,641	54.0	1	1,094,592	37.8	1	807,235	44.9	1	1,579,199	72.4	1
Blueback herring	155,707	22.3	2	258,303	31.6	2	637,519	22.0	3	510,741	28.4	2	122,006	5.6	4
Atlantic tomcod	78,627	11.3	4	34,236	4.2	3	747,702	25.8	2	120,275	6.7	3	159,683	7.3	2
Bay anchovy	96,058	13.8	3	12,142	1.5	6	146,879	5.1	4	106,737	5.9	4	129,975	6.0	3
Hogchoker	18,839	2.7	5	14,795	1.8	5	25,472	.9	8	46,524	2.6	5	23,234	1.1	8
Striped bass	5,977	.9	9	6,130	.8	7	27,677	1.0	6	42,282	2.4	6	50,511	2.3	5
Rainbow smelt	7,790	1.1	8	3,049	.4	12	26,988	.9	7	38,945	2.2	7	32,277	1.5	6
American shad	1,148	.2	13	4,223	.5	9	12,704	.4	13	31,993	1.8	8	25,083	1.1	7
Alewife	4,243	.6	10	3,549	.4	10	58,592	2.0	5	30,908	1.7	9	8,728	.4	9
Clupeid unid.	108	.1	21	179	.1	25	19,743	.7	11	25,444	1.4	10	6,024	.3	13
Weakfish	8,969	1.3	7	556	.1	19	7,587	.3	14	12,927	.7	11	8,261	.4	10
White catfish	10,171	1.5	6	18,767	2.3	4	24,755	.9	9	7,498	.4	12	3,268	.1	16
Spottail shiner	3,949	.6	11	5,154	.6	8	5,308	.2	16	3,886	.2	13	7,287	.3	11
American eel	773	.1	15	877	.1	17	2,827	.1	19	1,999	.1	14	2,737	.1	17
Pumpkinseed	573	.1	17	1,718	.2	14	2,949	.1	18	1,738	.1	15	4,091	.2	14
Gizzard shad	921	.1	14	2,777	.3	13	6,636	.2	15	1,684	.1	16	1,022	<.1	21
Spot	0	0.0	N/A	1,471	.2	16	16,267	.6	12	3	<.1	56	1	<.1	60
Bluefish	1,616	.2	12	1,525	.2	15	21,403	.7	10	889	<.1	18	4,030	.2	15
Centrarchid unid.	277	.1	18	3,135	.4	11	3,283	.1	17	537	<.1	22	6,113	.3	12
Others	1,643			2,903			7,349			5,781			8,210		
Total	696,714			816,130			2,896,232			1,798,026			2,181,740		

\*Units No. 1, No. 2, and No. 3 combined for 1975 and 1976, Units No. 2 and No. 3 for 1977, 1978, and 1979  
 †Unidentifiable clupeids were primarily blueback herring and alewives, unidentifiable Clupeidae and Centrarchidae are not counted as separate species



APPENDIX A.7

Annually and Seasonally Adjusted  
Monthly Impingement Rates

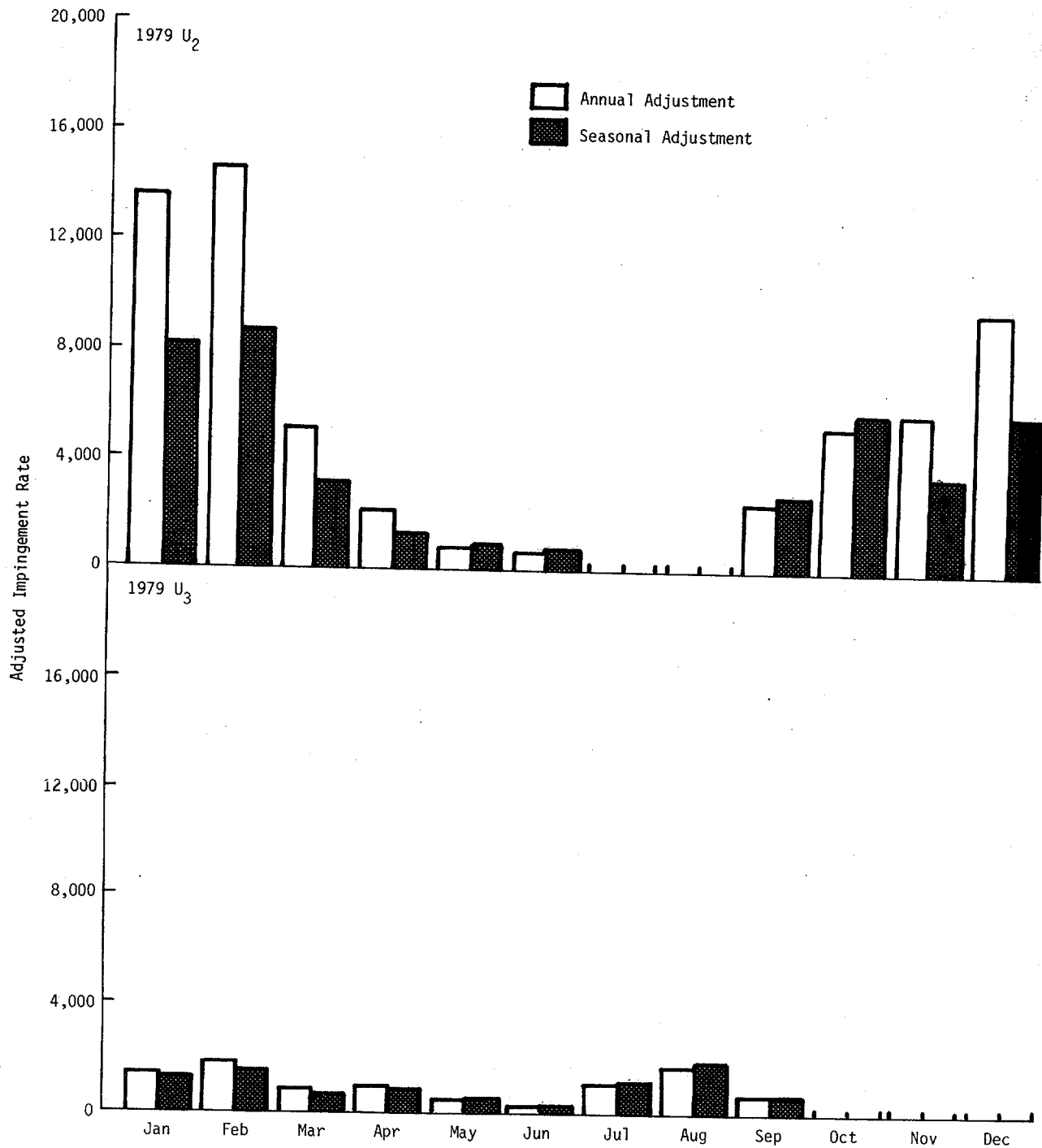


Figure A-1. Annually and Seasonally Adjusted Monthly Impingement Rates for All Species Combined (number impinged/volume pumped) at (a) Unit No. 2 (annual adjustment = 3.5; seasonal = 3.8 for May through October and 2.1 for the remainder of the year) and (b) Unit No. 3 during 1979 (annual adjustment = 1.4, seasonal = 1.5 for May through October and 1.2 for the remainder of the year)

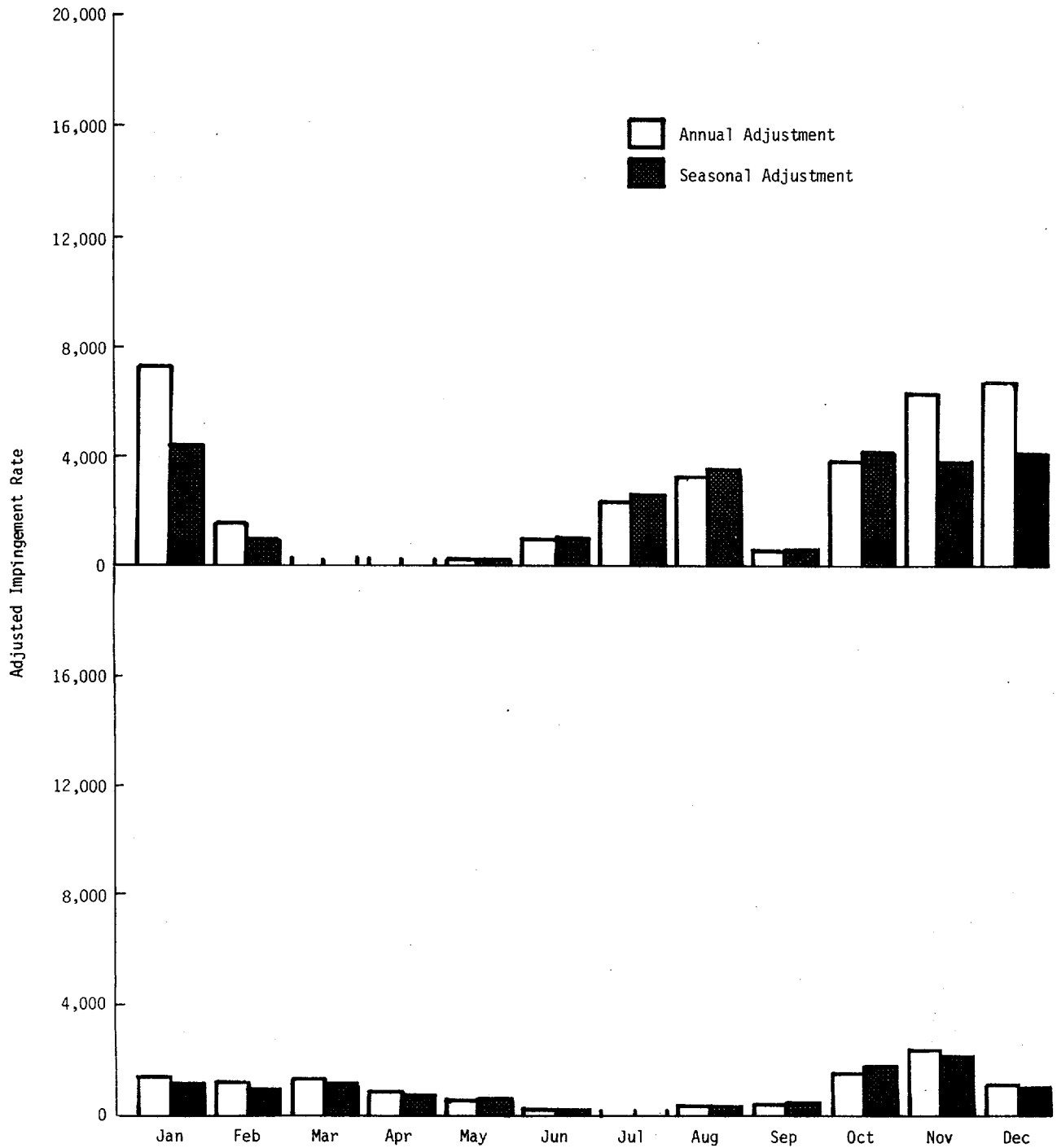


Figure A-2. Annually and Seasonally Adjusted Monthly Impingement Rates for All Species Combined (number impinged/volume pumped) at (a) Unit No. 2 (annual adjustment = 3.5; seasonal = 3.8 for May through October and 2.1 for the remainder of the year), and (b) Unit No. 3 during 1978 (annual adjustment = 1.4, seasonal = 1.5 for May through October and 1.2 for the remainder of the year)

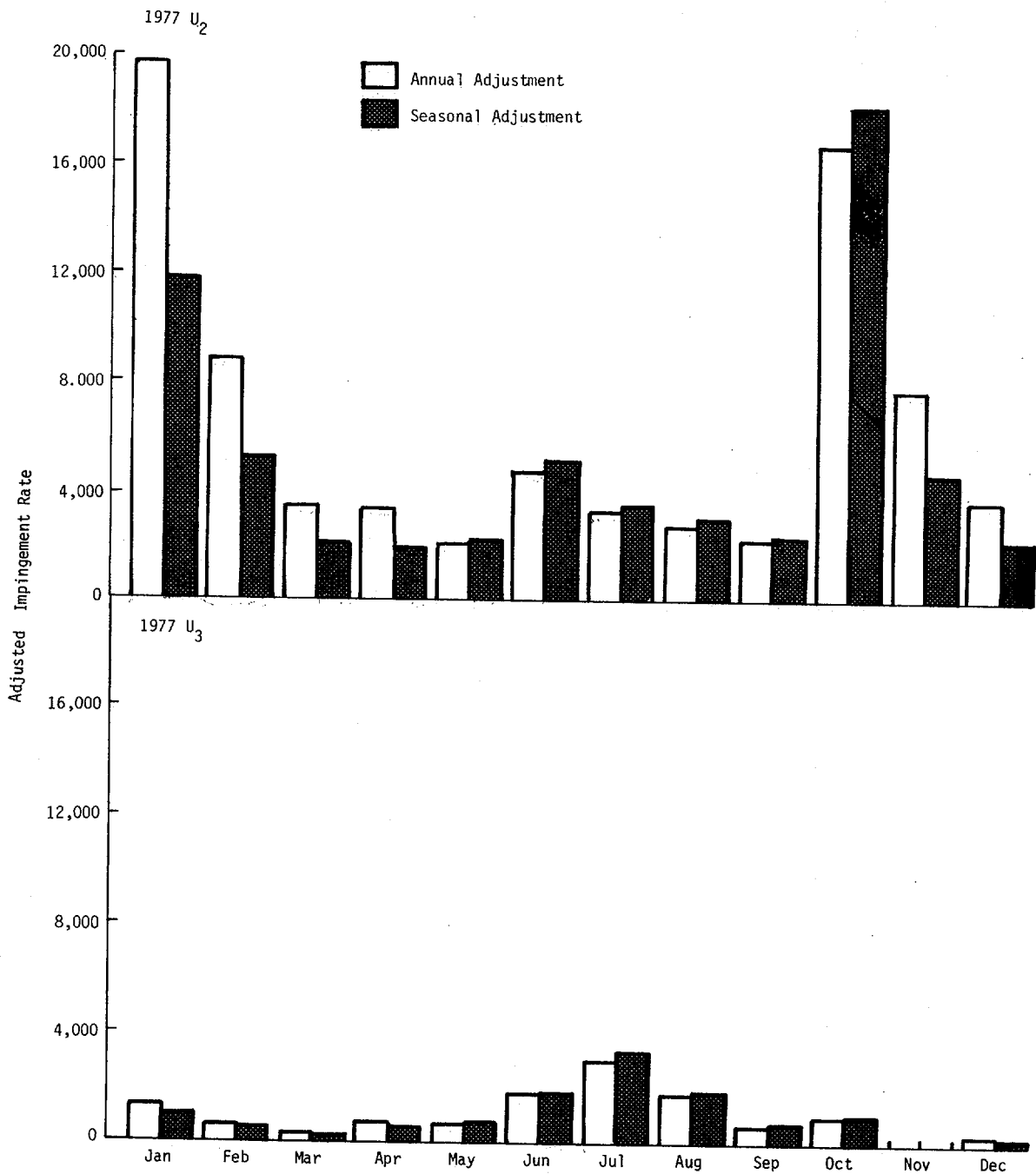
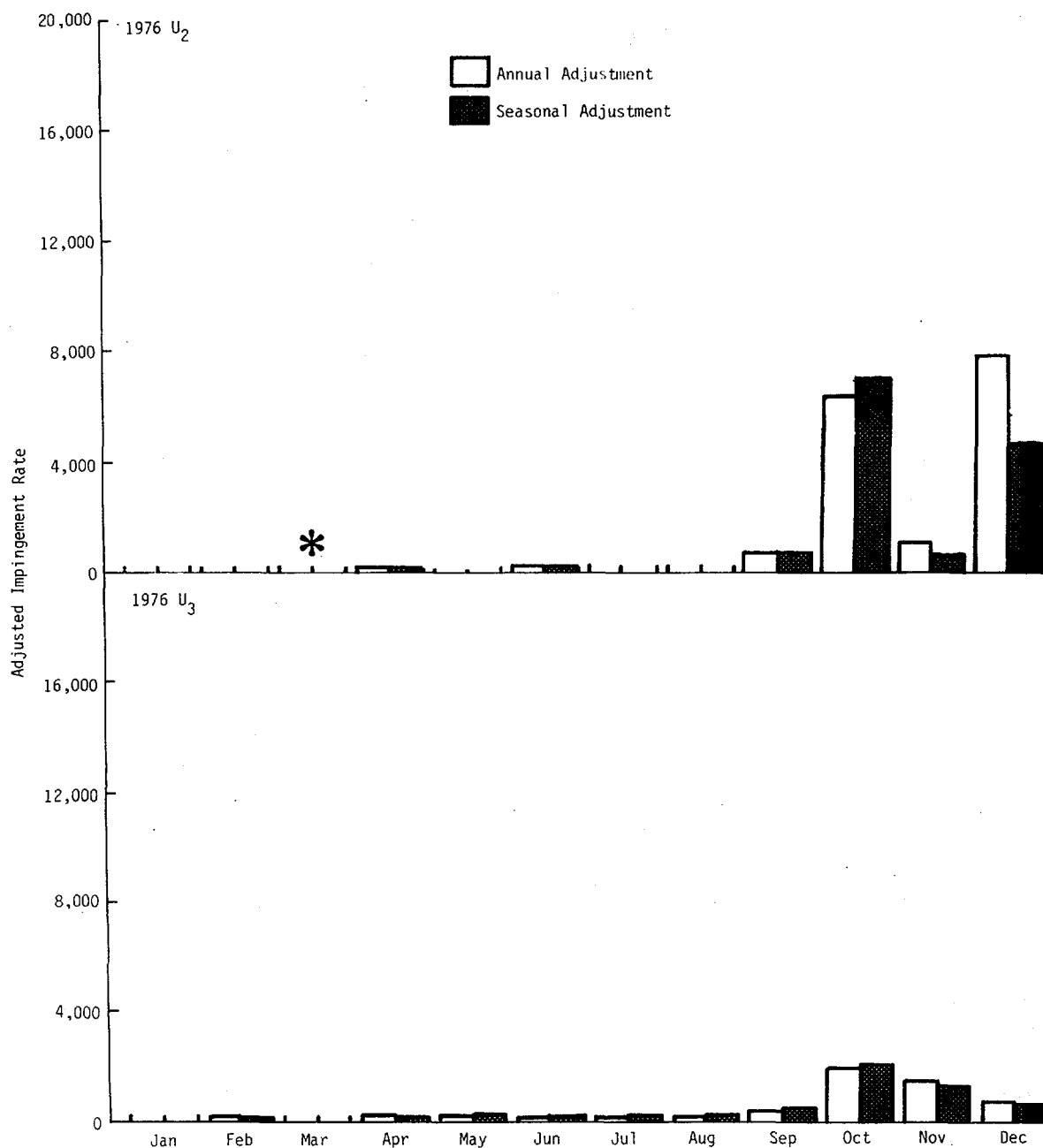


Figure A-3. Annually and Seasonally Adjusted Monthly Impingement Rates for All Species Combined (number impinged/volume pumped) at (a) Unit No. 2 (annual adjustment = 3.5; seasonal = 3.8 for May through October and 2.1 for the remainder of the year), and (b) Unit No. 3 during 1977 (annual adjustment = 1.4, seasonal = 1.5 for May through October and 1.2 for the remainder of the year)



\* Part time use of air curtain prior to this time makes comparison inappropriate

Figure A-4. Annually and Seasonally Adjusted Monthly Impingement Rates for All Species Combined (number impinged/volume pumped) at (a) Unit No. 2 (annual adjustment = 3.5; seasonal = 3.8 for May through October and 2.1 for the remainder of the year), and (b) Unit No. 3 during 1976 (annual adjustment = 1.4, seasonal = 1.5 for May through October and 1.2 for the remainder of the year)



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RIVER STUDIES

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APPENDIX B.1

Species Collected in Impingement and Nearfield  
Sampling, 1974 through 1979





Table B-1

Species Collected in Impingement Sampling (Indian Point Units No. 2 and No. 3) during 1975 through 1979 and in Nearfield Sampling, Hudson River Estuary, during 1974 through 1979

Species	Salinity Preference*	Impingement					Nearfield						
		1975	1976	1977	1978	1979	1974	1975	1976	1977	1978	1979	
White Perch	e	X**	X	X	X	X	X	X	X	X	X	X	X
Blueback Herring	e	X	X	X	X	X	X	X	X	X	X	X	X
Atlantic Tomcod	e	X	X	X	X	X	X	X	X	X	X	X	X
Bay Anchovy	e	X	X	X	X	X	X	X	X	X	X	X	X
Hogchoker	e	X	X	X	X	X	X	X	X	X	X	X	X
Striped Bass	e	X	X	X	X	X	X	X	X	X	X	X	X
Rainbow Smelt	e	X	X	X	X	X	X	X	X	X	X	X	X
American Shad	e	X	X	X	X	X	X	X	X	X	X	X	X
Alewife	e	X	X	X	X	X	X	X	X	X	X	X	X
Weakfish	m	X	X	X	X	X	X	X	X	X	X	X	X
White Catfish	f	X	X	X	X	X	X	X	X	X	X	X	X
Spottail Shiner	f	X	X	X	X	X	X	X	X	X	X	X	X
American Eel	e	X	X	X	X	X	X	X	X	X	X	X	X
Pumpkinseed	f	X	X	X	X	X	X	X	X	X	X	X	X
Gizzard Shad	f	X	X	X	X	X	X	X	X	X	X	X	X
Tesselated Darter	f	X	X	X	X	X	X	X	X	X	X	X	X
Bluefish	m	X	X	X	X	X	X	X	X	X	X	X	X
Northern Pipefish	m	X	X	X	X	X	X	X	X	X	X	X	X
Atlantic Menhaden	m	X	X	X	X	X	X	X	X	X	X	X	X
Goldfish	f	X	X	X	X	X	X	X	X	X	X	X	X
Banded Killifish	f	X	X	X	X	X	X	X	X	X	X	X	X
Yellow Perch	f	X	X	X	X	X	X	X	X	X	X	X	X
Bluegill	f	X	X	X	X	X	X	X	X	X	X	X	X
Golden Shiner	f	X	X	X	X	X	X	X	X	X	X	X	X
Crevalle Jack	m	X	X	X	X	X	X	X	X	X	X	X	X
Three-Spined Stickleback	e	X	X	X	X	X	X	X	X	X	X	X	X
Brown Bullhead	f	X	X	X	X	X	X	X	X	X	X	X	X
Silver Hake	m	X	X	X	X	X	X	X	X	X	X	X	X
Striped Searobin	m	X	X	X	X	X	X	X	X	X	X	X	X
White Bass	f	X	X	X	X	X	X	X	X	X	X	X	X
Squirrel or Red Hake	m	X	X	X	X	X	X	X	X	X	X	X	X
Butterfish	m	X	X	X	X	X	X	X	X	X	X	X	X
Carp	f	X	X	X	X	X	X	X	X	X	X	X	X
Atlantic Sturgeon	e	X	X	X	X	X	X	X	X	X	X	X	X
Largemouth Bass	f	X	X	X	X	X	X	X	X	X	X	X	X
Lookdown	m	X	X	X	X	X	X	X	X	X	X	X	X
Brown Trout	f	X	X	X	X	X	X	X	X	X	X	X	X
Brook Trout	f	X	X	X	X	X	X	X	X	X	X	X	X
Central Mudminnow	f	X	X	X	X	X	X	X	X	X	X	X	X
Redfin Pickerel	f	X	X	X	X	X	X	X	X	X	X	X	X
Northern Pike	f	X	X	X	X	X	X	X	X	X	X	X	X
Chain Pickerel	f	X	X	X	X	X	X	X	X	X	X	X	X
Cutlips Minnow	f	X	X	X	X	X	X	X	X	X	X	X	X
Satinfin Shiner	f	X	X	X	X	X	X	X	X	X	X	X	X
Blacknose Dace	f	X	X	X	X	X	X	X	X	X	X	X	X
Longnose Dace	f	X	X	X	X	X	X	X	X	X	X	X	X
Northern Hog Sucker	f	X	X	X	X	X	X	X	X	X	X	X	X
Black Bullhead	f	X	X	X	X	X	X	X	X	X	X	X	X
White Hake	m	X	X	X	X	X	X	X	X	X	X	X	X
Brook Stickleback	f	X	X	X	X	X	X	X	X	X	X	X	X
Green Sunfish	f	X	X	X	X	X	X	X	X	X	X	X	X
Atlantic Croaker	m	X	X	X	X	X	X	X	X	X	X	X	X
Tautog	m	X	X	X	X	X	X	X	X	X	X	X	X
Striped Mullet	m	X	X	X	X	X	X	X	X	X	X	X	X
Silvery Minnow	f	X	X	X	X	X	X	X	X	X	X	X	X
Comely Shiner	f	X	X	X	X	X	X	X	X	X	X	X	X
Fallfish	f	X	X	X	X	X	X	X	X	X	X	X	X
American Sand Lance	m	X	X	X	X	X	X	X	X	X	X	X	X
Striped Anchovy	m	X	X	X	X	X	X	X	X	X	X	X	X
Atlantic Mackerel	m	X	X	X	X	X	X	X	X	X	X	X	X

\*m = marine, e = euryhaline, f = freshwater  
 \*\*X - indicate species was collected



Table B-1 (Contd)

Species	Salinity Preference*	Impingement					Nearfield						
		1975	1976	1977	1978	1979	1974	1975	1976	1977	1978	1979	
Winter Flounder	m	X**	X	X	X	X					X	X	
Black Crappie	f	X	X	X	X	X	X	X	X	X	X	X	X
Mummichog	e	X	X	X	X	X	X	X	X	X	X	X	X
Sea Lamprey	m	X	X	X	X	X							
Atlantic Silverside	m	X	X	X	X	X	X	X	X	X	X	X	X
Hickory Shad	e												
Redbreast Sunfish	f	X	X	X	X	X	X	X	X	X	X	X	X
Rough Silverside	m	X		X	X	X			X	X	X	X	X
White Mullet	m		X	X	X	X			X	X	X	X	X
Atlantic Needlefish	m		X	X	X	X	X	X	X	X	X	X	X
Four-Spine Stickleback	e	X	X	X	X	X	X	X	X	X	X	X	X
White Sucker	f	X	X	X	X	X	X	X	X	X	X	X	X
Shortnose Sturgeon	e	X	X	X	X	X	X	X	X	X	X	X	X
White Crappie	f	X	X	X	X	X					X		
Black Sea Bass	m				X	X							
Four-Beard Rockling	m			X	X	X							
Silver Perch	m				X	X	X						
Spot	m		X	X	X	X				X	X		
Grubby	m		X	X	X	X							
Common Shiner	f		X	X	X	X	X				X		
Emerald Shiner	f	X	X	X	X	X	X	X	X	X	X	X	X
Smallmouth Bass	f	X	X	X	X	X							
Moonfish	m				X	X			X				
Scup	m			X	X	X							
Smallmouth Flounder	m				X	X							
Northern Puffer	m		X	X	X	X							
Northern Searobin	m			X	X	X							
Summer Flounder	m		X	X	X	X	X						X
Windowpane	m				X	X							
Tidewater Silverside	e			X	X	X	X	X	X	X	X	X	X
Sea Horse	m				X	X							
Rock Bass	f	X		X	X	X					X		
Spotfin Shiner	f			X	X	X	X	X					
Eastern Mudminnow	f	X		X	X	X							
Conger Eel	m				X	X							
Rainbow Trout	f		X										
Silver Lamprey	f				X								
Longhorn Sculpin	m					X							
Mackerel Scad	m					X							
Totals	m- 39	50	58	72	72	74	50	47	43	48	47	42	
	e- 17	}					}						
	f- 43												
Totals for All Years	99	93					67						

\*m = marine, e = euryhaline, f = freshwater  
 \*\*X - indicate species was collected



APPENDIX B.2

Dominant Fish Species Collected during Nearfield  
and Indian Point Long River Sampling



Table B-2

Catch/Effort (C/f) and Percentage (C/f of individual species ÷ C/f of all species combined X 100) of Ten Most Abundant Fish Species Collected during Indian Point Nearfield Sampling Using 30.5-m Beach Seine, Hudson River Estuary, 1974 through 1979

Species	1974		1975		1976		1977		1978		1979	
	C/f	Percent	C/f	Percent	C/f	Percent	C/f	Percent	C/f	Percent	C/f	Percent
Blueback herring	8.08	7	33.10	22	56.28	37	77.14	49	96.07	49	3.31	4
Banded killifish	21.10	18	56.25	37	15.71	10	10.43	7	28.10	14	28.21	34
American shad	10.13	9	4.73	3	13.53	9	5.19	3	19.18	10	3.48	4
White perch	14.15	12	6.58	4	16.09	10	12.61	8	19.10	10	12.95	15
Striped bass	7.50	6	6.10	4	5.72	4	9.25	6	7.73	4	3.53	4
Bay anchovy	27.14	23	14.55	10	7.31	5	16.77	11	5.58	3	9.05	11
Spottail shiner	10.61	9	10.06	7	12.83	8	9.74	6	5.64	3	3.88	5
Tesselated darter	3.70	3	5.27	3	7.54	5	3.86	2	4.38	2	4.71	6
Alewife	1.29	1	1.41	1	6.05	4	2.28	1	2.42	1	0.43	1
Pumpkinseed	3.30	3	3.51	2	2.47	2	1.58	1	1.02	1	1.76	2
Others	9.02	8	10.60	7	10.36	7	9.20	6	6.57	3	12.43	15
All species combined	116.02	99	152.16	100	153.89	101	158.05	100	195.79	100	83.74	101



Table B-3

Catch/Effort (C/f) and Percentage (C/f of individual species ÷ C/f of all species combined X 100) of Seven Most Abundant Fish Species Collected during Indian Point Nearfield Sampling Using Unlined Bottom Trawl, Hudson River Estuary, 1974 through 1979

Species	1974		1975		1976		1977		1978		1979	
	C/f	Percent	C/f	Percent	C/f	Percent	C/f	Percent	C/f	Percent	C/f	Percent
Atlantic tomcod	8.07	13	9.71	10	15.09	15	49.99	44	20.84	26	5.73	11
White perch	12.96	21	11.61	12	13.96	14	4.28	4	17.18	22	6.29	12
Hogchoker	25.91	42	18.94	19	8.23	8	5.32	5	18.87	24	11.80	23
Bay anchovy	4.33	7	19.95	21	32.65	33	21.05	18	10.14	13	10.67	21
Blueback herring	3.65	6	18.31	19	20.36	21	25.51	22	4.24	5	10.67	21
Rainbow smelt	0.09	<1	1.16	1	0.88	1	1.40	1	2.32	3	1.01	2
Alewife	2.86	5	11.21	12	2.55	3	3.41	3	0.83	1	1.39	3
Others	4.11	7	6.32	7	5.56	6	3.63	3	4.24	5	3.49	7
All species combined	61.98	101	97.21	101	99.28	101	114.59	100	78.66	99	51.05	100



Table B-4

Catch/Effort (C/f) and Percentage (C/f of individual species ÷ C/f of all species combined X 100) of Seven Most Abundant Fish Species Collected during Indian Point Nearfield Sampling Using Bottom Trawl with Fine-Mesh Liner, Hudson River Estuary, 1974 through 1979

Species	1974		1975		1976		1977		1978		1979	
	C/f	Percent	C/f	Percent	C/f	Percent	C/f	Percent	C/f	Percent	C/f	Percent
Bay anchovy	49.91	50	72.20	43	74.24	40	66.50	31	19.87	25	42.83	46
Hogchoker	8.19	8	19.94	12	5.59	3	9.92	5	14.94	19	21.64	23
Atlantic tomcod	7.84	8	14.74	9	8.45	5	35.57	17	21.62	28	7.69	8
White perch	9.65	10	25.82	15	11.85	6	5.62	3	5.28	7	4.79	5
Blueback herring	17.42	17	16.81	10	76.34	41	80.77	38	6.75	9	3.39	4
Rainbow smelt	0.63	1	0.89	1	2.67	1	4.24	2	5.20	7	3.28	4
Atewife	2.42	2	9.90	6	1.99	1	5.53	3	0.78	1	2.86	3
Others	4.05	4	9.47	6	6.10	3	4.97	2	3.52	5	6.10	7
All species combined	100.11	100	169.77	102	187.12	100	213.12	101	77.96	101	92.58	100



Table B-5

Catch/Effort (C/f) and Percentage (C/f of individual species ÷ C/f of all species combined X 100) of Five Most Abundant Fish Species Collected during Indian Point Nearfield Sampling Using Surface Trawl, Hudson River Estuary, 1974 through 1979

Species	1974		1975		1976		1977		1978		1979	
	C/f	Percent	C/f	Percent	C/f	Percent	C/f	Percent	C/f	Percent	C/f	Percent
Blueback herring	136.99	58	840.23	63	626.26	74	855.93	69	416.52	69	164.33	47
Bay anchovy	75.96	32	464.35	35	200.45	24	360.23	29	135.46	22	167.10	48
American shad	20.32	9	13.32	1	11.69	1	9.02	1	31.15	5	13.30	4
Alewife	0.55	<1	6.65	1	0.54	<1	6.74	1	19.01	3	1.23	<1
Bluefish	3.68	2	1.30	<1	0.57	<1	1.62	<1	0.61	<1	0.58	<1
Others	0.22	<1	0.32	<1	7.08	1	0.48	<1	2.50	<1	0.28	<1
All species combined	237.72	101	1326.17	100	846.59	100	1234.02	100	605.25	99	346.82	99



Table B-6

Percentage of Combined Catch/Effort (C/f of individual species ÷ C/f of all species combined X 100) during Standard Stations (SS) and Long River (LR) Beach Seining in Indian Point Region, Hudson River Estuary during 1976 through 1979

Species	1976		1977		1978		1979	
	SS	LR	SS	LR	SS	LR	SS	LR
Alewife	4	4	2	3	1	4	1	1
Bay anchovy	5	12	11	13	3	4	13	10
American shad	9	9	3	5	10	16	5	6
Pumpkinseed	2	3	1	1	1	1	2	3
Tessellated darter	5	4	3	1	2	2	7	2
Banded killifish	11	9	7	3	15	4	40	12
Blueback herring	39	34	52	60	51	57	5	52
Spottail shiner	9	9	7	5	3	3	5	4
Striped bass	4	2	6	3	4	3	5	2
White perch	11	13	8	6	10	6	18	9

Table B-7

Catch/Efforts for Ten Most Abundant Species Collected during Long River Beach Seining in Indian Point Region, Hudson River Estuary, during 1976 through 1979

Species	1976	1977	1978	1979
Alewife	3.69	3.64	4.50	0.85
Bay anchovy	11.54	13.82	4.39	10.24
American shad	8.38	5.62	19.19	6.61
Pumpkinseed	2.58	0.98	0.92	2.68
Tessellated darter	3.49	1.43	1.85	2.04
Banded killifish	8.71	2.76	5.05	12.91
Blueback herring	31.90	63.70	69.07	55.58
Spottail shiner	8.35	5.42	3.82	3.73
Striped bass	2.26	3.58	3.92	2.46
White perch	11.95	6.80	7.79	9.44
Total	92.85	107.75	120.50	106.54





Table B-8

Results of Kendall's Coefficient of Concordance Test on Ranking of Proportional Abundance of Species Collected by Indian Point Nearfield Sampling, Hudson River Estuary 1974 through 1979

	Kendall Coefficient of Concordance (W)
Beach Seine	0.38*
Unlined Bottom Trawl	0.12
Lined Bottom Trawl	0.30
Surface Trawl	0.94*

\*Significant at  $\alpha=0.05$

Table B-9

Collection of Blueback Herring by Long River and Standard Station Beach Seine Sampling in Indian Point, Hudson River Estuary during Late October, 1979

Long River				Standard Stations			
Sample Number	Period	Number Caught	Percent of Total Catch*	Sample Number	Period	Number Caught	Percent of Total Catch*
2909	17 Oct	43	0.3	471	17 Oct	1	0.1
2938	17 Oct	50	0.4	472	17 Oct	1	0.1
2928	18 Oct	1	<0.1	473	17 Oct	11	1.4
2929	18 Oct	27	0.2	474	17 Oct	175	21.8
2930	18 Oct	9826	78.2	475	17 Oct	47	5.9
2931	18 Oct	5	<0.1	476	17 Oct	0	0
2932	18 Oct	81	0.6	478	25 Oct	7	0.9
3055	25 Oct	3	<0.1	479	25 Oct	0	0
3056	25 Oct	1	<0.1	480	25 Oct	0	0
3057	25 Oct	1320	10.5	481	25 Oct	2	0.2
3065	26 Oct	0	0	482	25 Oct	0	0
3066	26 Oct	0	0	483	25 Oct	0	0
3107	30 Oct	0	0	496	30 Oct	73	9.1
2866	31 Oct	0	0	497	30 Oct	0	0
2867	31 Oct	0	0	498	30 Oct	0	0
3106	31 Oct	0	0	499	30 Oct	69	8.6
3108	31 Oct	0	0	500	30 Oct	2	0.2
3109	31 Oct	6	0.1	501	30 Oct	0	0
3110	31 Oct	100	0.8				
3131	31 Oct	0	0				

\*This refers to only blueback herring of which 12,561 were caught by Long River Beach Seine and 802 were caught by Standard Station Beach Seine efforts during 1979



APPENDIX B.3

Water Quality Parameters for  
Indian Point Region, 1975 through 1979

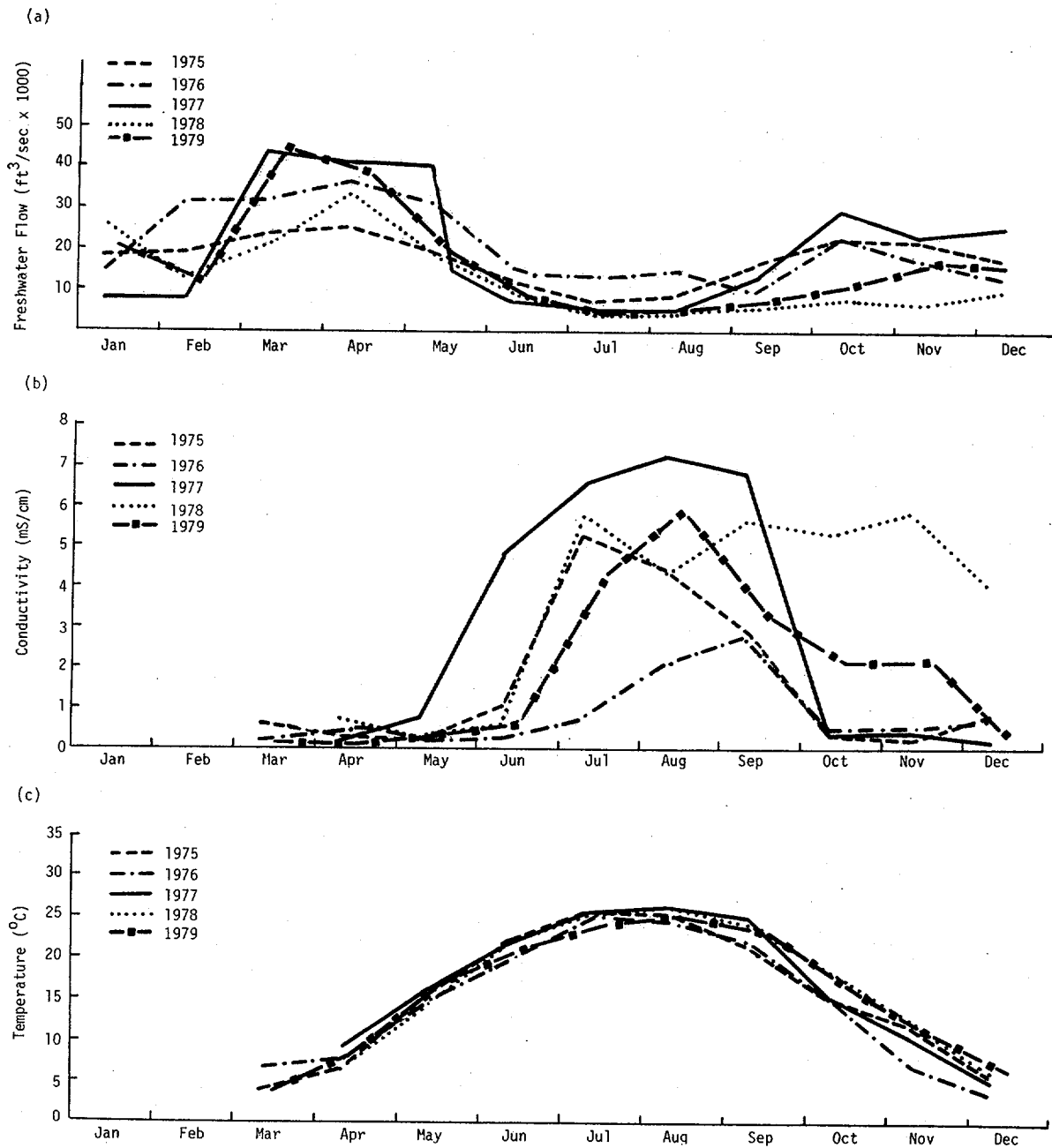


Figure B-1. Monthly Mean Freshwater Flow at Green Island (a) and Conductivity (b) and Water Temperature (c) in Indian Point Region, Hudson River Estuary, 1975 through 1979

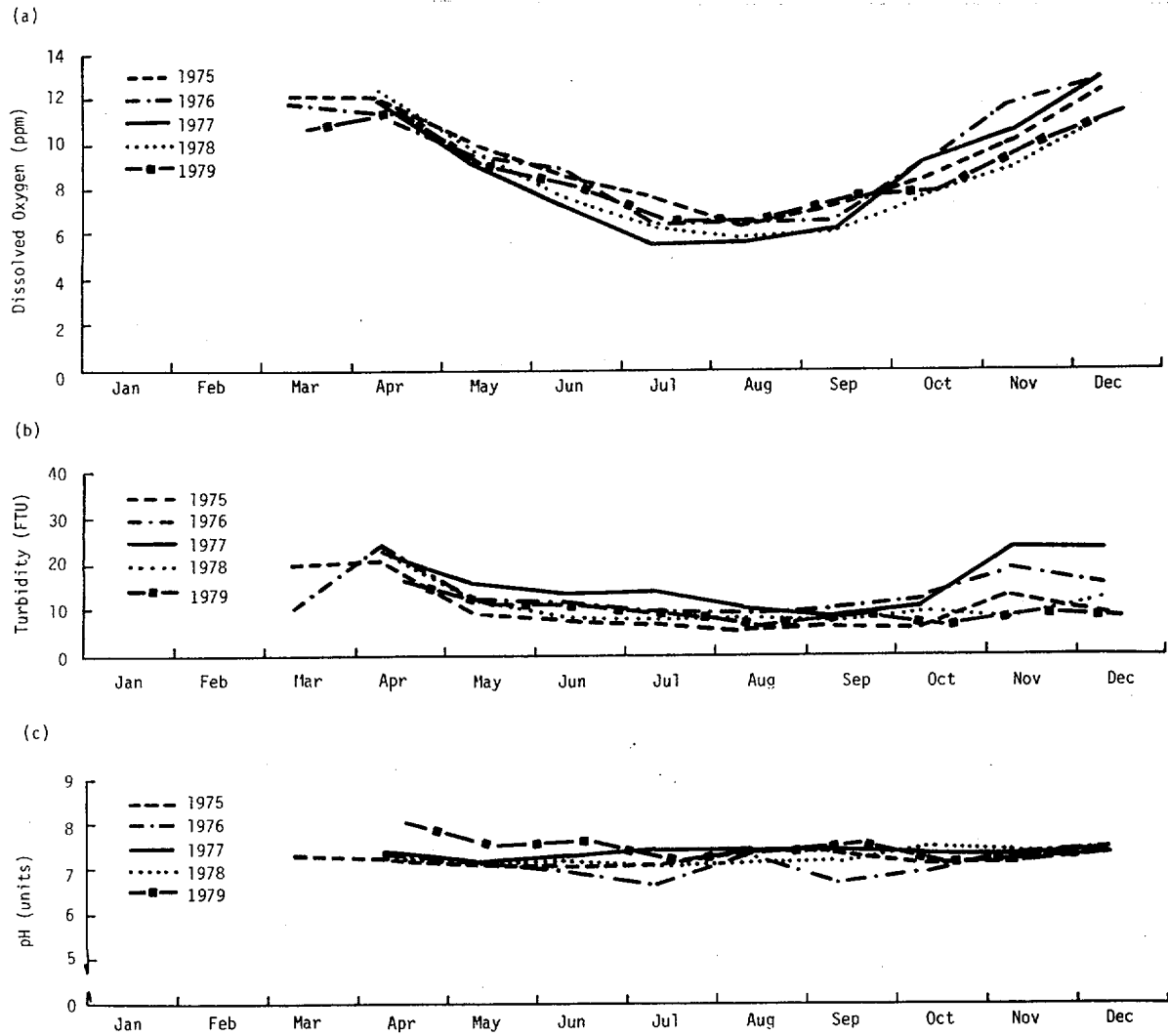


Figure B-2. Monthly Mean Dissolved Oxygen (a), Turbidity (b), and pH (c) in Indian Point Region, Hudson River Estuary, 1975 through 1979



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APPENDIX C

FIELD AND LABORATORY PROCEDURES

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## APPENDIX C

### FIELD AND LABORATORY PROCEDURES

Field and laboratory procedures summarized in this section encompass those methods used for the collection of data during the 1979 sampling year. The data collected specifically for this report and task-specific schedules are described in Table C-1 and in detail below. The study designs used in previous years for impingement monitoring, Standard Stations and Long River Fisheries Sampling, the Adult Striped Bass Stock Assessment Program, and water quality data collection has been presented in previous reports (TI 1979a, 1980a). Quality control procedures were maintained in all sampling programs to ensure an average accuracy rate of 90% or better for the identification and total count of striped bass, white perch, Atlantic tomcod, and all other species combined.

1. Impingement Monitoring at Indian Point Electric Generating Station

- a. Collection and Processing

During 1979, fish impinged on the intake screens of Units No. 2 and No. 3 of the Indian Point Generating Station were collected when the intake screens were routinely washed once daily between 0630 and 1200 hrs to remove accumulated fish and debris. Occasionally, heavy trash loading or fixed screen malfunction required more frequent or even continuous screen washing. Whenever possible, on those occasions fish were collected and counted using the same basic procedures as in routine sampling. Intake screens at Unit No. 1, which was not operational, were not routinely washed. When occasional washing occurred, the impinged fish were collected and processed following standard operating procedures as for the other units.

For each collection of fish (all screen washes per unit), individuals were identified to species and enumerated. Striped bass, white perch, Atlantic tomcod, blueback herring, alewife, and American shad were separated into four length classes (LC):



Table C-1  
 Schedule of Field Tasks during 1979 and Application of Data to Indian Point Annual Report

Task	Data Collected												Data Uses (Indian Point Annual)	
	J	F	M	A	M	J	J	A	S	O	N	D		
Standard Station Beach Seine Bottom Trawl Surface Trawl														Species composition and relative abundance
Long River Fisheries Beach Seine Bottom Trawl														Species composition and relative abundance
Adult Striped Bass Program														Recovery of hatchery-reared individuals
Water Quality Program														Environmental factors affecting impingement, abundance, and species composition
Impingement Monitoring														Annual and seasonal impingement patterns, relative abundance, and species composition



- LC 1 = 0 mm through Div<sub>1</sub>
- LC 2 = Div<sub>1</sub> + 1 mm through Div<sub>2</sub>
- LC 3 = Div<sub>2</sub> + 1 mm through 250 mm
- LC 4 = 251 mm and larger

The division values defined the upper total length limit for each age group [i.e., LC 1 contained young-of-the-year (YOY) fish, while LC 2 contained primarily yearling fish] and were determined by examining size distributions of previous years' data, spot checking age by scale analysis, and using reference literature. The division values were updated periodically to allow for growth.

Striped bass and white perch in each sample were individually counted and tallied by length class. Other species, except Atlantic tomcod, were processed as follows: 1) total weight of each species was determined (by length class, where appropriate), and up to 100 individuals per length class were counted per sample; 2) if the collection of a species/length class exceeded 100, the total number was estimated by extrapolation using the total weight, and the weight of the 100 fish subsample. Adult Atlantic tomcod from each sample were individually counted, as were YOY tomcod during the winter marking season (15 November through 31 December). From 1 April to 15 November, numbers of YOY tomcod were estimated by subsampling when total daily counts were greater than 100 (using the subsampling technique described above). For the key species (striped bass, white perch, and Atlantic tomcod), individual lengths and weights were determined from biweekly subsamples of 25 fish per length class (when available).

#### b. Power Plant Operation and Environmental Variables

To provide a basis for computing impingement rates and for analyzing the factors affecting impingement rates at Units No. 2 and No. 3, cooling water circulator flow rates and the duration of circulator pump operation were monitored along with fish collections from the





intake screens. Frequency of pump start-ups and shutdowns was also monitored along with water quality parameters which were recorded daily at the intake of each unit and in the common discharge for all three units.

### c. Determination of Impingement Rates

The magnitude of fish impingement under ideal conditions is best assessed by dividing the total number of impinged fish by the total volume of cooling water circulated for each desired time period [adjusted (unselected) impingement rates, Appendix A]. However, factors such as ice floes, trash loading, unscheduled screen washes, equipment failure, and plant maintenance sometimes interfere with computing an accurate volume of water pumped during a particular collection period. To calculate more accurate daily impingement rates, daily impingement collection data were screened by TI to select days on which fish counts could be accurately matched to the water volume from which those fish were impinged. Rates computed from selected days are termed selected rates and are used in the calculation of estimated maximum daily counts (EMD's) (Section IV) for the analysis of impingement variation in this report. Selected rates were originated by TI in 1977 and compared to more conventional unselected rates in a previous report (TI 1979b). Recent refinements of the selection process, made possible by improved organization of the data base, have allowed a revision of the selection process. The net result of improved selection procedures was the inclusion of a greater portion of the impingement data than was used in previous reports. The extent of change can be determined by comparing percent of days selected in this most recent selection process (Appendix Table A-15) with similar tables in previous reports (TI 1979b and 1980a). Selection criteria for data used in the analyses presented in Section IV have been built into a standard computer function which can be easily and consistently applied to future data. Key criteria applied in deciding whether to include each individual screen wash were as follows:



- 1) The circulator associated with each screen being washed at a unit at a given time must have operated continuously since the last time that screen was washed.
- 2) The duration of the collection period for any screen being washed at a given time must not have exceeded 28 hours. (This was to allow a maximum fish accumulation period of approximately one day, yet encompass regularly scheduled washes which occurred between 0800 and 1200 daily.)
- 3) A collection period could only be selected for inclusion when each screen at the unit being washed was washed normally and its associated circulator was operating or was not washed regardless of whether the circulator was operating. Unusual operating conditions at any screen such as an unscheduled wash, an abnormal collection, etc. caused the entire unit's collection to not be selected for that particular screen wash.
- 4) Any wash during which an air curtain was operated at the unit was excluded. (This affected only washes at Unit No. 2 prior to 1 April, 1976.)

These criteria are essentially identical to those applied in earlier analyses (TI 1979b and 1980a) with the exceptions of a more precise definition of the collection period ( $\leq 28$  hours) and the ability to select on the basis of individual screen washes rather than selecting or excluding an entire day regardless of how many washes occurred that day. It was this latter change, made possible by an improved organization of the data base, which primarily provided the increase in data included compared to prior analyses.

#### d. Collection Efficiency Tests

Tests were conducted during 1979 to estimate the percentage of fish that were impinged but not collected during the impingement monitoring process. Losses of impinged fish occurred due to a variety of causes such as predation, water currents, and disintegration of fish after impingement. Such losses were aggravated at Unit No. 2 by the



screen wash procedure itself in which fish were washed from the fixed screens and into the river prior to being reimpinged on and collected from the traveling screens.

To measure collection efficiency, dead striped bass and white perch were dyed various colors or tagged, and released at three depths in front of intake screen nos. 22 and 26 (Unit No. 2) and nos. 32 and 36 (Unit No. 3). Each test was composed of three releases at each of the two screens; the units were not tested simultaneously. A different color of dye was used in each release to examine the effect of impingement duration on fish loss. The first fish were released at about 1000 hrs, immediately after the morning screen wash. Subsequent releases were made at 1600 hrs and on the following day at 0600 hrs. When unscheduled washes interrupted a test, releases were halted, but collections continued. Recovery of dyed fish began with the next screen wash and continued during all succeeding screen washes. Fish were released at three depths (2.7 m, 4.6 m, and 6.4 m) at both Unit No. 2 and Unit No. 3. Because previous studies had indicated greater impingement near the surface (TI 1975b), 18 test fish were released at the 2.7 m, 6 at 4.6 m, and 6 at 6.4 m depths. At Unit No. 3, the three release locations (depths) were about 1.5 m in front of the traveling screen, while at Unit No. 2, the three positions were located about 1 m in front of the fixed screen. Individual screen efficiency was tested one time at each unit by releasing 30 dyed and tagged white perch as described above at each screen at 1600 hrs. Recovery of these fish began with the next screen wash and continued during all succeeding screen washes.

## 2. Standard Stations Program at Indian Point

The Standard Stations Program sampled juvenile and older fishes in the vicinity of the Indian Point Generating Station. Sample collection and laboratory processing were similar from 1975 through 1979. Sampling in 1979 involved 14 fixed stations between RM 39 and RM 43 (Figure C-1). Beginning in April and continuing through December, seven shore zone stations (Table C-2) were sampled weekly during the day, approximately two hours before low tide, with a 30.5 m beach seine.

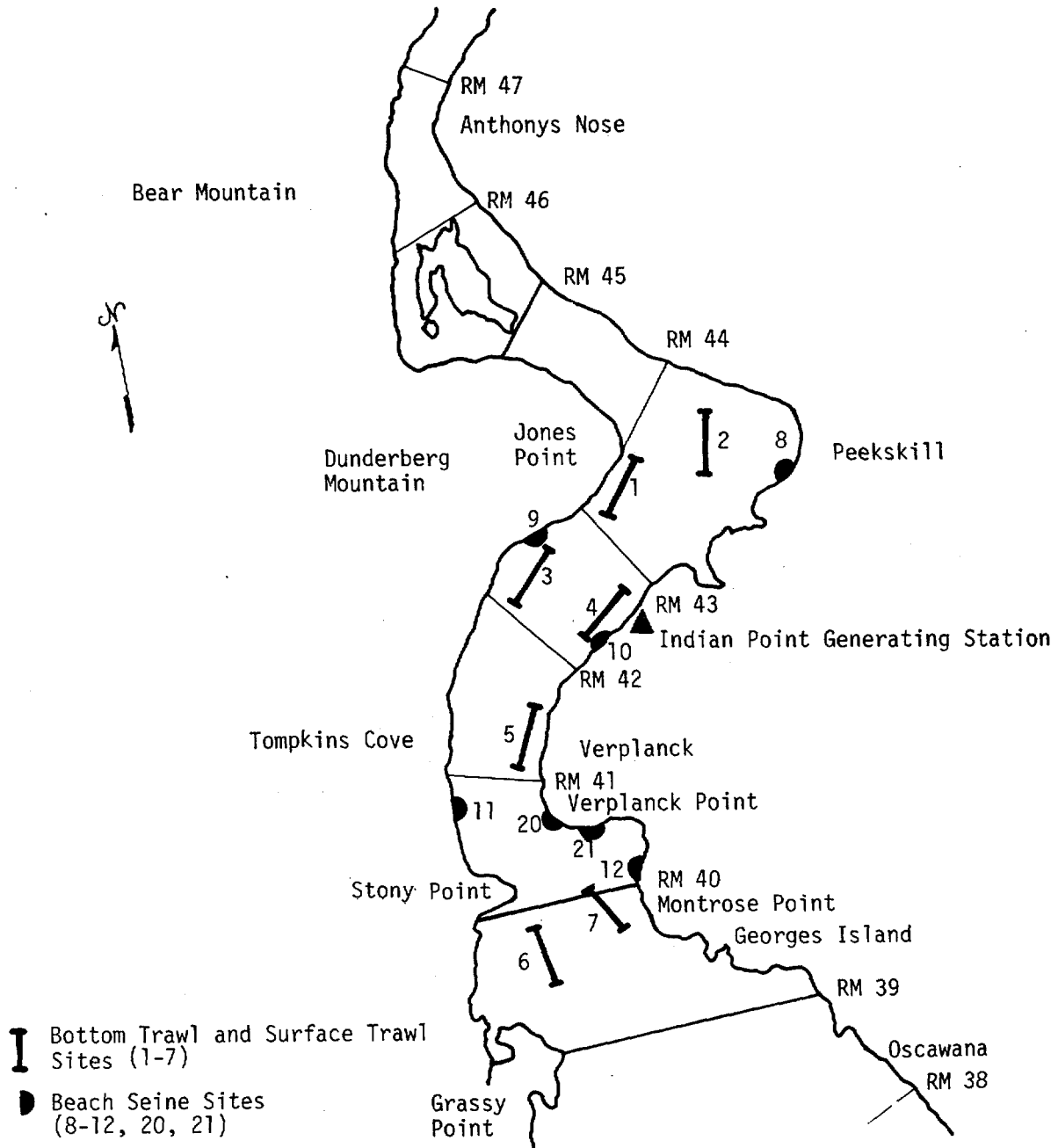


Figure C-1. Indian Point Standard Station Beach Seine, Bottom Trawl, and Surface Trawl Sites, Hudson River Estuary, RM 39 through 43, 1979



Table C-2

Location and Description of Standard Station Beach Seine Sites  
near Indian Point, Hudson River Estuary, 1979

Station	Location	Description
8	In Peekskill Bay (RM 43, east side) immediately south of public launching ramp	Mud bottom, beach covered with accumulation of glass; maximum depth* 1.5 m; heavy aquatic vegetation during summer; far from channel
9	South of Jones Pt. (RM 42, west side) near former reserve fleet headquarters	Medium sized rocks and gravel changing to mud as depth increases; maximum depth 1.0 m; heavy aquatic vegetation during summer; far from channel
10	100 m south of Indian Point discharge canal (RM 42, east side)	Sand/gravel beach, changing to mud bottom with increasing depth; maximum depth 3.7 m; little vegetation; close to channel
11	35 m south of Trap Rock Corp. barge mooring area (RM 40, west side)	Sand bottom; beach sloping steeply to 2.1 m; little vegetation; close to channel
12	Greens Cove (RM 40, east side) 100 m south of Cortlandt Yacht Club	Brick and rock beach, changing to mud with increasing depth; maximum depth 1.0 m; very dense vegetation in summer; far from channel
20	Verplanck Point (RM 40, east side) 10 m south of wharf	Sand beach, with an accumulation of detritus on bottom as depth increases; maximum depth 1.7 m; little vegetation; close to channel
21	South of Verplanck Point (RM 40, east side) near trailer park	Sand/gravel bottom; maximum depth 1.4 m; far from channel

\*At a distance of approximately 30 m from the shoreline at low tide



During the latter half of 1979, one beach (Station 11, see Figure C-1) was often obstructed by barges from a nearby rock quarry and therefore not sampled. Seven offshore stations (Table C-3) were sampled twice biweekly during the day from April through December using a bottom trawl; once with a fine (1.5 cm stretch) mesh liner and again on another day the same week without the fine mesh liner (3.2 cm stretch mesh cod end). From July through December, each offshore trawl station was also sampled biweekly during the day with a surface trawl (4 mm stretch mesh). Additional gear dimensions have been detailed in a previous report (TI 1980a).

Table C-3  
Location and Depth of Standard Station Trawl Sites  
near Indian Point, Hudson River Estuary, 1979

Station	Location	Depth (m)
1	RM 43 west side, off Jones Pt.	9
2	RM 43 east side, in Peekskill Bay	5
3	RM 42 west side, south of Jones Pt.	6
4	RM 42 east side, in front of Indian Point Generating Station	15
5	RM 41 east side, south of overhead power cables	14
6	RM 39 west side, south of Stony Pt.	14
7	RM 39 east side, between Verplanck Pt. and Montrose Pt.	5

All fish collected by each tow were placed on ice to retard deterioration for subsequent laboratory processing. Each sample was sorted by species into four length classes (LC) as defined below. The number of fish in each length class was recorded for each species, and a random subsample (maximum of 20 fish) from each length class for each species was measured and weighed. The four length classes were defined as:



- LC 1 = 0 mm through  $Div_1$
- LC 2 =  $Div_1 + 1$  mm through 150 mm
- LC 3 = 151 mm through 250 mm
- LC 4 = 251 mm and larger

The division value ( $Div_1$ ) was a variable length which changed seasonally and was used to separate the youngest age group from older fish. The division value was determined for each species by examining the size distribution of the population at regular intervals (when data were available) during the year. Length class 1 contained fish from the current year class; i.e., YOY from the current spawning season through 31 December and yearlings from 1 January until the following spawning season. The division values were reduced at the beginning of each spawning season; thus, any yearlings collected thereafter were counted in LC 2. The division value was revised on 1 June for all species except the winter-breeding Atlantic tomcod for which the revision occurred on 1 April.

Atlantic tomcod from two standard station bottom trawl samples per biweek, collected on different days, were processed for biological characteristics; total length and weight was recorded for up to 80 YOY and 40 adult Atlantic tomcod per sample.

### 3. Long River Fisheries Sampling

#### a. Beach Seine Survey

The Beach Seine Survey yielded data on abundance and distribution of juvenile and older fishes in the shore zone of the estuary and provided a major portion of the mark-recapture effort. During April through June and September through December of each year, the estuary from the Yonkers through Albany regions (RM 12 through RM 152) was sampled biweekly using 30.5 m beach seines; on alternate weeks, sampling was confined to an area from Yonkers through Poughkeepsie (RM 12 through RM 76). During July and August of each year, all regions (RM 12 through RM 152) were sampled weekly.



One hundred samples per week were collected during the daytime from nearly 300 available beach sites. In 1979, samples were allocated on a regional basis based on the amount of shore zone surface area within each region but with a minimum of five samples per region (prior to 1979, the allocation was primarily keyed to the distribution of young-of-the-year striped bass). Sites were chosen daily and sampled only once per day, although some sites could have been sampled two or more times per week. The 30.5 m seine was set perpendicular to the shore, then towed clockwise to the beach to form a semicircular impoundment. The wings (end panels) of the net were pulled onto the beach thereby concentrating the catch in the middle (bunt) of the net (TI 1978, 1979a).

For each sample (beach seine tow), fish were sorted by species and length group as in Appendix Subsection C.2. YOY fish were preserved for identification and enumerated in the laboratory, with the exception of YOY striped bass and white perch during the fall marking period, YOY Atlantic tomcod during the winter marking period, and readily identifiable and easily counted species (e.g., bluefish), which were processed in the field. Yearling and older fish were counted and released in the field except for yearling striped bass and white perch needed to fill length/weight quotas and certain uncommon species which were kept for the reference collection.

Up to 45 length and 25 weight measurements of yearling striped bass and white perch during April through June and YOY during July through December were recorded each week in each of two super-regions (Yonkers through Poughkeepsie and Hyde Park through Albany). Up to 20 length measurements were recorded each week during July through December for YOY alewife, blueback herring, American shad, bay anchovy, spottail shiner, white catfish, weakfish, shortnose sturgeon, and Atlantic sturgeon per the following regions:





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<u>Region</u>	<u>RM (inclusive)</u>
Yonkers	12 - 23
Tappan Zee	24 - 33
Croton-Haverstraw	34 - 38
Indian Point	39 - 46
West Point	47 - 55
Cornwall	56 - 61
Poughkeepsie	62 - 76
Hyde Park through Albany	77 - 152

All YOY striped bass and white perch were checked for marks during the fall marking season (September through December) and possible recaptures were preserved and taken to the laboratory for verification. All unmarked YOY striped bass and white perch, if in good condition and not needed to fill length/weight quotas, were marked by clipping one or two fins and released. Yearling striped bass and white perch were finclipped from April through June (spring marking season) and tagged during September through December. Two year old and older striped bass and white perch were tagged during both spring and fall marking periods. Yearling and older fish were tagged using either a Floy fingerling tag or a nylon internal anchor tag, dependant upon the total length of the fish. Atlantic tomcod were marked (finclipped or tagged using Carlin tags) during their spawning season (approximately November through February).

b. Interregional Bottom Trawl Survey

The Interregional Bottom Trawl (IRT) Survey yielded data on the abundance and distribution of juvenile and older fishes inhabiting the offshore bottom strata of the river. It also provided a deep-water recapture effort for marked fish. On alternate weeks during April through November, 38 fixed stations (Figure C-2) from RM 27 through RM 76 were sampled once during daytime with an otter-type bottom trawl equipped with a fine mesh (1.3 cm) cod-end cover (see TI 1979a for gear dimensions). Catches were sorted and counted by species and length group as in Appendix Subsection C.2. Young-of-the-year fish were usually preserved for laboratory processing while yearling and older fish were processed in the field and released. Up to 40 length and 20 weight measurements per super-region (YK through PK and HP through AL)

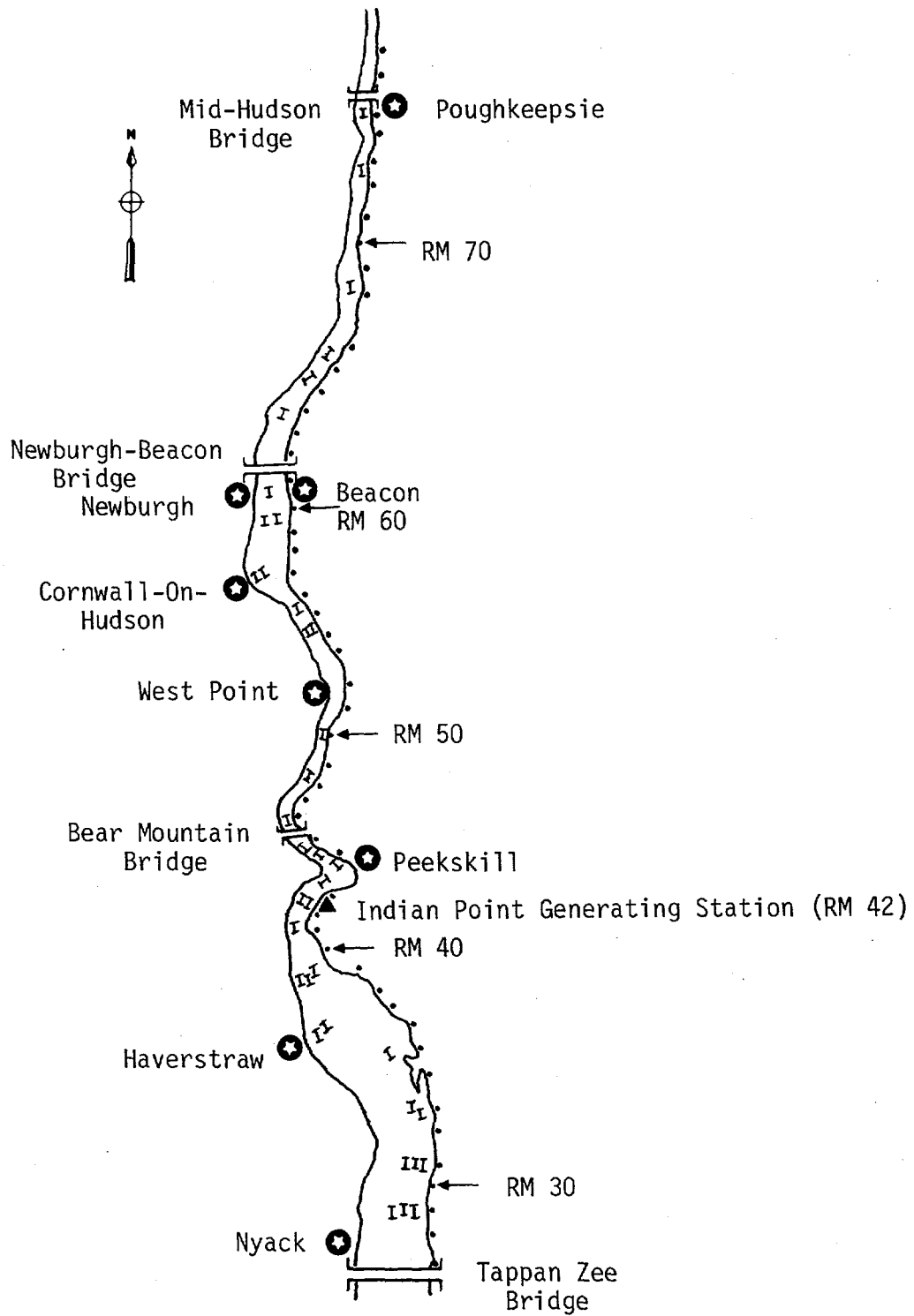


Figure C-2. Interregional Bottom Trawl Survey Sampling Sites, Hudson River Estuary, RM 27 through RM 76, 1979



were taken each sampling period (biweek) for yearling striped bass and white perch during April through June. When available, two samples containing at least 50 Atlantic tomcod were collected and returned to the laboratory per sampling period. Randomly selected subsamples from these two samples were processed for biological characteristics using methods identical to those described for Standard Stations bottom trawl samples. No fish were marked from the IRT Survey.

#### 4. Adult Striped Bass Stock Assessment Program

A comprehensive study of adult striped bass ( $>200$  mm TL) has been conducted since 1976 to determine the age and size structure, sex ratios, mortality rates, movements, and biological characteristics of the Hudson River spawning population. Adult striped bass have been collected for this program by both TI personnel and commercial fishermen. Because the commercial fishery for striped bass in the Hudson River was officially closed in early 1976, age and size composition of the commercial catch were estimated in 1979 by contracting three commercial fishermen to fish two days per week with their usual gear (gill nets) and to supply fish directly to TI. Each fisherman was accompanied by TI personnel during net-tending. In addition, tag returns (reward of \$5.00 or \$10.00 per tag) from sport and commercial fishermen provided information on movements and exploitation rates. Striped bass collected in this program also provided brood fish for the ongoing Hatchery Program as well as an opportunity to recover mature hatchery-reared individuals that were stocked during 1973 through 1975.

Gill nets, haul seines, and a 15 m bottom trawl were used by TI to collect adult striped bass. Based on distribution during the previous year, the gill net effort was concentrated in the vicinity of the Tappan Zee Bridge, Croton Bay, and Haverstraw Bay early in the spawning season (March and April), then shifted upriver to the Indian Point area in May, and returned downriver in June as the spawning season was ending. Two clusters of anchored gill nets (91 m x 2.4 m each) separated by an interval of several river miles were tended regularly during the day and night. Each cluster contained four standard nets of



different mesh sizes (10, 13, 15, and 18 cm stretch multifilament) and usually from one to four additional nets of comparable mesh sizes. The less size selective haul seines were used to collect striped bass in the shore zone, primarily in Haverstraw Bay (RM 33 through RM 38). The 15 m trawl was used for the first time in mid-May 1979. Tows were made from the Tappan Zee through Cornwall regions and although sampling was conducted on an experimental and not routine basis, the adult striped bass collected were used by the Adult Striped Bass Stock Assessment Program.

Suspected hatchery-reared striped bass were brought to the laboratory and examined for evidence of fin clips and magnetic nose tags to verify their hatchery origin. Dead striped bass were kept for laboratory processing and were also checked for evidence of fin clips and nose tags. The maturity of recaptured hatchery-reared fish was determined by calculating the ratio of body weight to gonad weight. A ratio of less than 235:1 for males and less than 70:1 for females indicated sexual maturity and therefore the ability to spawn. Live fish that were in good condition, showed no evidence of fin clips, and were not needed for biological characteristics purposes (stomach or gonad samples, etc.) were measured, scale sample removed, sex determined (if possible), tagged and released.

#### 5. Water Quality Tasks

In 1979, water quality data were collected concurrently with or subsequent to each impingement, standard stations, ichthyoplankton and long river fisheries sample. The instrumentation used to measure water quality parameters, as well as other details, are described in Table C-4. All instruments and thermometers were calibrated prior to daily sampling and checked for accuracy periodically during the sampling day.

Water quality data were collected at different depths and measured differently depending upon the task. Ichthyoplankton and fall shoal water samples were collected upon tow completion and at ichthyoplankton gear depth with a modified Van Dorn sampler. Temperature and



dissolved oxygen concentration were measured upon retrieval of the Van Dorn sampler. A sample bottle was filled and returned to the laboratory for conductivity determination. In situ measurements of temperature, dissolved oxygen, pH, and conductivity were taken upon completion of the biological sampling for standard station trawls and, except for pH, interregional bottom trawls. Readings were taken at the following depth strata:

Task	Depth Strata		
	Surface	Middle	Bottom
Standard Station Bottom Trawl	Yes	Yes	Yes
Standard Station Surface Trawl	Yes	No	No
Interregional Bottom Trawl	No	No	Yes

NOTE: pH measurements were determined at surface only

Water temperature and dissolved oxygen were measured in situ for standard station and long river beach seine sampling efforts. Surface water samples were collected and returned to the laboratory for measurement of turbidity (from standard stations beach seine and trawl efforts), and conductivity (from standard stations and long river beach seine efforts). For the impingement task, water quality measurements were taken 0.3 m below the surface at each location as follows:

Unit 1 - off the pier

Unit 2 - at the south end of the intake near screen no. 21

Unit 3 - along the metal sea wall at the south end of the intake near screen no. 31

Discharge Canal - south of Unit No. 3 at the de-icing pump

In situ water temperature, dissolved oxygen measurements, and a surface water sample for conductivity determination were taken at Indian Point Units No. 1, No. 2, and No. 3. Only water temperature was collected in the discharge canal. Variables related to plant operation were obtained directly from plant engineers.



Table C-4

Water Quality Measurements Taken with Each Biological Sample;  
 Sample Depth\*, Field or Laboratory Determination†, and  
 Instrumentation\*\* Used to Measure Each Parameter during 1979

Task	Sample* Depth	Instrumentation** for each Task and Water Quality Factor				
		Water Temperature	pH	D.O.	Conductivity	Turbidity
Standard Station						
Beach Seines	S	F4 <sup>†</sup>	F7	F4	L5	L3
Surface Trawls	S	F1	F7	F1	F1	L3 <sup>†</sup>
Bottom Trawls	S,M,B	F1	F7	F1	F1	L3 <sup>†</sup>
Long River						
Beach Seines	S	F4	--	F4	L5	--
Bottom Trawls (IRT)	B	F1	--	F1	F1	--
Ichthyoplankton	G	F2	--	F2	L5***	--
Impingement	S	F4	--	F4	L5	--

\*S = Surface, M = Middle, B = Bottom, G = At biological gear sampling depth

†F = Field, L = Laboratory

\*\* (1) Hydrolab Surveyor Model 6D in situ Water Quality Analyzer

Reserve Equipment:

(a) YSI Model 57 Dissolved Oxygen Meter (Temperature, D.O.)

(b) YSI Model 33 Salinity-Conductivity-Temperature Meter

(No in situ pH measurement was taken when reserve equipment was used)

(2) YSI Model 57 or 54 Dissolved Oxygen Meter or B.O.D. - Weston and Stack

(3) Hach Model 2100-A or Ecolab 104 Turbidimeter

(4) YSI Model 57 Dissolved Oxygen Meter

(5) YSI Model 31 or 33 Conductivity Bridge or Markson Model 10 Conductivity Meter

(6) YSI Model 33 Salinity-Conductivity-Temperature Meter

(7) IL Model 175 Porto-matic pH meter

†Turbidity was measured for surface samples only

\*\*\*F(6) prior to approximately 22 October 1979

Dashes indicate no physicochemical measurements taken

Note: Temperature and conductivity measurements which were not taken in situ because of meter problems were determined from a sample collected at the surface. Water temperature was determined with a mercury, alcohol, or dial thermometer and the sample bottle was capped and returned to the laboratory for further analysis.