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HUDSON RIVER ECOLOGICAL STUDY
IN THE AREA OF INDIAN POINT
1974 ANNUAL REPORT

July 1975

Prepared for

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
4 Irving Place
New York, New York 10003

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SECTION I

HISTORICAL PERSPECTIVE AND GENERAL SCOPE OF OVERALL PROGRAM

The potential influence of electric-generating plants on the Hudson River estuary is of paramount concern to utilities, government agencies, and the general public. Currently, several utilities are utilizing much scientific expertise in an effort to describe the Hudson ecosystem, measure and ultimately predict the potential impact of existing and proposed power plants on selected species of the biota, and recommend means for mitigation of impact. A brief discussion of the past and current status of these ecological studies as they relate to the Indian Point facility follows.

To provide information necessary to evaluate the ecological impact of the Indian Point Nuclear Generating Station, Consolidated Edison Company of New York, Inc., began an intensive study of the Hudson River estuary in the area of Indian Point in June 1969 under the guidance of the Hudson River Policy Committee. The Raytheon Company monitored the river's chemical and physical parameters, identified the various life forms, and compiled a list of relative abundances for the major aquatic species during 1969-1970 (Raytheon, 1971). Based on this survey, the scope of work was expanded in 1971 and implemented in 1972 to permit direct empirical/experimental assessment and mathematical modeling of plant impact on the Hudson River estuary from Haverstraw Bay to the Newburgh-Beacon Bridge. Three contractors, Texas Instruments Incorporated (TI), New York University (NYU); and Lawler, Matusky, and Skelly Engineers (LMS) (formerly Quirk, Lawler, and Matusky), are conducting the major aspects of this program in an integrated manner.

TI's Hudson River ecology study in the area of Indian Point has two major objectives:

- Determine the ecological significance of exploiting screenable fishes on the intake screens of Indian Point Units 1, 2, and 3
- Determine the biological impact of thermal and chemical effluents on fish and benthos

In July 1974, the Indian Point study was expanded to include the area south to the George Washington Bridge.

TI's studies, which are directed toward achieving the Indian Point project objectives, include:

- Population-dynamics study of white perch, striped bass, Atlantic tomcod, and *Cyathura polita*, an isopod crustacean
- Impingement monitoring and testing (separate report, TI, 1975d)
- Water-quality study in conjunction with studies of the relative abundance and spatial distribution of fishes and benthos
- Physiological/behavioral and bioassay studies of fishes

Analyses of data from the impingement monitoring and testing program are presented in a separate report entitled *Impingement Study Report for the Period 1 January 1974 through 31 December 1974* (TI, 1975d).

On February 1, 1974, Con Edison awarded to Texas Instruments a contract jointly financed by Orange and Rockland Utilities, Inc., and Central Hudson Gas and Electric Corporation, to perform a synoptic analysis of striped bass populations comprising the Atlantic fishery. This study, entitled *Contribution of Hudson River Striped Bass to the Mid-Atlantic Fishery*, employs electrophoretic, meristic, morphometric, and scale-pattern characteristics to differentiate subpopulations from the major spawning rivers (Potomac, Elk, Choptank, Rappahannock, and Hudson) on the Atlantic coast. An attempt is being made to identify those subpopulations contributing to the Atlantic fishery and to assess the Hudson River striped bass population's relative contribution to this fishery. Section VIII of this report summarizes the results of these studies for Phase I.

As new power-generating facilities came on line and proposals for new sites on the Hudson emerged, the need for a comprehensive environmental study of the estuary arose. Consequently, on May 31, 1974, Con Edison awarded TI a contract jointly financed with Orange and Rockland Utilities Inc. and Central Hudson Gas and Electric Corporation for a multiplant impact study of the Hudson River estuary to document the present state of the aquatic ecosystem and to estimate the impact of entrainment and impingement on populations of key fish species at existing and potential electric-generating plants along the Hudson River. The multiplant program, which represents beginning postoperational studies for generating facilities scheduled to go on line in 1974 and 1975, will assess the combined and individual ecological impact of power plants on the fish populations of the Hudson River by accomplishing two major objectives:

- Describe the life history, behavior, and population dynamics of key fish species in the Hudson River from Troy Dam downstream into the western part of Long Island Sound and the lower bays
- Analyze and interpret both past and current ecological data to indicate significant changes that may be related to the addition of power-generating capacity on the Hudson River

TI is continuing to monitor impingement at Indian Point while LMS performs impingement monitoring and near-field distribution-pattern studies at the Bowline, Lovett, Danskammer, and Roseton plants and continues to refine the long-term life-cycle model for striped bass. NYU is conducting near-field entrainment studies as well as studies on abundance, distribution, and mortality of entrainable organisms at Indian Point.

Data from the Indian Point study program as well as from other power plants have been utilized in the *First Annual Report for the Multiplant Impact Study of the Hudson River Estuary* (TI, 1975c). Impact, stated as the percent reduction of the year class of a particular species, was estimated for each plant by unit and for all plants combined. The impact estimates and other considerations relating to Indian Point Unit 2 are summarized in Section X of this report.

The data collected during these studies will permit construction of empirical and mathematical models of the Hudson River ecosystem to serve as management tools which can be employed to insure optimum use of the resource.

This third annual report to Consolidated Edison Company of New York, Inc., by the Ecological Services branch of Texas Instruments Incorporated discusses the analysis and interpretation of data collected for the Indian Point study in the Hudson estuary from January through December 1974.

SECTION II

SUMMARY AND CONCLUSIONS

The 1974 Hudson River ecological survey in the vicinity of Indian Point was a continuation and expansion of studies initiated in 1972 and 1973. Benthic studies (Section IV) and physiological and behavioral studies (Section V) were completed in 1974. Other facets of the studies (e.g., impingement monitoring and relative contribution) are integrated with the multiplant impact assessment and are reported separately [*A Report on the Feasibility of Using Innate Tags To Identify Striped Bass (Morone saxatilis) from Various Spawning Rivers* (relative contribution) and *Impingement Study Report for the Period 1 January 1974 through 31 December 1974*].

Physical and chemical parameters monitored in the vicinity of Indian Point include general meteorological conditions, water temperature, hydrogen ion concentration (pH), dissolved oxygen concentration, turbidity, and conductivity (a measure of salt concentration).

The movement of saltwater into the estuary depends primarily on freshwater flow and tidal amplitude. Turbulent mixing caused by tidal flow and shallow areas of the estuary retards the movement of salt northward in the Hudson River; salinities of >0.1 °/oo are not usually found above Newburgh Bay. Salinity in the vicinity of Indian Point varies from 0 to 4.3 °/oo. The position of the salt front (where salinity is approximately 0.1 °/oo) is governed principally by tidal amplitude and freshwater flow through the estuary. The relationship of salt-front position, tidal amplitude, and freshwater flow is generally described by the following equation:

$$R_s = -17.33\,(\ell n\ U_5) + \frac{25.59}{A_4} + 78.17$$

where

R_s = location of 0.1 $^o/oo$ salinity isopleth in miles above Battery Park (RM 0)

U_5 = freshwater release in thousands of cubic feet per second at Green Island 5 days prior to salt-front position

A_4 = tidal amplitude in feet 4 days prior to salt-front position

Dissolved-oxygen concentrations are typically highest in the winter and lowest in the summer, corresponding to the seasonal temperature regimes. Low oxygen concentrations (< 4 mg/ℓ) over wide areas may occur under exceptional conditions during summer, as occurred between West Point and Kingston (RM 52 and 92 respectively) in May 1974. Temperatures rarely exceed 25°C (77°F) in the open-channel waters during summer and approach 0°C (32°F) during winter. Turbidity generally varies directly with the freshwater flow; highest turbidities are usually encountered during spring when freshwater flow is greatest. The pH of the estuary is usually stable (7.0 to 7.5). The extreme pH values recorded (6.4 and 8.0) are well within the range tolerated by most organisms.

The abundance and diversity of benthic organisms in the test and control areas near Indian Point (RM 42-44) during 1974 were greater than those recorded for 1973. A community-structure shift toward increased numbers of halophilic (salt-preferring) species was noted in 1974. Although there was usually little difference between temperatures of sediments and water, the sediment was usually slightly warmer than the water. Analysis of variance indicated no significant difference ($P = 0.05$) between sediment and bottom-water temperatures in the test and control regions. These results indicate that operation of the Indian Point Nuclear Generating Station had little or no effect on the benthic communities in the vicinity of the plant.

Striped bass and white perch prefer temperatures a few degrees above their acclimation temperature unless the warmer temperature is near the lethal range. For example, striped bass acclimated to 16°C (61°F) prefer temperatures near 20°C (68°F). Fish acclimated to temperatures above 10°C (50°F) consistently avoided lethal temperatures. Striped bass acclimated to temperatures lower than 10°C did not always avoid lethal temperatures [24°-26°C (75°-78°F)] as well as did white perch acclimated to the same temperature. Striped bass acclimated to 21°C (70°F) avoided temperatures of 30°C (86°F), and white perch acclimated to 25°C (77°F) avoided temperatures of 32°C (90°F). These data indicate that, while lethal temperatures in the thermal plume from the plant may occur, it is unlikely that striped bass or white perch will be adversely affected. In winter, when temperature differences are at their maximum, the temperature of the thermal plume will be much lower than the temperature at which 50% of the striped bass and white perch die. During cooler months, the thermal plume may act as an attractant to white perch or striped bass. The potential for a fish kill due to coldshock in the event of a plant shutdown is small because fishes do not have access to the discharge canal itself due to the high water velocities at the exit ports; also, the ΔT is within the cold-tolerance range of white perch and striped bass.

The abundances of selected fishes at beach-seine and bottom-trawl standard stations in the vicinity of Indian Point were compared to temperatures and conductivities during 1974; conductivity and temperature were the two variables most strongly related to the abundance of these species. Highest catch per unit effort typically occurred immediately before, during, and immediately after a peak in conductivity associated with the intrusion of salt water into the sampling area. This phenomenon was particularly evident for white perch and Atlantic tomcod.

Striped bass of the 1974 year class (age 0) first appeared in beach-seine samples in July and in bottom-trawl catches in September. Young-of-the-year fish had reached a mean total length of 90 mm by the end of their

1974 growth in October. Male and female striped bass are usually mature at ages IV and V respectively. The mean number of eggs per female ranges from approximately 7 x 10^5 to approximately 2 x 10^6.

White perch young-of-the-year entered beach-seine catches later in the year (September) in 1974 than in 1973. White perch also completed most of their 1974 growth by October when young-of-the-year had reached an average total length of approximately 70 mm. The length/weight relationship for all white perch was similar during summer and fall. Some male white perch ages II and III were mature while all age-IV and older males were mature. Female white perch are all mature by age V, with many age-III and most age-IV females being mature. A comparison of white perch from impingement and river samples indicates little difference in the two groups — at least during summer and fall. A comparison of the length/weight regression lines for white perch collected in the Hudson River and from impingement samples indicates a slightly lower condition factor for impinged fish; those over 90 mm in total length weigh less than do river fish of the same length, with the difference becoming greater for longer fish.

The principal food of Atlantic tomcod was invertebrates, with fish or fish eggs constituting a very minor part of the diet in 1974. Tomcod age determination is difficult because of the false annulus present on most scales. Growth of Hudson River tomcod essentially stopped during summer when young-of-the-year averaged 74 mm (TL) and resumed in September; by year's end, mean total lengths had reached 160 mm. Tomcod mature during late fall, and most spawn during December-January; those spawning in the vicinity of Indian Point appeared to be 11 to 13 months old. Fecundity of Atlantic tomcod is described by the equation:

$$\log E = 2.536 \log TL - 1.552$$

where

E = total number of eggs

TL = total length in millimeters

Analysis of meristic, morphometric, and biochemical information gathered from Hudson River and Chesapeake Bay stocks enable the assignment of a particular fish to the Hudson River stock with about 80% probability.

The impact resulting from entrainment and impingement of fish at Indian Point Unit 2 varies from year to year, depending on the distribution of vulnerable organisms. The best estimate of impact (reduction of year-class size) of Unit-2 operation on the 1973 year class of striped bass was 1.46%, and for post-1972 plants (Indian Point Unit 2 and Bowline Units 1 and 2 was 5.02%.

SECTION III

PHYSICAL AND CHEMICAL STUDIES

A. INTRODUCTION

This phase of the overall study program is concerned with the variation of the physical and chemical parameters that may significantly influence the lives of fishes and other organisms in the Hudson River estuary; such variation may alter the distribution, reproduction, and growth patterns of fishes and other organisms. Dissolved oxygen, temperature, conductivity (salinity), turbidity, pH, tidal variation, freshwater flow, and general meteorological conditions were the parameters monitored in the vicinity of Indian Point.

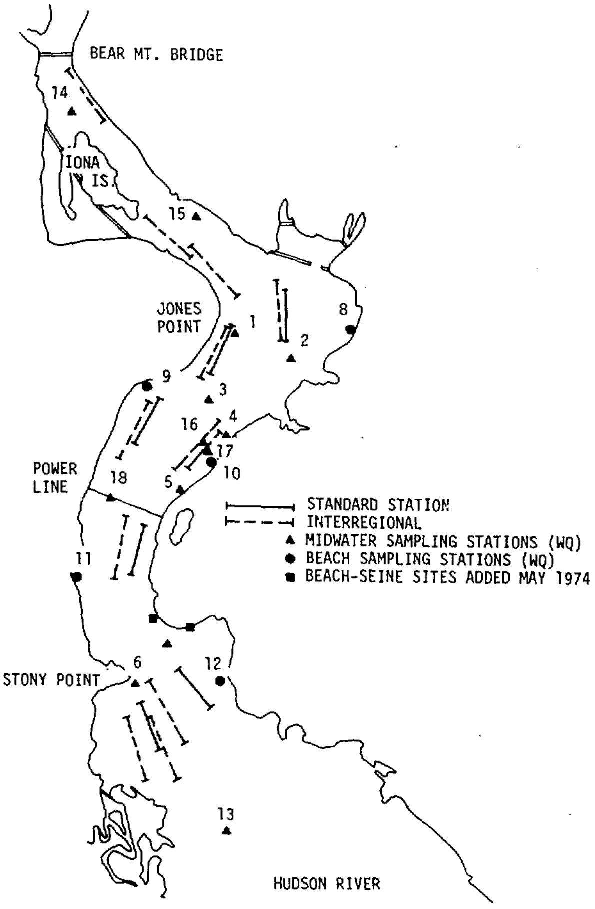


Figure III-1. Comparison of 1973 Water-Quality Sampling Locations with 1974 Trawling/Water-Quality Tow Locations (Numbers refer to 1973 water-quality sampling locations)

B. METHODS

1. Water-Quality Methods

During 1972 and 1973, environmental conditions in trawling and seining areas near Indian Point were measured weekly (Figure III-1 and Table III-1). At each station, temperature, specific conductance, dissolved oxygen, pH, and turbidity (percent transmittance) were measured *in situ*.

Until mid-August 1973, a Martek Mark II water-quality monitor was used for all measurements other than that of turbidity; after that date, a Hydrolab Model 6D monitor system was used. Both utilize equivalent sensors and similar associated measurement circuits. Turbidity was determined in the field with a Hydroproducts Model 210 transmissometer having a 10-cm light path. Measurements were made at depth intervals of 3.0 m (≃ 10 ft); if the last interval brought the sensor package within 1.0 m of the bottom, no readings were made.

Table III-1

Comparison of 1972 and 1973 Water-Quality Standard-Station Numbering Systems

Station Numbers		
1973	1972	
1	1	
2	2	
3	3	
4	4	
5	-	
6	6	
7	7	
8	8B	
9	9B	
10	10B	
11	11B	
12	12B	
13	15	
14	11	
15	13	
16	–	
17	5	
18	–	
—	16	Croton Point - Bowline Transect
—	14	
—	13B	

During 1974, water-quality data were collected *in situ* from operating trawl and seine boats. Biological sampling was conducted at least weekly and trawling and beach-seine stations coincided closely with previously used water-quality standard stations (Figure III-1). There was no deviation from basic sampling patterns.

Expansion of the study area into downstream portions of the estuary required correction for salinity influences on dissolved-oxygen readings. Appendix A details the equations used for this correction.

a. Water-Quality Measurements Associated with Trawls

During surface- and bottom-trawl efforts, water quality was measured by towing the Hydrolab sensor package above and in front of the trawl gear, beginning when the trawl was set and continuing until all parameters (temperature, specific conductance, dissolved oxygen, and pH) were measured at 3.0-m intervals as in 1973. Sampling locations are indicated in Figure III-1. Surface-water samples were returned to the Verplanck laboratory for measurement of turbidity with a Hach 2100A turbidimeter.

b. Water-Quality Measurements Associated with Interregional Bottom-Trawl Surveys

Identical water-quality sampling methods were applied to both trawling efforts. These included the same parameters, depth intervals, and essentially the same sampling locations (Figure III-1) with the addition of stations outside the Indian Point region.

✓c. Water-Quality Sampling during Standard-Station Beach Seining

Temperature was measured *in situ* at each station with a mercury thermometer. Water samples were taken in 500-mℓ polyethylene bottles at each beach-seine site (Figure III-1). Numbered bottles were filled and capped under the surface of the water and returned to the laboratory for determination of specific conductance, pH, and turbidity. Specific conductance was measured with a YSI Model 31 conductivity bridge. Hydrogen ion concentration (pH) was measured with a Sargent-Welch Model PBL pH meter. Turbidity was measured in Formazin Turbidity Units (FTU) (APHA 1971) using a Hach 2100A turbidimeter. Dissolved-oxygen concentrations also were measured if the delay in returning the sample was minimal; such dissolved-oxygen data were not used in statistical analyses however, but were used only to detect depletion of oxygen.

d. Water-Quality Sampling during Whole-River Beach-Seine Surveys

Parameters measured and the methods utilized at standard-station beach-seine sites apply also to beach-seine survey water sampling. Dissolved-oxygen concentrations were measured in the field using a YSI Model 54 dissolved-oxygen meter.

2. Meteorological Monitoring Methods

Meteorological data were collected continuously as in previous study years (Texas Instruments, 1972a, 1973a). Data recorded include wind direction and speed, temperature, relative humidity, and barometric pressure. This information was included in analyses and interpretations.

3. Flow-Data Acquisition

Estimates of daily freshwater release at Green Island, New York, were acquired from the U.S. Geological Survey office at Albany, New York. Tide height and current predictions were provided by the National Ocean Survey of the National Oceanographic and Aeronautical Administration.

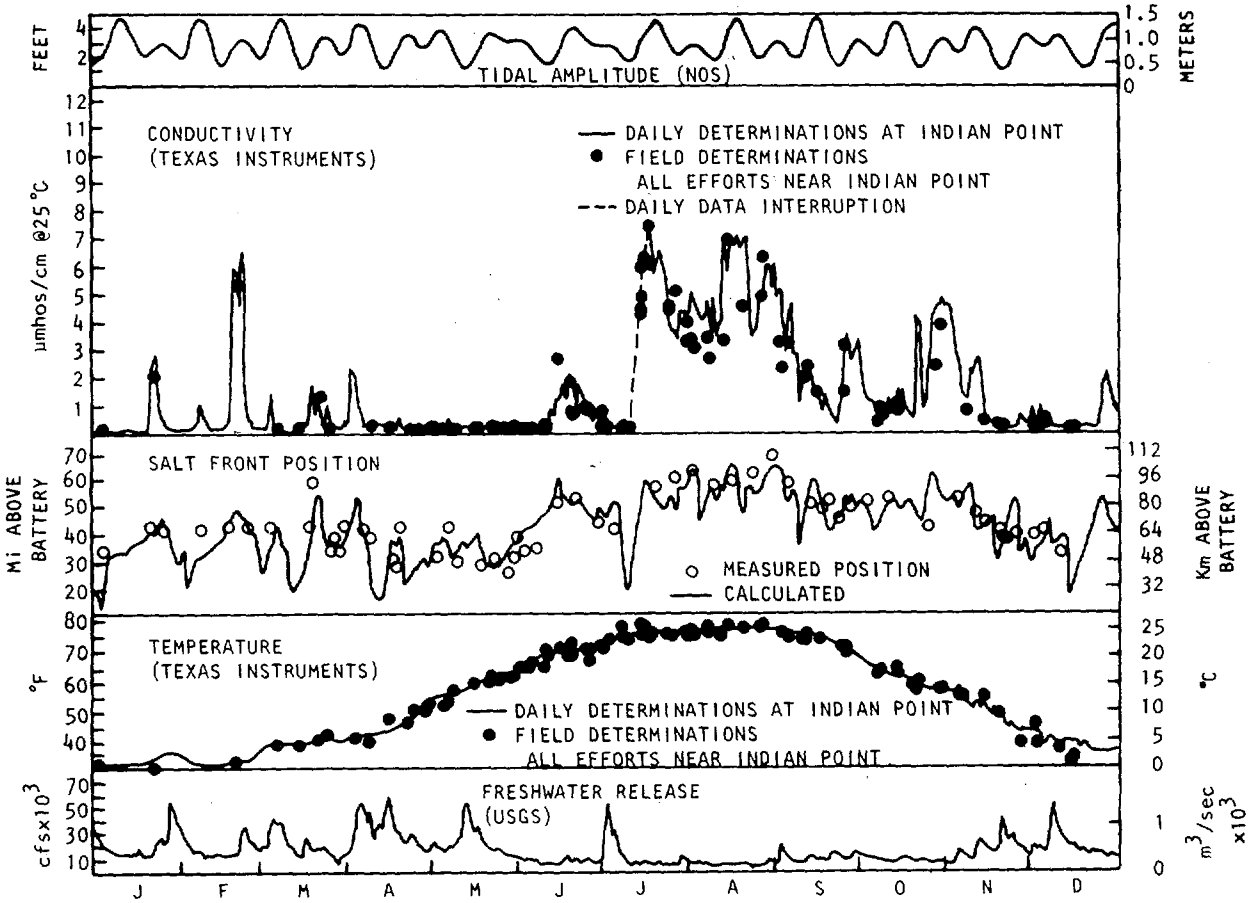
4. Salt-Front Location

Estimates of the longitudinal position of the salt front were made by inspecting conductivity values obtained from water sampling. An index value of 300 µmhos/cm (equivalent to salinity of approximately 0.1 $^{o}/oo$) was used throughout the present study to indicate the extent of saltwater intrusion.

C. RESULTS

1. Conductivity

Salinity in the Indian Point region in 1974 (Figure III-2) followed the same general temporal pattern observed in preceding study years (Appendix C). During the early months of the year, intrusions of saline water were regular and of relatively short duration. The more intensive, extended summer intrusion was preceded by a period of no appreciable intrusion. Movement of saline water out of the estuary was an erratic process involving several reinvasions during the later months of the year.



1974

Figure III-2. Temporal Distribution of Freshwater Release, Water Temperature, Salt Front Position, Conductivity, and Tidal Amplitude

The mixing caused by the sill complex between Grassy Point (km 62) and Peekskill Bay (km 69) resulted in comparable conductivity values at the Indian Point plant intakes (solid line, Figure III-2) and from all field sampling activities in the area of the plant (single data points, Figure III-2). The maximum conductivity observed in the area of Indian Point was 7.5 mmhos/cm (~ 4.3 $^{0}/oo$ salinity) following a rapid intrusion of saltwater during the second week of July.

In the 10 years of intrusion-related variables (Figure III-2 and Appendix C), individual year plots include the results of U.S. Geological Survey studies, the Raytheon study (1971), and the study years 1972 and 1973.

2. Temperature

Water temperatures at Indian Point during 1974 appear in Figure III-2. The summertime temperature plateau had few deviations from 25°C (77°F). The maximum temperature observed was 26.5°C (80°F) while the minimum was 0.5°C (33°F) during mid-February. Plots of water temperatures near Indian Point for the years from 1965 through 1973 appear in Appendix C.

3. Dissolved-Oxygen Concentrations

The time curve for dissolved oxygen during 1974 appears to be the inverse of that for ambient water temperature (Figure III-3). The winter plateau was approximately 13 mg/ℓ. The maximum value observed was 13.7 mg/ℓ in mid-February; the minimum was 0.8 mg/ℓ in mid-July (12-m depth; RM 41.5). Data from studies over the 1965-1974 period are also summarized in Figure III-3.

4. Hydrogen Ion Concentrations (pH)

Few hydrogen ion concentrations outside the pH range of 7.0 to 7.5 were observed during 1974 (Figure III-3): the maximum value observed was 8.0 (July) while the lowest was 6.4 (May). No trend in pH values was apparent during 1974 or preceding years (Figures III-3 and III-4).

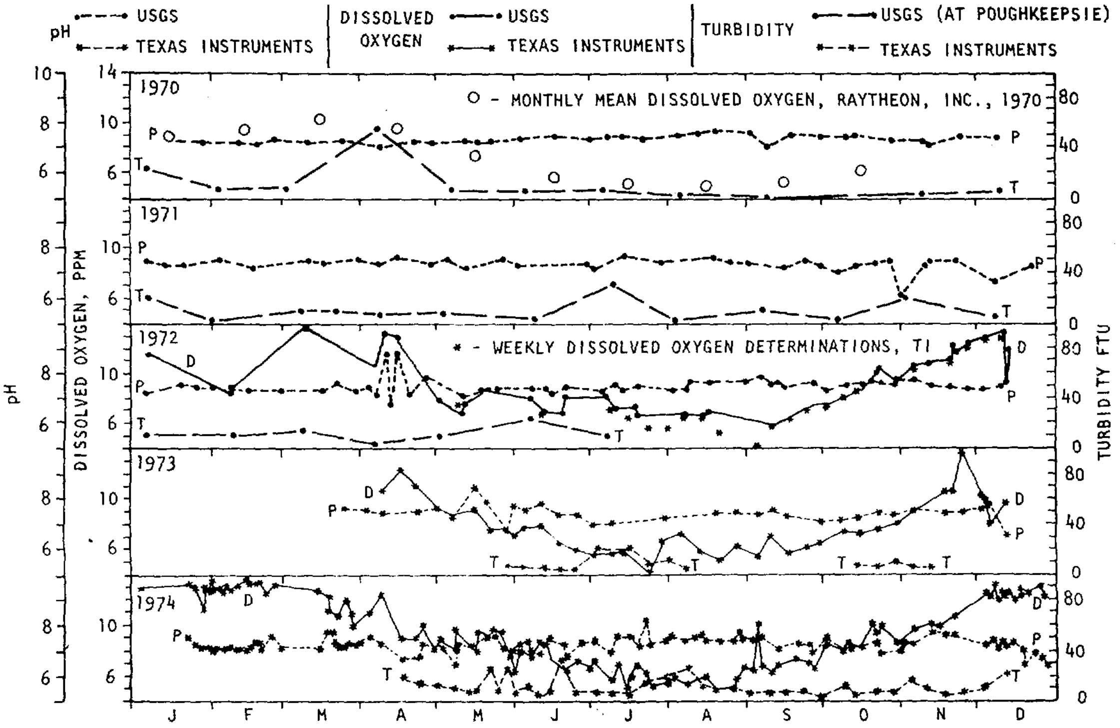


Figure III-3. Temporal Distribution of Dissolved Oxygen, Turbidity, and pH in Indian Point Area, 1970-1974

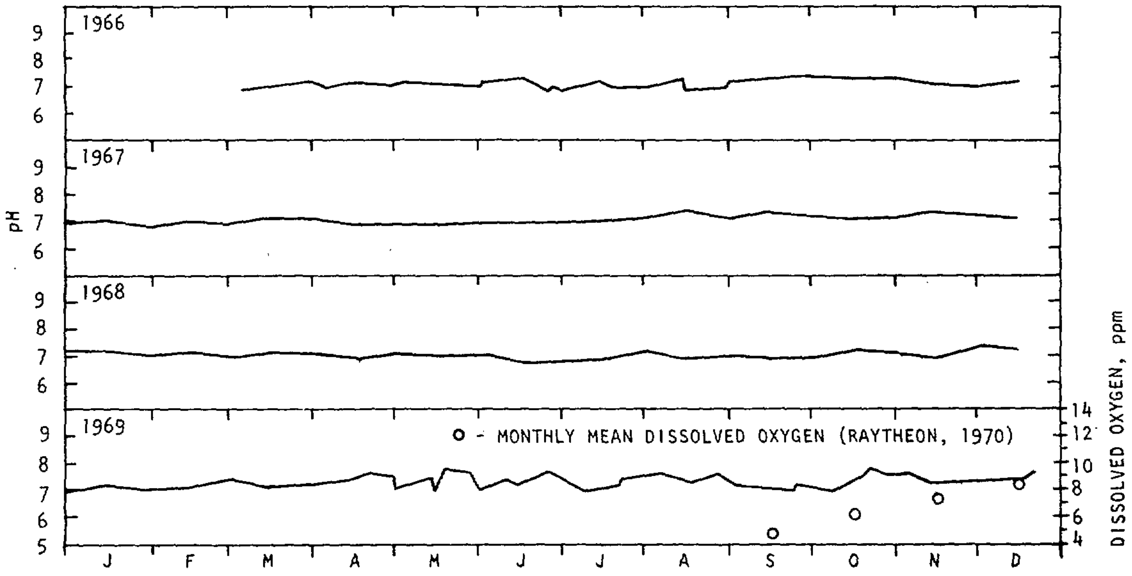


Figure III-4. Temporal Distribution of pH and Dissolved Oxygen in Indian Point Area, 1965-1969. (Data on pH from USGS records)

5. Turbidity

Turbidity in the Indian Point area was 2-32 FTU (Figure III-3). Peak values occurred following freshwater releases at Green Island. Similar occurrences were indicated during 1965-1973.

D. DISCUSSION

1. Salinity Distribution

The distribution of saltwater within the lower Hudson River was highly variable both temporally and spatially during 1974. This variability was imposed by interactions between freshwater flows, tidal activities, and channel morphometry and, to a lesser extent, by evaporation and other meteorological factors. Of these variables, only those which were time-dependent could be utilized for estimating temporal movements of the salt front. Morphometric characteristics were considered subjectively. The variables which allowed estimation of salinity distribution through time were restricted to freshwater release at Green Island and tidal amplitudes. These parameters account for virtually all of the control over salinity distribution within the Hudson estuary.

Comparison of flow and mixing variables with salinity intrusion was accomplished by calculating a multiple correlation, using tidal amplitudes and freshwater releases as independent variables and salt-front position as a dependent variable. A given salt-front position is the cumulative result of conditions during the previous few days; consequently, utilization of flow and mixing variables necessitated the introduction of lag times into estimation of the mathematical relationship between intrusion, flow, and mixing. Initial choices of lag times were based on inspection of the graphical presentations in Figure III-2.

Peak conductivity values generally followed minimum tidal amplitudes at Indian Point by slightly less than 5 days; approximately the same lag time was observed between peak freshwater releases at Green Island and the beginning of rapid salinity decreases at Indian Point. More accurate determination of these lag times was accomplished by comparing correlation coefficients for 3-, 4-, and 5-day lags for tidal amplitudes and 4- and 5-day lags for freshwater-released data. The maximum coefficient value was $r = 0.9403$ for tidal amplitudes 4 days before and freshwater flows 5 days before a given salt-front location.

The equation giving the best fit to observed intrusions was:

$$R_s = -17.33 (\ln U_5) + 25.59/A_4 + 78.17 \quad (1)$$

where

R_s = longitudinal salinity intrusion length (in miles) above Battery Park, indicated by location 0.1 °/oo salinity isopleth at mid-channel

U_5 = freshwater release at Green Island 5 days ahead of a given salt-front location (in thousands of cubic feet per second)

A_4 = tidal amplitude at Indian Point 4 days ahead of a given salt-front location (in feet)

The 95% confidence interval for A_4 = 2.9 ft (0.9 m) and U_5 = 12,000 cfs (340 m^3/sec) was determined to be ±1.37 mi (2.2 km), expanding to ±3.51 mi (5.6 km) when U_5 = 50,000 cfs (1420 m^3/sec) and to ±5.70 mi (9.1 km) when U_5 = 1,000 cfs (30 m^3/sec).

Comparisons of calculated and observed salinity intrusion distances for 1974 appear in Figure III-2 and for 1965 through 1973 appear in Appendix C. During the 10-year period, 80% of the observed locations were within 5 mi or 3 days of the calculated values. The majority of the deviations between observed and expected values represent the influences of sill structures in the areas of Verplanck Point and Storm King Mountain. These structures delayed salt intrusion until tidal amplitude had decreased to a level which allowed the saltwater/freshwater interface to pass the high-turbulence zone produced at the peak of the sill. As the interface rose, it ceased to be strongly influenced by the sill; intrusion into the fjord-like portion of the estuary proceeded largely unimpeded until the salt front reached the sill at Storm King Mountain where the most intense retardation occurred as a result of increased tidal amplitude above West Point (Figure III-5), shallow channel depths above Cornwall, and constriction of channel width between Storm King and Breakneck Mountains (Figure III-6). This retardation is expressed as observed front positions near Cornwall. Interpretation of these differences was simplified by comparing the shape of salt-front position curves above RM 43 (km 69) with the shape of conductivity plots; once the salt front had passed a given mile point, saltwater intrusion continued to be evidenced at that mile point by rising conductivities, despite restriction of salt-front progress by some structure further upstream. This was apparently the case at Indian Point, since front progress and conductivity curves substantially resembled each other (Figures III-2 and III-5). Correlation between calculated salt-front positions and conductivities at Indian Point was highly significant ($p < 0.01$, $r = 0.6330$, 132 degrees of freedom). The equation describing this relationship is as follows:

$$C_{25} = -4.22\,(\ell n\ U_5) + 6.23/A_4 + 9.82 \qquad (2)$$

where C_{25} = conductivity at Indian Point in mmhos/cm @ 25°C. The variables U_5 and A_4 were given for Equation (1). The 95% confidence interval for this equation is narrowest at 13.6 mi (22 km) above Indian Point (±0.392 mmhos/cm), widening to 10 mi (16 km) in either direction (±0.639 mmhos/cm) from km 69 + 21.8 near Storm King Mountain (RM 57).

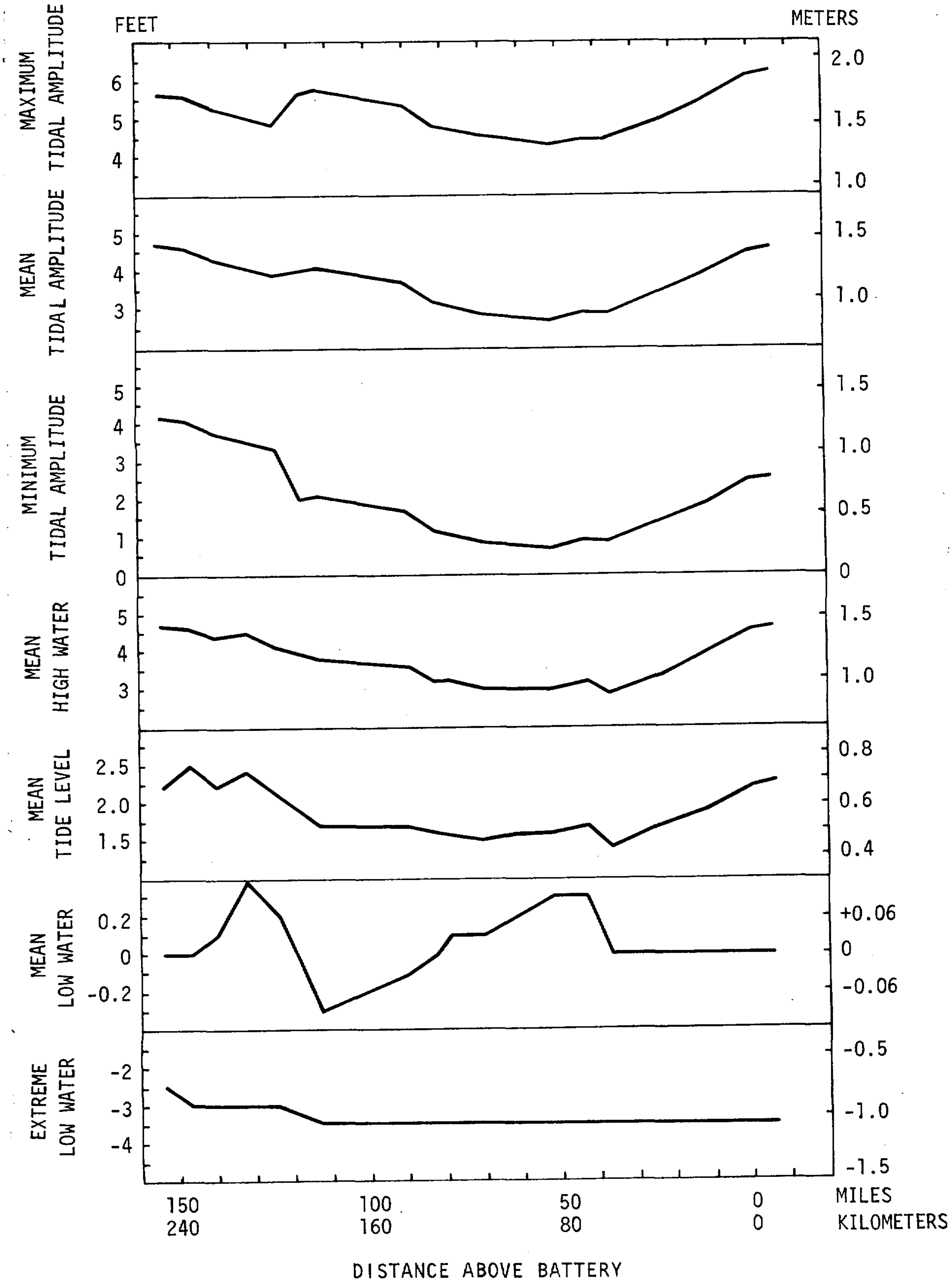


Figure III-5. Longitudinal Changes in Major Indices of Tidal Activity

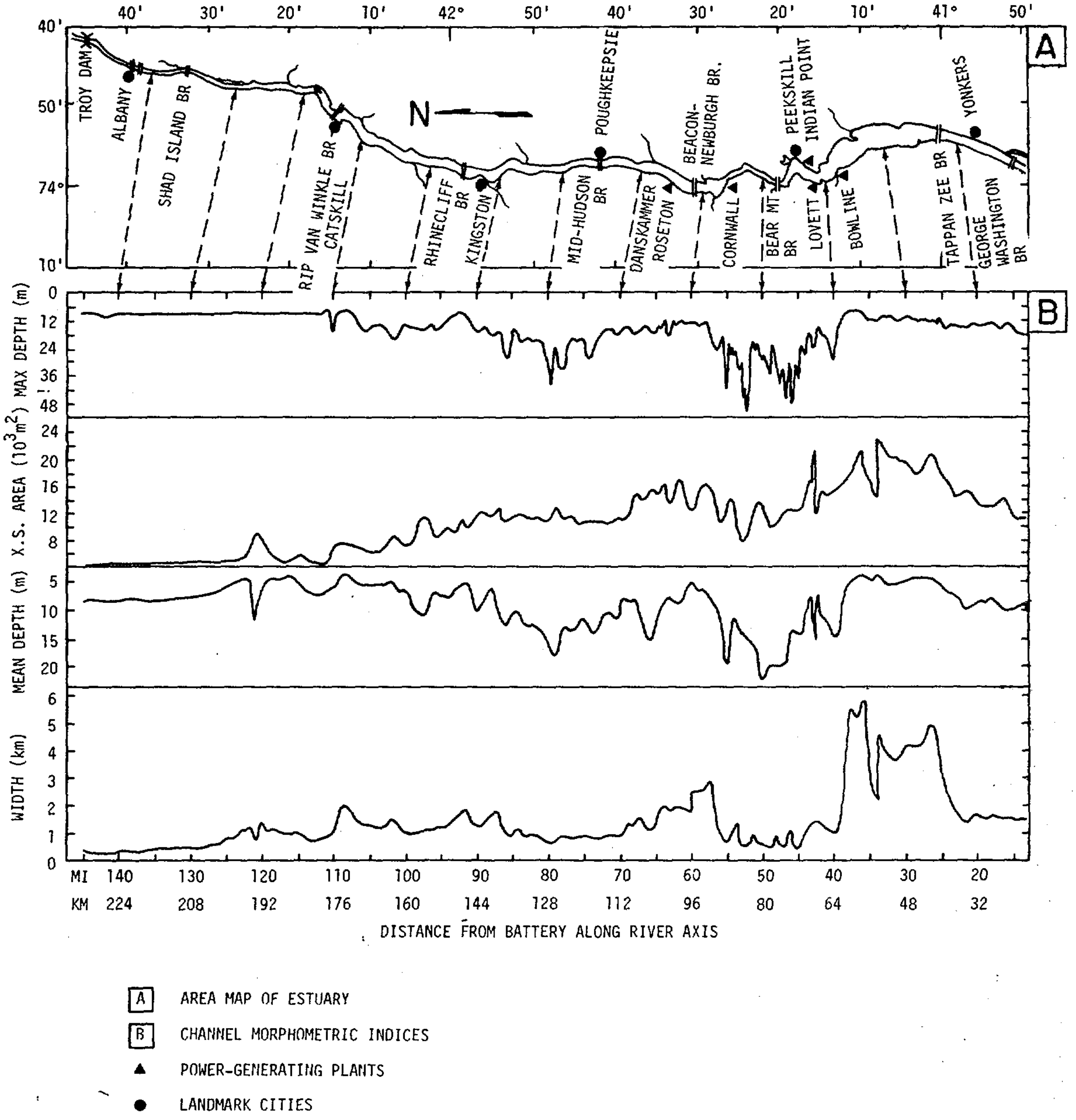


Figure III-6. Major Morphometric Characteristics of Lower Hudson River Estuary

An additional dimension to the concept of salinity distribution within the estuary is provided by the longitudinal distribution of conductivity values. This index was incorporated, with intrusion length and conductivity at Indian Point, into a 3-dimensional format illustrating the spatial and temporal relationships between the three indices of salinity intrusion into the estuary channel (Figure III-7). This should be viewed in terms of a salt-intrusion surface having temporal and spatial dimensions and sloping from a maximum elevation (conductivity) at the ocean end of the estuary to a minimum elevation at greatest intrusion length (salt-front position). This relationship may also be useful in predicting when large numbers of fish are likely to be impinged on the protective screens at the Indian Point plant (TI, 1975d).

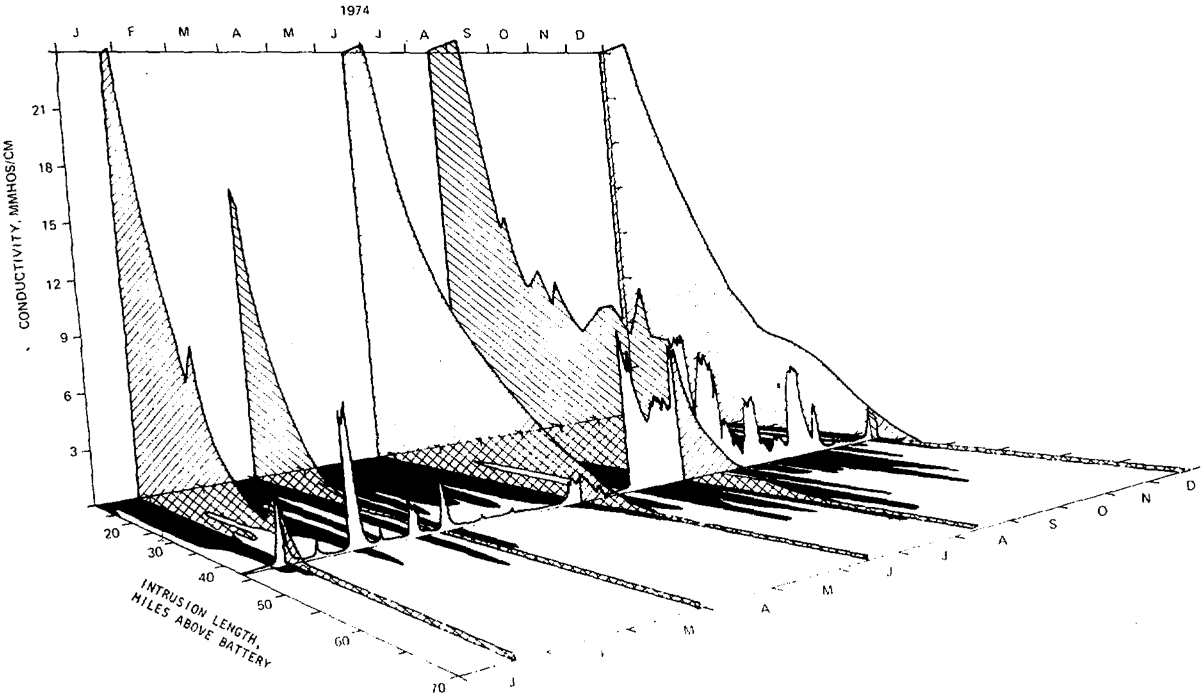


Figure III-7. Semidiagrammatic 3-Dimensional Interrelationships between Three Indices of Salinity Intrusion in Hudson River during 1974

2. Temperature, Dissolved Oxygen, and Turbidity Distribution

Major short-term variations in temperature, dissolved-oxygen concentrations, and turbidity could be traced to freshwater releases. Most large variations occurred during the warmer months. Shortly after the beginning of each major freshwater release during spring and early summer, temperature increase rates were retarted and occasionally reduced river temperature (Figure III-2); three such reductions occurred during 1974 (February, April, and late May). Increases in cooling rates during autumn also were present but less evident since there were no apparent reversals of curve slope.

Occasional depressions of dissolved-oxygen concentration have been observed throughout the 1972-1974 study period. Many have been localized depletions due, in part, to morphometric or hydrologic trapping of water bearing high organic loads; this effect was reported for the benthic studies control area at Jones Point during April 1973 (TI, 1974a).

Depletion of oxygen in deep water was recorded during the third week of July 1973; this depletion included approximately the lower half of the river volume between Bear Mountain and Stony Point where isolated near-complete depletions were found (one near bottom at Fish Island and one at a depth of 12 m near Stony Point). The most severe depletion of oxygen encountered during the 1972-1974 study period occurred in the last week of May 1974; during the May 29-31 period, oxygen concentrations between West Point (RM 52) and Kingston (RM 92) were reduced to as low as 1.5 mg/ℓ with only four data points above 4.0 mg/ℓ (TI, 1975c). The maximum duration of this depletion period was 4 days, with the most probable duration of very low oxygen concentrations being 2 days. Microbial activity supported by influxes of organic detritus may be the cause of such reductions (TI, 1974a).

The influence of localized hydrologic traps was emphasized following the peak freshwater release of July 2-10, 1974. During the week of July 14, depressed dissolved-oxygen readings (down 0.8 mg/ℓ) were observed at a single sampling location, an area previously shown to be a large countercurrent or eddy where detritus was concentrated in open water (TI, 1974a).

No recognizable trends in turbidity were evident from the data presented in Figure III-3. All determinations during the 5-year period illustrated were made by the same method, providing reasonable data comparability.

3. Hydrogen Ion Concentrations

The stability of pH values within the Hudson River estuary is evident from Figures III-3 and III-4. The small number of deviations from the 7.0-7.5 interval suggests a stable relationship between the river and those factors capable of significantly influencing hydrogen ion concentrations (input of detritus, saline water intrusion, meteorological conditions, metabolic activities.)

E. CONCLUSIONS

From the collected data, one may conclude the following:

(1) Freshwater flow (release — through its influence on salinity intrusion, temperature, dissolved oxygen, and turbidity — appears to be the single most important environmental variable studied.

(2) Salinity intrusion can be predicted with relatively simple equations incorporating only freshwater release and tidal amplitude as independent variables.

(3) Major deviations from the annual sinusoidal pattern generally observed for river temperature are attributable to influxes of cool runoff water.

(4) Turbidities within the river vary with runoff and freshwater release into the estuary, which vary seasonally according to rainfall and snow-melt in the upper watershed.

SECTION IV

RELATIVE ABUNDANCE AND POPULATION DYNAMICS OF INDIAN POINT BENTHOS DURING 1972-1974

A. INTRODUCTION

Benthic studies at Indian Point were designed to assess the effects of thermal and chemical effluents from Consolidated Edison's nuclear generating facility on benthic invertebrates in the area. Specific study objectives included determining community composition, diversity, biomass, and relative abundance; assessing naturally occurring variations in community structure; comparing community variations between a test area at the power-plant site and a control area beyond the influence of plant operation; and evaluating population dynamics of *Cyathura polita*, a benthic isopod that is important in both numbers and biomass in the estuary.

Complete analyses of data from benthic studies during 1972-1974 will be presented in a later report.

B. METHODS

Three replicate 0.1-m^2 Petersen grab samples were taken monthly at 12 stations in the Hudson River near Peekskill, New York, during 1974. The stations were divided equally between test and control regions on opposite sides of the river (Figure IV-1). Samples were washed through 500-μ U.S. Standard sieves and preserved in 4% formaldehyde with Rose Bengal stain. All specimens were removed from the residual debris, identified, and enumerated. Total wet-weight biomass was determined for each sample. Intact specimens of *Cyathura polita* were measured, sexed, and weighed. During the reproductive season (April-August), female *Cyathura* were examined to determine numbers of eggs or larvae contained within the marsupium.

Table IV-1

Taxon List for Hudson River Ecological Survey Benthic Collections at Indian Point between April 1972 and December 1974

- CNIDARIA
  - *Cordylophora lacustris*
  - *Hydra americana*
- PLATYHELMINTHES
  - Planaridae
  - *Dugesia* sp
  - *Dugesia tigrina*
- NEMERTEA
  - Paleonemertea
- NEMATHELEMENTHES
  - Unidentified Nematoda
- ACANTHOCEPHALA
  - Sipunculida
- ANNELIDA
  - Polychaeta
    - *Scolecolepides viridis*
    - *Boccardia hamata*
    - *Hypaniola* sp
    - Nereis larvae
    - *Nereis succinea*
    - Serpulidae
  - Oligochaeta
    - *Limnodrilus* sp
    - *Peloscolex* sp
    - *Stylaria* sp
    - Unidentified
    - Naididae*
  - Hirudinea
    - Hirudinia
    - Glossiphoniidae
    - *Piscicola* sp
- ARTHROPODA
  - Crustacea
    - Decapoda
      - *Crangon septemspinosa*
      - *Rhithropanopeus harrisi*
      - *Orconectes limosus*
      - *Palaemonetes pugio*
      - *Callinectes sapidus*
    - Mysidacea
      - *Neomysis americana*
    - Amphipoda
      - *Gammarus* sp
      - *Monoculodes* sp
      - *Corophium* sp
      - *Asellus* sp
      - *Leptocheirus* sp
      - Unidentified
      - *Crangonyx* sp *
    - Isopoda
      - *Livoneca ovalis*
      - *Cassidina lunifrons*
      - *Cyathura polita*
      - *Edotea* sp.
      - *Chiridotea almyra*
    - Cumacea
      - Unidentified
    - Cirripedia
      - *Balanus improvisus*
    - Copepoda
      - Harpacticoida
      - Cyclopoida
      - Calanoida
    - Ostracoda
      - Unidentified
    - Cladocera
      - Cladoceran ephippium
      - Macrothricidae
      - *Daphnia* sp
      - *Bosmina* sp
      - *Latona* sp
      - *Leptodora kindti**
  - Insecta
    - Phloethripidae
    - Isotomidae-Collembola
    - Unidentified insect larvae
    - *Agraylea* sp
    - Leptoceridae
    - Trichopteran adult
    - *Limnophora* sp
    - *Amphiagrion* sp
    - *Enallagma* sp
    - *Ischnura* sp
    - Odonata larvae
    - *Cryptochironomous* sp
    - *Palpomyia* sp
    - Chironomid larvae
    - Chironomid pupae
    - *Chaoborus* sp
    - Trichopteran larvae*
    - Ephemeropteran larvae*
    - Dipteran pupae*
    - Ceratopogonidae larvae*
  - Arachnida
    - Hydracarina
- MOLLUSCA
  - Gastropoda
    - *Amnicola* sp
    - Nudibranchia
    - Unidentified juvenile
    - *Ferrissia* sp *
  - Pelecypoda
    - Lamsilinae
    - Sphaeridae
    - *Congeria leucophaeta*
    - *Pisidium* sp
    - *Elliptio* sp
- ECTOPROCTA
  - *Cristatella mucedo*
  - *Hyalinella* sp
  - *Pectinatella magnifica*
  - *Lophopodella carteri*

* Taxa added during 1974

One 0.5-m^2 epibenthic sled tow and one 0.5-m diameter plankton net tow were taken monthly in each area (test and control) to obtain an overview of epibenthic community structure. Both nets were 500-μ mesh, and the samples were processed in the same manner as Petersen grab samples. Detailed descriptions of procedures may be found in *Hudson River Ecological Studies in the Area of Indian Point, 1st Semiannual Report* (TI, 1972).

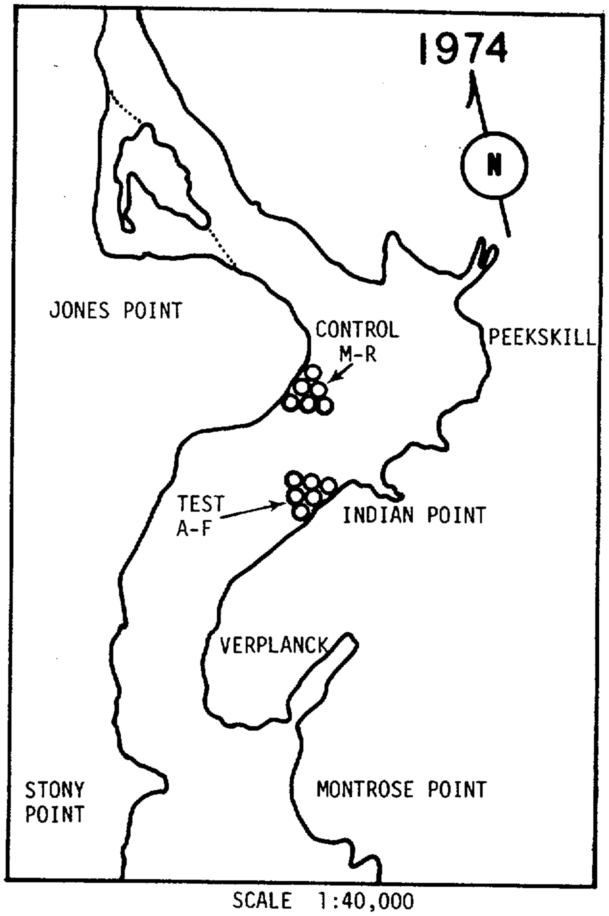


Figure IV-1. 1974 Indian Point Benthic Sampling Stations

C. RESULTS AND DISCUSSION

1. Community Analyses

a. Community Composition

During 1974, nine taxa were added to the list of taxa known to occur in the vicinity of Indian Point. The complete list (Table IV-1) consists of 86 taxa representing nine phyla. The majority of 1974 additions were single observations of rare organisms which do not seem to represent a significant portion of the community or indicate trends in community composition.

b. Relative Abundance

As in 1973 (TI, 1974), the tubificid worm *Limnodrilus* was the most common form in the control area (Table IV-2); during 1974, however, its dominance was reduced and, in the test region, its mean annual numbers were exceeded by those of *Scolecolepides viridis* (Polychaeta) and *Amnicola* sp

Table IV-2

Annual Mean Numbers of Individuals/m^2 at Indian Point Test and Control Regions during 1972, 1973, and 1974

Dominant Taxa		1972		1973		1974	
	Survey	Test	Control	Test	Control	Test	Control
Limnodrilus sp	547.7	324.7	415.7	1349.5	2870.8	2730.9	3601.6
Cyathura polita	162.0	201.3	219.9	244.6	137.8	467.5	434.6
Boccardia hamata	215.0	132.2	783.9	221.4	767.1	133.6	955.0
Scolecolepides viridis	74.6	89.9	69.1	212.4	244.0	2824.5	2086.8
Gammarus sp	82.8	156.1	93.0	442.4	219.1	287.4	154.4
Amnicola sp	992.1	662.8	486.9	15.7	3.5	4008.3	975.8
Balanus improvisus	133.4	240.9	22.9	47.8	108.9	1016.9	825.8
Congeria leucophaeta	123.9	290.2	11.0	97.6	35.4	295.9	74.3
Chironomid larvae	191.1	129.3	43.4	121.7	26.2	226.9	52.0
Corophium sp	56.8	48.8	15.2	57.8	27.2	150.2	158.7
Chaoborus sp	2.6	5.1	1.6	26.8	12.1	46.2	43.4
Peloscolex sp	56.8	85.9	62.1	23.5	13.8	8.2	3.6
Chiridotea almyra	2.6	2.3	6.3	2.9	12.2	21.9	30.1
Edotea sp	2.6	1.1	5.3	6.3	25.1	12.8	32.1
Nematoda	25.7	18.4	21.2	7.6	0.9	12.5	4.0
Rhithropanopeus harrisi	6.3	17.5	1.2	10.9	1.1	18.7	18.9
Hypaniola sp	4.8	2.7	5.1	5.1	4.4	10.7	2.0
Nudibranchia	2.8	1.1	1.1	1.7	1.8	21.0	4.6
Monoculodes sp	0.2	0.3	0.2	1.9	2.2	5.4	4.0
Paleonemertea	0.4	0.4	0.2	0.5	0.9	3.8	2.8
Hydracarina	0.7	1.1	0.2	0.1	0.1	0.3	0.3
Piscicola sp	0.3	0.5	1.0	0.2	0.2	0.5	0.1
Trichoptera - adult	0.1	0.1	0.3	0.2	0.1	0.7	1.0
Leptocheirus sp	1.4	0.9	-	2.0	0.7	18.9	5.8
Planaridae	8.9	13.3	2.9	-	-	0.4	0.2
Sphaerium sp	0.3	-	0.2	-	-	4.5	1.6
Collembola	0.1	-	0.2	-	-	0.3	0.2
Chironomid pupae	0.1	-	0.2	-	-	3.1	0.4
Hydra americana	0.1	-	-	-	0.6	0.2	-
Daphnia sp	0.1	0.1	-	-	-	0.1	1.2
Cassidina lunifrons	0.1	0.1	-	-	-	0.2	0.4
Acanthocephala	0.1	0.1	-	0.1	-	-	-
Nereis succinea	0.1	0.1	-	-	-	-	0.2
Sipunculida	0.1	0.1	-	-	-	-	-
Dugesia sp	0.1	0.2	-	-	-	-	-
Palpomyia sp	0.1	0.1	-	-	-	-	-
Enallagma sp	0.1	-	-	-	-	-	-
Decapod - larva	0.1	0.1	-	-	-	-	-
Turbellaria	0.1	0.3	-	-	-	-	-
Neomysis americana	-	-	-	0.1	0.1	0.2	-
Odonata - larva	-	-	-	0.1	-	-	0.1
Agraylea sp	-	-	-	0.1	-	-	-
Glossiphoniidae	-	-	-	-	0.1	-	-
Elliptio sp	-	-	-	-	-	0.2	-
Ceratopogonidae	-	-	-	-	-	0.1	0.2
Ferrissia sp	-	-	-	-	-	0.1	0.1
Crangonyx sp	-	-	-	-	-	0.1	-
Crangon septemspinosus	-	-	-	-	-	-	0.3
Ephemeroptera - adult	-	-	-	-	-	-	0.2
Naididae	-	-	-	-	-	-	0.1
Leptodora sp	-	-	-	-	-	-	0.1
Harpacticoida	4344.1	7836.7	2527.2	0.2	0.1	52.5	10.3
Ostracoda	208.3	198.8	82.9	-	-	0.1	0.1
Cyclopoida	17.6	23.6	11.4	0.4	-	34.5	18.9
Calanoida	1.0	1.2	1.3	0.2	-	11.1	0.3
Macrothricidae	0.3	-	2.0	-	-	-	0.3
Total No. of Taxa	44	38	32	31	28	40	43
Mean Total No/m^2	7268.5	10488.5	4895.1	2901.7	4516.5	12409.2	9500.7

(Gastropoda). While some variation in absolute ranking of major taxa was observed between the test and control areas, the same taxa constitute the dominant assemblage in both areas.

Total numbers of taxa and annual mean numbers of specimens/m^2 were greatly increased during 1974 in both the test and control regions. *Balanus improvisus*, *Amnicola* sp, *Congeria leucophaeta*, and *Rhithropanopeus harrisi*, annually reproducing species which were present in relatively low numbers during 1973, experienced considerable increase during 1974. Other species such as *Scolecolepides viridis* showed progressive increases in 1973 and 1974 over their 1972 population levels. The number of taxa observed during 1974 was increased over 1973 not only by the reappearance of halophilic forms (*Cassidina lunifrons*, *Nereis succinea*) which were collected during 1972 but were missing in 1973, but by the collection of several taxa (*Crangon septemspinosa*, *Crangonyx* sp; *Ferrissia* sp) which had not been taken previously in grab samples. These increases apparently reflect the influence of greater duration of salt exposure in the Indian Point area during both 1973 and 1974.

c. Diversity

Indian Point 1974 test and control region species diversity indices (Hurlbert, 1971; Margalef, 1957; Pielou, 1966) showed a similar pattern of seasonal variation (Table IV-3). The test region however, exhibited somewhat higher diversity throughout the year; it was very similar to that during 1973 (Appendix B), whereas the control region generally increased over 1973 levels. This was apparently due to the continued regeneration of community structure following a disruption caused by deposition of large amounts of terrigenous detritus in the control region (TI, 1974a) during the spring of 1973 and decreases in diversity resulting from proliferation of *Limnodrilus* sp (Tubificidae).

Table IV-3

Monthly Diversity Indices at Indian Point Test and Control Region Stations during 1974

		Test Area Stations						Control Area Stations					
Month	Index	A	B	C	D	E	F	M	N	O	P	Q	R
Apr	SW	0.85	0.79	0.80	0.42	0.66	0.32	0.50	0.43	0.32	0.45	0.66	0.54
	H	4.31	3.76	3.67	0.76	2.28	0.67	1.49	1.33	0.57	0.92	3.25	1.74
	J	0.63	0.60	0.6	0.33	0.49	0.25	0.45	0.41	0.29	0.38	0.66	0.47
May	SW	0.66	0.47	0.47	0.38	0.40	0.49	0.65	0.43	0.46	0.55	0.51	0.41
	H	2.21	1.43	1.35	1.08	0.97	1.29	2.14	0.99	1.45	1.70	1.55	1.24
	J	0.55	0.44	0.36	0.37	0.37	0.38	0.62	0.38	0.46	0.42	0.49	0.36
Jun	SW	0.61	0.60	0.61	0.48	0.71	0.53	0.61	0.63	0.62	0.66	0.49	0.41
	H	1.78	1.99	2.14	1.40	3.03	1.65	2.12	2.21	2.21	2.42	1.45	1.23
	J	0.49	0.50	0.47	0.39	0.54	0.41	0.51	0.51	0.53	0.64	0.37	0.35
Jul	SW	0.51	0.61	0.65	0.71	0.75	0.62	0.46	0.55	0.56	0.63	0.38	0.50
	H	0.96	1.95	2.39	2.63	3.25	2.06	1.02	1.57	1.27	1.73	0.61	1.56
	J	0.41	0.44	0.49	0.52	0.56	0.46	0.38	0.46	0.45	0.49	0.32	0.43
Aug	SW	0.58	0.80	0.75	0.65	0.34	0.36	0.67	0.74	0.49	0.48	0.62	0.25
	H	2.09	3.36	3.03	2.06	0.63	0.89	2.87	3.02	1.39	1.42	2.44	0.47
	J	0.52	0.56	0.55	0.47	0.27	0.27	0.53	0.58	0.39	0.35	0.48	0.20
Sep	SW	0.57	0.71	0.68	0.65	0.50	0.46	0.67	0.67	0.60	0.55	0.54	0.39
	H	1.91	3.15	2.52	2.23	1.23	1.19	2.55	1.94	2.39	1.20	1.36	1.09
	J	0.49	0.59	0.52	0.50	0.42	0.39	0.51	0.53	0.49	0.45	0.40	0.33
Oct	SW	0.79	0.83	0.77	0.32	0.36	0.58	0.81	0.63	0.72	0.65	0.47	0.46
	H	3.44	3.84	3.09	0.40	0.52	1.35	3.37	1.37	2.29	2.22	1.11	1.29
	J	0.63	0.60	0.58	0.25	0.27	0.44	0.61	0.46	0.56	0.50	0.38	0.38
Nov	SW	0.75	0.39	0.84	0.58	0.59	0.68	0.65	0.51	0.62	0.65	0.72	0.59
	H	2.92	0.86	4.38	1.25	1.34	1.99	2.27	1.42	2.26	2.77	3.49	1.77
	J	0.56	0.30	0.66	0.44	0.44	0152	0.50	0.44	0.51	0.53	0.59	0.46
Dec	SW	0.73	0.55	0.71	0.53	0.66	0.36	0.60	0.76	0.67	0.60	0.58	0.42
	H	2.39	1.71	2.23	0.92	1.57	0.59	2.08	3.00	2.66	1.88	1.80	1.23
	J	0.56	0.41	0.54	0.40	0.51	0.28	0.51	0.58	0.54	0.50	0.51	0.35

*SW = Shannon-Weaver log 10
H = Hurlbert
J = Pielou

While species diversity and evenness calculations are widely used in evaluating community trends and variation, the distribution of resultant indices is not generally normal and, therefore, not adaptable to analysis by parametric statistical methodology. A new evenness index developed by Heip (1974) has been shown to approximate normal distribution; this index is based on the Shannon-Weaver information function (Margalef, 1957), which is presently calculated for Indian Point benthic samples. Initial steps have been taken to transform Shannon-Weaver values for 1972, 1973, and 1974 to Heip indices for this time period. These indices will be analyzed and the results reported in the thermal-effects final report.

d. Biomass

Seasonal fluctuations in mean wet-weight biomass (Figure IV-2) were similar between the test and control regions, but mean values for the test region were consistently higher than those for the control region. While seasonal patterns during 1974 were generally consistent with observations during 1972 and 1973 (Appendix B), mean total biomass for both regions was greatly increased over 1973 levels and approximately equal to those of the 1972 collecting season.

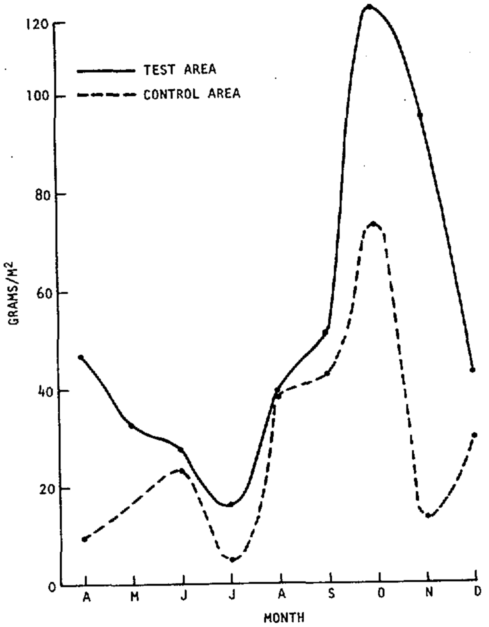


Figure IV-2. Monthly Mean Wet-Weight Biomass/m^2 at Indian Point Test and Control Regions during 1974.

e. Comparison with Previous Studies

Indian Point benthic community structure studies during 1972-73 (TI, 1973a, 1974a) and 1969-70 (Raytheon, 1971) indicate shifts in community composition from dominance by more halophilic forms in 1969-70 toward less salt-tolerant forms during 1972-73 as a result of variations in the salinity regime. Bottom salinities at Indian Point during 1969-70 (Raytheon, 1971) approximately equaled those observed during 1972-73, but length of exposure during 1969-70 considerably exceeded that observed in 1972-73. The 1969-70 period represented the end of a period of low rainfall and reduced runoff, which greatly increased both duration and extent of the annual intrusion of the salt front into the Indian Point region (US Department of Interior, 1965, 1966, 1967, 1968, 1969, 1970). During 1973-74, duration of salt intrusion in the Indian Point region increased over the 1971-72 period and, by 1974, benthic community composition and relative abundance showed a general reversal of the earlier trend, again favoring the halophilic forms (Tables IV-4 and IV-5).

Table IV-4

Comparison of Relative Abundance of Dominant Taxa during August-December Periods of 1969, 1972, 1973, and 1974

	Mean No./m^2					
Taxon	1969*	1972	1973 Test	1973 Control	1974 Test	1974 Control
Congeria leucophaeta	56	192	124	64	521	134
Gammarus sp	104	72	320	137	189	76
Cyathura polita	160	192	280	138	555	654
Leptocheirus sp	384	2	3	<1	24	10
Balanus improvisus	1408	227	86	197	1803	1486
Monoculodes sp	0	<1	<1	3	9	7
Nemertea	16	<1	<1	2	6	44
Rhithropanopeus harrisi	0	8	9	<1	31	22
Corophium sp	0	27	94	48	236	285
Edotea sp	16	5	11	45	23	58

*From Raytheon, 1971

Table IV-5

Comparison of Relative Abundance of Dominant Taxa during January-October Periods of 1970, 1972, 1973, and 1974

	Mean No./m^2					
Taxon	1970*	1972	1973 Test	1973 Control	1974 Test	1974 Control
Congeria leucophaeta	560	107	89	45	239	83
Gammarus sp	320	83	353	211	287	181
Cyathura polita	316	162	260	139	448	411
Leptocheirus sp	224	1	2	<1	16	6
Balanus improvisus	116	130	62	141	816	943
Monoculodes sp	52	<1	<1	2	2	2
Nemertea	36	<1	<1	1	4	3
Rhithropanopeus harrisi	24	7	9	1	16	12
Corophium sp	8	66	72	34	94	195
Edotea sp	<1	3	8	32	14	40

*From Raytheon, 1971

2. *Cyathura polita* Population-Dynamics Studies

Seasonal variation in population density of the estuarine isopod *Cyathura polita* (Stimpson) during 1974 was similar between the Indian Point test and control regions. Both regions exhibited relatively low numbers during the early months, high reproduction and corresponding increases in total numbers during May-September, and general decreases through fall and early winter (Figure IV-3).

This pattern is consistent also with those determined for the test region during 1972-73 and the control region in 1972. While seasonal fluctuations in the control region during 1973 generally following this pattern, reproductive success and corresponding population numbers were low. This population disruption was probably the result of the intolerance of *Cyathura* to low dissolved-oxygen conditions (Dean and Haskin, 1964; Burbanck, 1964) which resulted from deposition of large amounts of detrital material in the area early in the reproductive period and reduction of free oxygen associated with its decomposition. This phenomenon was discussed more completely in the Indian Point 1973 annual report (TI, 1974a).

Length-frequency distributions of *Cyathura polita* in the Indian Point test and control regions during 1974 (Tables IV-6 and IV-7) were quite similar, the only apparent variation lying in maximum size which was somewhat higher (3-mm total length) in the test area. This variation may, however, have been attributable entirely to chance since relative numbers of individuals in the upper size categories were quite low.

Prior evaluation of year-class distribution has been limited to subjective procedures for determining natural breakpoints in size distribution of *Cyathura*. Statistical procedures for evaluation year-class distribution are being evaluated and will be incorporated in thermal effects analyses if a suitable procedure can be determined.

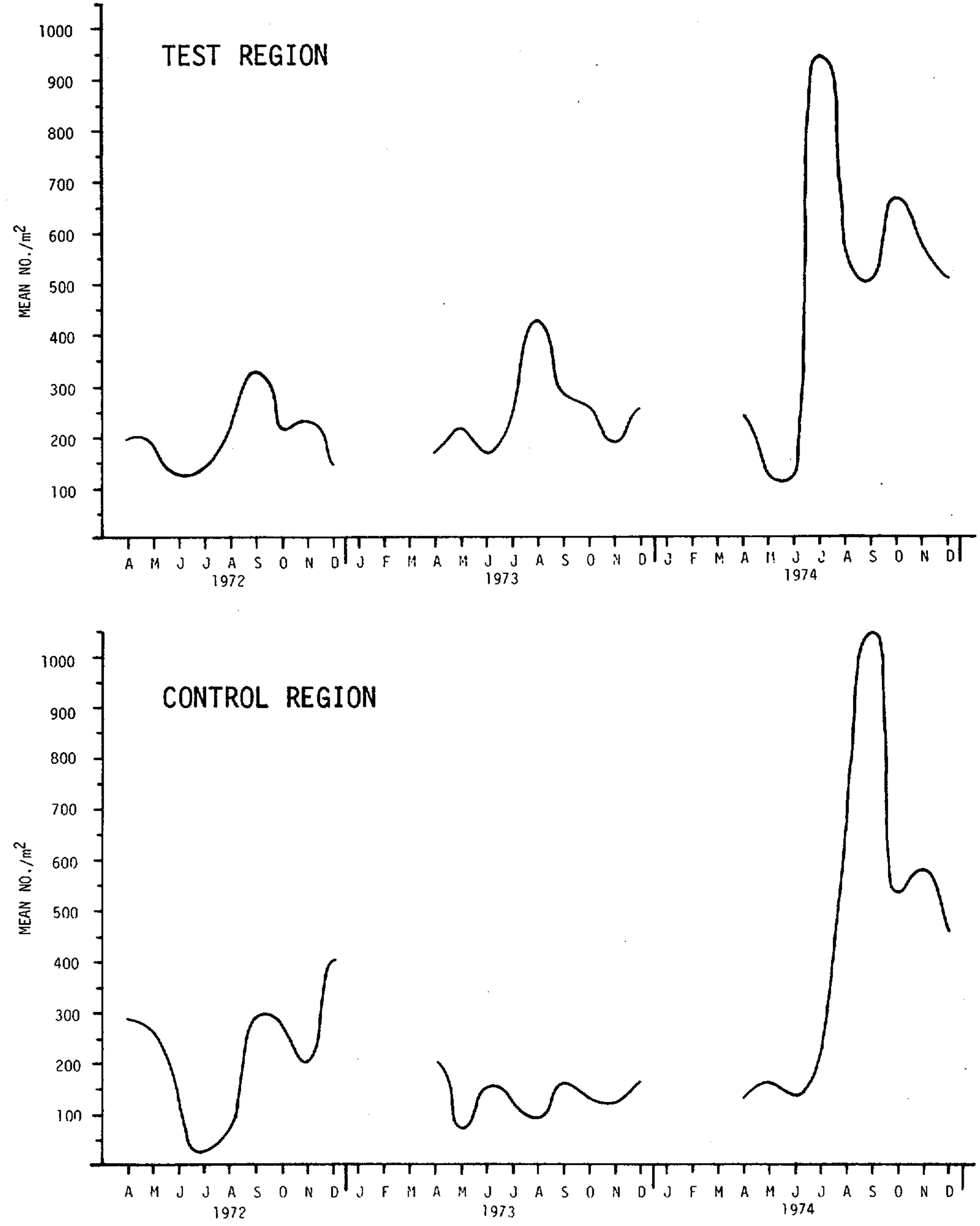


Figure IV-3. Mean Monthly Density per Square Meter of *Cyathura polita* (Stimpson) in Indian Point Test and Control Regions between April 1972 and December 1974

Table IV-6

Cyathura polita Size Class-Frequency Distribution in 1974 Control Region Collections

Size Class (mm)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1						1			
2						238	80		
3		2		247	104	314	165		
4	11	25	5	6	101	214	224	65	52
5	29	57	12		178	124	150	221	191
6	33	53	28	2	302	138	70	292	197
7	27	27	31	8	96	140	54	120	112
8	23	17	25	24	72	174	26	41	77
9	15	18	16	16	8	159	35	56	39
10	16	16	29	21	6	88	16	45	36
11	11	9	15	7	16	58	12	27	28
12	18	13	14	9	28	60	7	19	16
13	13	10	8	4	22	31	8	12	17
14	11	6	6	2	7	22	9	4	7
15	4	2	1	1	3	14	2	9	8
16	5	3	6	1	2	4	6	5	9
17	3	1			1	5		5	7
18		1	2	1			2	3	3
19	2	2		2				1	2
20	1								1
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
Total	222	262	198	351	946	1784	866	925	802

Table IV-7

Cyathura polita Size Class-Frequency Distribution in 1974 Test Region Collections

Size Class (mm)	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1									
2						2			
3				109	37	158	71	4	
4	4	12	5	1076	70	213	199	63	58
5	15	70	12	88	88	120	293	213	174
6	44	44	28	1	177	62	152	216	195
7	54	59	31		39	107	123	105	108
8	57	28	25	16	47	44	138	108	83
9	35	28	-16	27	17	26	69	44	52
10	52	25	29	32	10	27	36	66	49
11	41	11	15	46	10	11	20	28	31
12	15	10	14	27	13	8	18	22	16
13	16	10	8	46	19	8	17	12	15
14	11	6	6	30	14	14	11	20	10
15	5	5	1	15	6	9	17	14	15
16	2	1	6	18	2	6	15	15	12
17	7	5		8	1	11	10	8	6
18	7	2	2	3		5	6	8	7
19	6			3	1	1	2	6	3
20	7	2		2			1	1	7
21	2								1
22	2								1
23	2						1		
24									
25									
26									
27									
28									
29									
30									
Total	384	318	186	1547	551	832	1199	953	843

During 1974, 127 and 68 reproductive female *Cyathura* were collected in the Indian Point test and control regions respectively (Table IV-8); these included recently spent individuals as well as all specimens containing eggs, embryos, and larvae within the marsupium. Calculations of mean number of young based only on those individuals containing young within the marsupium indicated that control region young per reproductive female considerably exceeded those in the test region (test = 23.0; control = 42.2). It is interesting to note, however, that theoretical total natality for the two regions was almost identical, as was standing crop of *Cyathura* in the two regions in the latter months of 1974, even though control region density was significantly lower during 1973. This seems to indicate the existence of compensatory mechanisms which facilitate differential fecundity rates in response to available habitat.

Table IV-8

Theoretical Natality of *Cyathura polita* in Indian Point Test and Control Regions during 1974

	Month (1974)	Total No. Reproductive (N)	No. Reproductive/m^2 (N/m^2)	Mean No. of young (n)	Theoretical Natality/m^2
Test	June	8	4.4	23.0	101.2
	July	52	28.9	23.0	664.7
	August	56	31.1	23.0	715.3
	September	11	6.1	23.0	140.3
	Total	127			1621.5
Control	June	14	7.8	42.2	329.2
	July	8	4.4	42.2	185.7
	August	32	17.8	42.2	751.2
	September	14	7.8	42.2	329.2
	Total	68			1595.3

3. Epibenthic Community Studies

Epibenthic macroinvertebrates in the Indian Point region during 1973 were heavily concentrated in the area that was 10 cm and 60 cm above the bottom sediments, and far less frequent in the upper waters during daylight hours (Table IV-9). It must be assumed, however, on the basis of previous studies on the Hudson River (TI, 1975a) that many of these organisms are more evenly distributed throughout the water column at night. Except for Calanoid copepods, numbers of individuals were somewhat higher in control area epibenthic sled collections and somewhat lower in plankton net collections than were the corresponding test area collections.

4. Sediment-Temperature Studies

During the 1974 sampling season, temperatures of sediments, and overlying water were determined for each station in the test and control regions simultaneous with monthly sampling. *In situ* apparatus designed and built for this application permitted simultaneous measurement of sediment temperature 1 cm below the interface and water temperature 2.5 and 30 cm above the interface. Annual and monthly mean test and control region temperatures for these three strata appear in Table IV-10.

Analysis of variance between stations, areas, months, and strata indicated that sediment temperatures were significantly higher than those of the overlying waters, although the differences were relatively small. No significant differences between individual stations or between the test and control regions were determined.

D. SUMMARY

Indian Point benthic productivity increased greatly in both the test and control regions during 1974. Standing crop (both biomass and mean numbers of individuals) more than doubled in the test region while increasing

Table IV-9

Numbers of Epibenthic and Planktonic Organisms/1000 m^3 in Indian Point Test and Control Regions during 1974

Taxon	Epibenthic Sled Test	Epibenthic Sled Control	Plankton Net Test	Plankton Net Control
Calanoida	19532.8	2101.3	172.0	134.8
Daphnia sp	1784.2	2202.2	216.7	238.5
Neomysis americana	2614.7	6435.5	3.6	1.8
Gammarus sp	3749.2	3487.1	9.0	5.3
Monoculodes sp	1144.7	2205.5	-	-
Leptodora kindti	1421.1	316.2	16.6	19.2
Chaoborus sp	1031.0	379.1	4.2	2.3
Amnicola sp	11.5	3265.0	76.9	1.1
Amnicolidae	27.9	66.2	2.3	114.6
Balanus improvisus	211.9	270.3	72.8	19.6
Cyclopoida	50.6	68.5	65.4	13.5
Cordylophora lacustris	24.4	24.7	3.1	3.7
Chironomid larvae	10.2	1.5	33.7	3.2
Chironomid pupae	10.2	1.5	65.4	13.5
Hydracarina	1.8	10.0	2.6	5.5
Zoeal larval	3.5	6.2	5.2	5.5
Piscicola sp	0.8	2.6	0.7	1.1
Sida sp	212.7	149.5	2.1	-
Corophium sp	12.8	10.4	0.5	-
Scolecolepides viridis	44.2	191.1	-	-
Crangonyx sp	11.6	157.7	-	-
Chiridotea almyra	6.3	27.8	-	-
Edotea sp	2.6	22.8	-	-
Pectinatella magnifica (Floatoblast)	4.2	-	-	-
Collembola	2.2	-	-	-
Cyathura polita	-	4.0	-	-
Rhithropanopeus harrisi	-	2.6	-	-
Leptocheirus sp	-	1.4	-	-
Lophopodella carteri (Floatoblast)	-	23.6	1.8	-
Naididae	-	-	1.0	1.3
Macrothricidae	-	-	39.5	-
Cladoceran ephippia	-	-	1.8	-
Hydra americana	-	-	1.4	-
Ostracoda	-	-	0.9	-
Ephemeroptera	-	-	0.7	-
Oligochaeta	-	-	0.5	-
Trichopteran larvae	-	-	0.5	-
Bosminidae	-	-	-	7.3
Trichopleran Adult	-	-	-	1.8
Hyalinella sp (Floatoblast)	-	-	-	1.4
Stylaria sp	-	-	-	0.9
Total No. of Taxa	26	28	27	21
Annual Mean No/1000 m^3	32622.5	21460.6	800.9	595.9

Table IV-10

Mean *In situ* Water and Sediment Temperature (°C) for Indian Point Test and Control Regions during 1974

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Test	Sediment	4.2	12.8	18.8	26.0	25.0	24.0	18.8	11.9	6.8	16.48
	Water										
	2.5 cm	3.5	12.3	17.8	24.0	24.5	24.0	18.7	11.6	6.3	15.86
	30 cm	3.5	12.0	17.8	24.0	24.0	24.0	18.5	11.5	6.3	15.73
Control	Sediment	5.2	12.7	20.0	25.3	24.8	24.5	17.0	14.0	4.8	16.48
	Water										
	2.5 cm	4.2	12.0	19.0	24.3	24.3	24.2	17.1	13.7	4.3	15.90
	30 cm	4.2	12.0	19.0	24.3	24.0	26.0	16.8	13.3	4.3	15.99

by more than 75% in the control region. Diversity during 1974 generally increased in the control region with reduced dominance of the tubificid worm *Limnodrilus*, but that of the test region did not appreciably change from 1973. Shifts in relative rank within the dominant assemblage of both areas supported predictions of increasing numbers of the more halophilic taxa in response to extended salt intrusion into the area during 1973.

As with the community as a whole, numbers of the estuarine isopod *Cyathura polita* increased dramatically during 1974. Fecundity of *C. polita* (mean number of offspring per reproducing female) was considerably higher in the control region than in the test region, but estimated total natality was virtually identical for the two regions — as were monthly mean numbers of individuals following the reproductive season and annual mean numbers.

In situ measurements during 1974 showed no significant variation in either sediment or bottom-water temperature between the Indian Point test and control regions.

SECTION V
PHYSIOLOGY AND BEHAVIOR

A. INTRODUCTION

The 1974 physiology/behavior study program was conducted to determine the acute and chronic effects of temperature on juvenile striped bass and juvenile and adult white perch; it supports the general Hudson River ecological survey and aids in determining the ecological impact of the Indian Point facility. Specific efforts proposed were to determine behavioral responses (thermal preference and avoidance) to above-ambient temperatures and physiological effects (temperature tolerance and active respiration) of increases and decreases of environmental temperature. The relationship of results to plant operation was to be evaluated.

Fish exposed to artificial or natural thermal gradients typically seek a preferred temperature (Meldrim and Gift, 1971; Coutant, 1974; Ferguson, 1958). Thermal-preference experiments provided information on the potential of the Indian Point thermal plume to attract white perch and striped bass.

Alabaster (1963) and Nakatani (1971) reported that there have been few instances of fish kills due to lethal effluent temperatures at electric-generating stations; they concluded that this was probably due to the ability of fish to actively avoid such areas. Gift and Westman (1971) documented the ability of white perch and striped bass to avoid lethal temperatures in a laboratory environment. Behavioral studies during 1974 provided complementary avoidance information on striped bass and white perch from mid-winter to early summer. Information on avoidance of lethal temperatures will be used to determine whether there is a potential for discharge temperatures to exclude either species from the Indian Point vicinity and whether the thermal plume will impede the movement of migratory fish such as striped bass.

Thermal-tolerance experiments in this study describe the Hudson River's upper and lower lethal temperature limits for white perch and striped bass.

In fish, as in other ectotherms, the rate of energy expenditure is strongly related to environmental temperature; i.e., as temperature increases, rate of energy expenditure generally increases. If temperature increases above a critical level, excessive energy demands for maintaining body processes limit the amount of energy available for other activities such as growth, reproduction, osmoregulation, etc. (Phillips, 1969). Respiration experiments provide the best single index for identifying the critical temperature level at which energy becomes limiting for necessary activity (Fry, 1971).

Complete results and analyses will be presented in a later report.

B. METHODS AND MATERIALS

1. General Experimental Design

Specimens utilized in the investigation were adult white perch [< 140 mm in total length (TL)], juvenile white perch (TL < 120 mm), and juvenile striped bass (TL < 150 mm). Several avoidance and tolerance experiments used hatchery-reared striped bass from Hudson River stock (TL < 232 mm and age < I). At the termination of each experiment, fish were measured (TL) and released. Each specimen was used only once.

Tests were replicated for each species and size group whenever possible. All behavioral experiments were conducted during the same time of day to minimize variation due to circadian rhythms (Schwassman, 1971). Behavioral and thermal-tolerance tests were scheduled throughout the year to coincide with 2°-3°C incremental changes in ambient river-water temperatures; this schedule was occasionally modified to adjust for fish availability. The relationship between thermal response and acclimation temperature for both species was determined by least squares regression analysis. Intra- and interspecific comparisons of thermal responses were also made on this basis. This text makes frequent reference to the difference between regression points and respective acclimation temperatures because thermal discharges from electric-generating stations are often referred to in terms of temperature change (ΔT) above that of the receiving water. In all except cold-tolerance and active-respiration experiments, acclimation temperature (T_a) and ambient river temperature were the same since specimens were held in a continuous flow of water drawn directly from the river. The relationship of temperature preference, avoidance, and tolerance of each species and size class to ambient river temperature was determined from January through July 1974.

2. Collecting and Holding Facilities

White perch and striped bass were captured by beach seine and trap net in the Indian Point vicinity and transferred directly to laboratory holding facilities where they were held in 1500-ℓ 120-cm-diameter fiberglass tanks receiving a once-through flow of river water at ambient temperature and salinity. Seasonal photoperiods were maintained artificially.

Specimens were fed commercially available frozen brine shrimp *(Artemia)* and held for 3 to 10 days before testing, but fish for winter experiments were held for a maximum of 3 months. To inhibit disease, prophylactic treatments (4 ppm of potassium permanganate or 0.4 ppm of malachite green for 1 to 4 hr) were performed on the day of capture and repeated during the holding period when necessary. Testing began no earlier than 2 days after prophylaxis. For active-respiration experiments, treatment was terminated at least 1 week prior to testing.

3. Thermal Preference

Five to 10 similar-sized specimens of one species were introduced into an isothermal water column (Hurley and Woodall, 1968; TI, 1973a) at ambient river temperature 16 hr before observations were begun to insure habituation to the experimental apparatus. Fish position and behavior were recorded 10 times at 2.5-min intervals during a 22.5-min observation period before a thermal gradient was initiated. Observation periods with a temperature gradient present were begun 1.5 hr after the gradient had been initiated and were repeated after 3.5, 5.5, 7.5, 23.5, and 27.5 hr (observation series). Water temperatures were measured before and after each observation period to determine the mean temperature in each section of the apparatus. The thermal gradient was stabilized before each observation series but was altered between them.

The preferred or selected temperature (T_p) is defined as the mean temperature of the section in which fish were most frequently seen during an observation series. The temperature range over which 75% of all observations occurred was calculated for each observation series. The 1.5-hr and 27.5-hr preferences were considered indicative of the immediate and long-term responses of the organisms to above-ambient temperatures for a given acclimation temperature (T_a). Observations between 1.5 and 27.5 hr provided information on behavioral changes during prolonged exposure to above-ambient river temperatures.

4. Temperature Avoidance and Tolerance

Upper-avoidance temperature (T_{ua}) is that temperature (or temperature range) causing repeated movements of the fish to some lower temperature in the testing apparatus (Gift and Westman, 1971); the median temperature tolerance limit (TL_m) is that temperature at which 50% of the test population (representing an "average" fish) can survive for 96 hr (Coutant, 1971). The critical temperature (T_c) is defined as the maximum temperature above ambient at which total survival of specimens was observed during TL_m experiments. Apparatus design and standard experimental procedures for T_{ua} and TL_m determinations have been described previously (TI, 1973a, 1973b).

The apparatus utilized for cold-tolerance determination was identical to that used for heat tolerance, but experimental procedures differed. Groups of 10 adult white perch and 10 hatchery-reared yearling striped bass (TL = 135 to 220 mm) were acclimated to 10°, 15°, or 20°C for at least 3 days and subjected to varying rates of temperature decrease to a minimum of 2°C. Times to equilibrium loss and death and percent survival over 96 hr were recorded. The time required for 50% of the potential temperature change to occur in an experiment varied from 10 to 15 min, depending on the initial T_a. The full temperature change for each experiment required <3 hr.

5. Active Respiration

Experiments were conducted in 1974 to determine active respiration rates for white perch and striped bass. The methods, results, and conclusions of this part of the physiology and behavior study will be included in a later report.

C. RESULTS

1. Thermal Preference

Preferred temperatures of white perch and striped bass increased with acclimation temperature from mid-winter to early summer (Tables V-1 and V-2). Juvenile and adult white perch selected similar temperatures during this period, but the thermal preferences of juvenile striped bass were 1°-8°C lower than those of white perch at respective acclimation temperatures (Figure V-1). All fish initially (1.5 hr) responded to increased temperatures by selecting those above their ambient acclimation temperatures (Figure V-2). Long-term (27.5 hr) preferences were several degrees higher than those demonstrated at 1.5 hr, especially when river temperatures were <16 °C.

Table V-1

Chronological Summary of Temperature Preference (T_p) Experiments with White Perch during 1974

Date (1974)	No. of Fish/Test	Size Range (mm)	Acclim. Temp. (°C)	Elapsed Time in Gradient						
				1.5 hr (°C) (T_p-75% range)	3.5 hr (°C) (T_p-75% range)	5.5 hr (°C) (T_p-75% range)	7.5 hr (°C) (T_p-75% range)	23.5 hr (°C) (T_p-75% range)	25.5 hr (°C) (T_p-75% range)	27.5 hr (°C) (T_p-75% range)
Jan 30	5	160-180	3	8 (6-8)	8 (8-10)	7 (7-8)	8 (8)	* *	* *	14 (13-14)
Feb 12	5	166-182	3	7 (7-8)	9 (9)	8 (6-8)	10 (10)	* *	* *	17 (17-20)
Mar 14	6	150-180	5	8 (7-9)	9 (8-9)	10 (9-10)	10 (10-15)	* *	* *	17 (17-20)
19	7	70-100	4	9 (9)	9 (9)	11 (11-12)	12 (12-13)	18 (16-18)	18 (18-21)	18 (17-24)
27	5	155-176	6	16 (10-16)	18 (15-23)	20 (18-20)	19 (19-20)	22 (22-24)	23 (22-23)	* *
Apr 2	7	80-97	6	9 (9)	11 (10-11)	12 (12)	14 (14)	18 (18)	18 (18)	20 (18-22)
17	6	166-185	9	14 (14)	19 (19)	21 (20-21)	* *	25 (25)	26 (26-28)	27 (26-28)
25	7	152-190	11	17 (16-19)	20 (19-20)	21 (21-22)	22 (22-23)	26 (24-28)	29 (26-30)	27 (24-27)
30	9	73-98	13	21 (18-21)	20 (18-24)	25 (20-25)	25 (19-25)	27 (27)	27 (25-27)	27 (25-27)
May 9	5	155-170	14	22 (22)	22 (21-23)	21 (21-23)	25 (24-25)	25 (23-25)	25 (25-27)	26 (25-26)
21	6	73-85	16	22 (22-26)	22 (22-26)	23 (23-28)	23 (23-27)	24 (24-29)	26 (23-29)	27 (26-29)
28	8	153-195	17	25 (24-25)	27 (25-28)	28 (27-29)	28 (26-28)	28 (26-28)	28 (26-29)	28 (27-28)
Jun 4	10	79-105	18	26 (24-26)	26 (24-26)	28 (26-28)	27 (27-29)	27 (25-30)	28 (26-31)	28 (28)
6	8	151-182	19	25 (25-26)	27 (27)	27 (26-27)	26 (25-26)	24 (21-24)	26 (21-26)	24 (21-27)
13	7	152-184	20	25 (25-26)	27 (27-28)	28 (27-28)	27 (27-29)	26 (25-26)	27 (27-29)	27 (27-28)
20	10	62-91	22	30 (28-30)	30 (30-31)	30 (28-31)	30 (30-32)	* *	30 (28-30)	28 (28-31)
25	10	84-115	22	29 (29-30)	29 (29-30)	30 (30-31)	30 (30-31)	31 (29-31)	31 (31)	32 (32-33)
27	6	163-197	21	27 (26-27)	28 (28-30)	30 (29-30)	29 (29-30)	* *	28 (28)	27 (27-30)
Jul 5	8	153-180	23	27 (26-27)	29 (29)	30 (30)	29 (29)	30 (29-31)	28 (28-30)	30 (29-31)

*Data not collected

Table V-2

Chronological Summary of Temperature Preference (T_p) Experiments with Striped Bass during 1974

Date	No. of Fish/Test	Size Range (mm)	Acclim. Temp. (°C)	Elapsed Time in Gradient						
				1.5 hr (°C) (T_p-75% range)	3.5 hr (°C) (T_p-75% range)	5.5 hr (°C) (T_p-75% range)	7.5 hr (°C) (T_p-75% range)	23.5 hr (°C) (T_p-75% range)	25.5 hr (°C) (T_p-75% range)	27.5 hr (°C) (T_p-75% range)
Mar 21	7	83-97	6	9 (9-10)	9 (9)	9 (8-9)	8 (8)	* *	13 (13)	14 (14-16)
Apr 9	10	80-110	6	11 (10-11)	13 (12-13)	12 (12)	12 (12-14)	16 (16-18)	17 (17-19)	17 (17-19)
23	8	76-97	10	14 (14-15)	16 (15-17)	16 (16-20)	17 (16-17)	23 (20-23)	20 (20-22)	20 (18-22)
May 2	4	80-115	12	17 (15-18)	21 (19-22)	19 (19-21)	23 (20-23)	25 (23-25)	24 (23-24)	23 (22-23)
23	4	95-115	17	20 (19-20)	21 (20-22)	21 (20-22)	22 (20-22)	24 (21-26)	23 (21-25)	24 (23-26)
30	12	90-105	18	21 (21-22)	23 (18-23)	24 (21-24)	22 (22-24)	26 (21-26)	24 (23-26)	24 (21-24)
Jun 19	10	77-103	22	23 (23-26)	25 (22-25)	26 (26-28)	27 (25-29)	* *	25 (24-28)	27 (26-27)
Sep 13	10	107-130	24	29 (29)	26 (25-28)	25 (25-30)	30 (26-30)	25 (25-30)	29 (24-29)	29 (25-29)

*Data not collected

Occasionally, specimens failed to avoid lethal temperatures in the preference apparatus, resulting in loss of equilibrium or death. Percentages of total numbers of juvenile and adult white perch and juvenile striped bass experiencing equilibrium loss or death (Tables V-1 through V-3) were 0, 2.6, and 6.2% respectively.

2. Thermal Avoidance

Size (or age) was an important factor influencing the upper avoidance temperature for white perch, with juveniles avoiding temperatures 7°C lower than those avoided by adults during winter (Figure V-3); by late spring, however, these size-specific differences were reduced to within 1°C. Upper avoidance temperatures of juvenile striped bass were considerably higher than those of juvenile white perch, especially when river temperatures were near 10°C. Juvenile white perch avoided temperatures 6° to 9°C above their acclimation temperature from late winter through early spring, while avoidance levels for adult white perch and juvenile striped bass decreased from 14° to 9°C and 15° to 10°C respectively over the same period of increasing acclimation (river) temperatures (Figure V-3). The 1974 temperature-avoidance experiments are summarized in Tables V-4 and V-5.

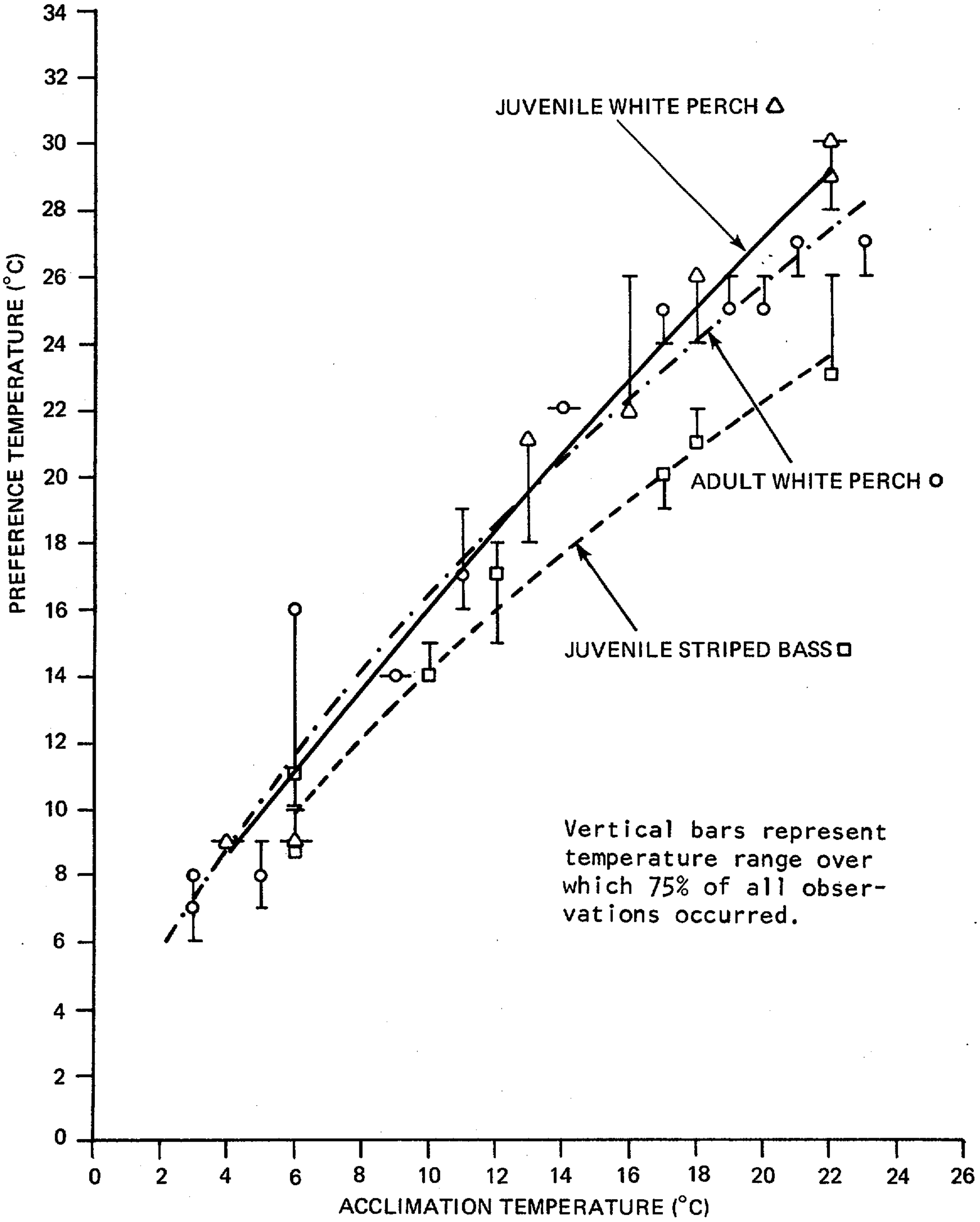


Figure V-1. Relationship of 1.5-Hr Preferred Temperature (T_p) and Acclimation Temperature (T_a) for White Perch and Striped Bass during 1974 (January through July)

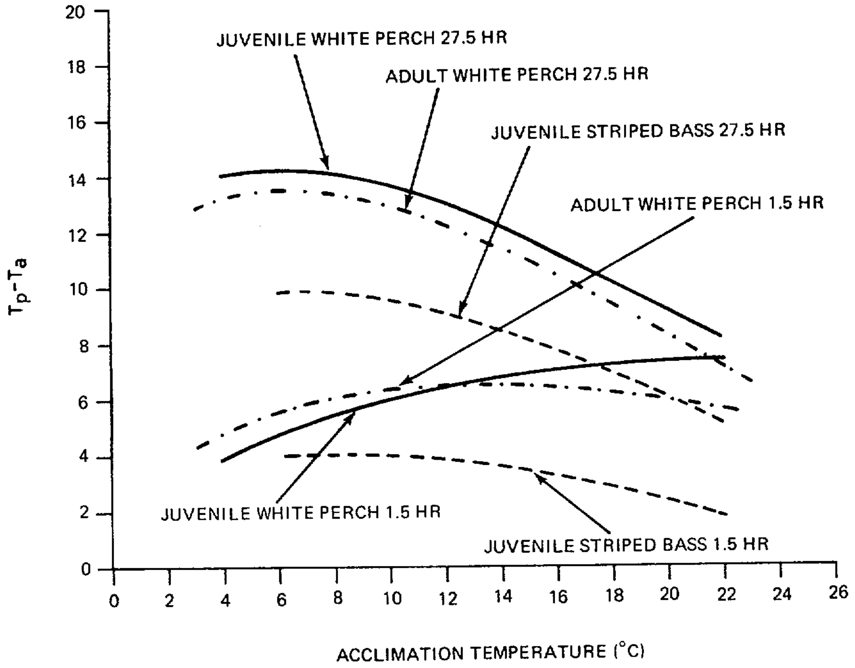


Figure V-2. Difference (°C) between Preferred Temperature (T_p) and Acclimation Temperature (T_a) for White Perch and Striped Bass at 1.5 Hr (Immediate Response) and 27.5 Hr (Long-Term Response) during 1974 (January through July)

The inability of fish to avoid lethal temperatures was also occasionally evident during avoidance experiments. Specimens were observed to move throughout the avoidance apparatus, even after temperatures in the warmest end were well above minimum lethal levels. Four of five experiments in which perch failed to avoid lethal temperatures were at acclimation temperatures of < 17°C; seven of eight such occurrences for striped bass were when T_a was < 18°C (Table V-3). All striped bass (20 specimens) used in avoidance experiments from February through mid-April (T_a < 9.5°C) failed to avoid lethal temperatures. Percentages of total numbers of juvenile and adult white perch and juvenile striped bass experiencing equilibrium loss or death (Tables V-3 through V-5) were 3.7, 5.0, and 34.1% respectively.

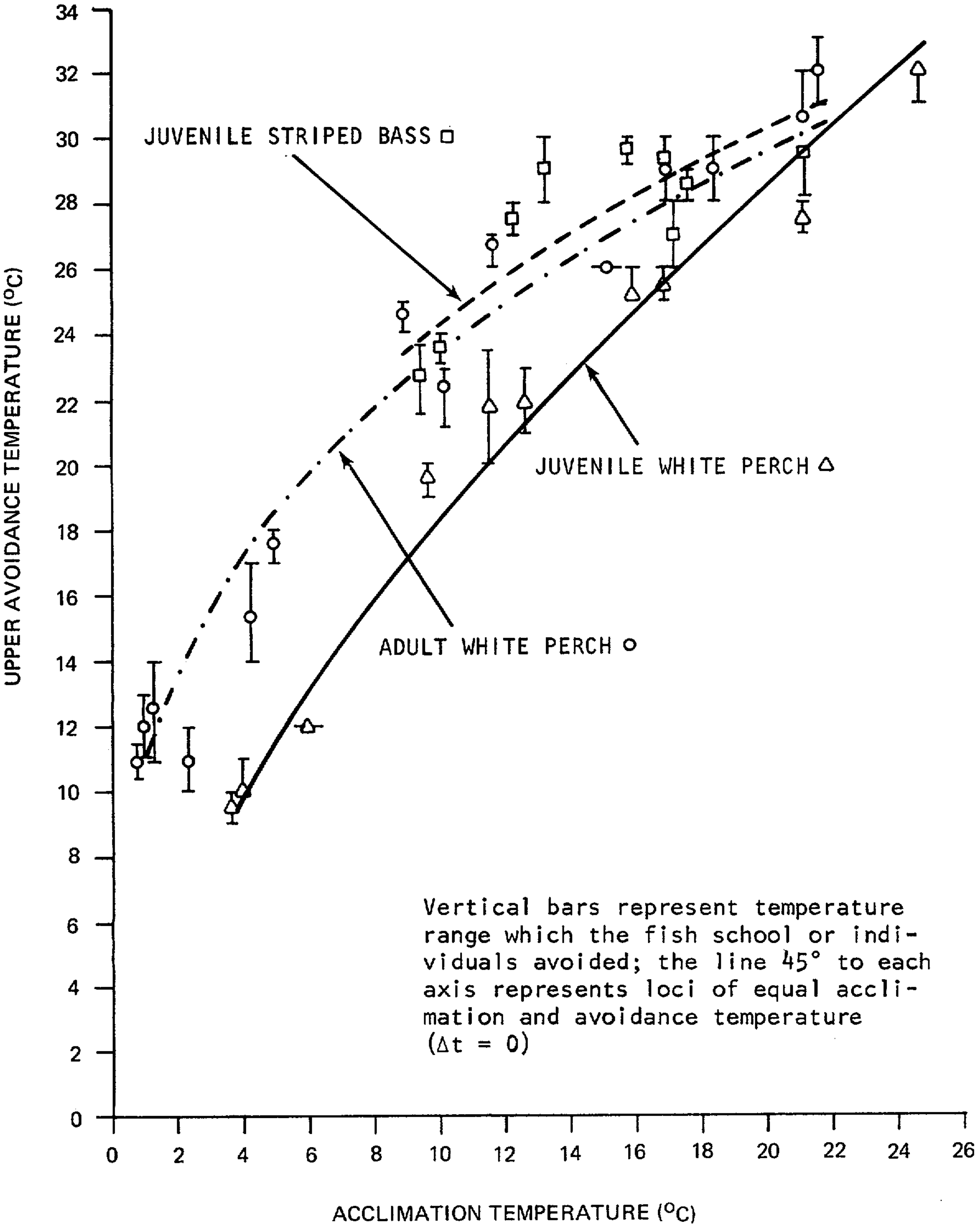
Table V-3

Summary of Experiments during Which Fish Failed to Avoid Lethal Temperatures

Date (1974)	Type of Experiment	Acclim. Temp. (°C)	Species and Size Class	No. of Fish in Experiment	No. Showing Equilibrium Loss or Death
3/27	Preference	6.0	Adult white perch	5	1
6/ 6	Preference	19.0	Adult white perch	8	1
4/23	Preference	10.0	Juvenile striped bass	8	4
2/15	Avoidance	1.2	Adult white perch	5	1
4/23	Avoidance	10.2	Adult white perch	6	1
5/23	Avoidance	17.0	Adult white perch	7	2
5/28	Avoidance	17.0	Juvenile white perch	9	2
6/18	Avoidance	21.3	Juvenile white perch	7	1
2/11	Avoidance	3.0	Juvenile striped bass	6	6
3/ 5	Avoidance	4.0	Juvenile striped bass	6	6
4/11	Avoidance	7.2	Juvenile striped bass	8	8
4/24	Avoidance	10.1	Juvenile striped bass	7	1
5/24	Avoidance	17.0	Juvenile striped bass	8	3
5/30	Avoidance	17.2	Juvenile striped bass	10	2
6/ 4	Avoidance	17.6	Juvenile striped bass	10	2
6/17	Avoidance	21.2	Juvenile striped bass	7	1

3. Heat Tolerance

Heat-tolerance experiments are summarized in Tables V-6 and V-7. The TL_m of each species changed directly with acclimation temperature and was near 34°C for both species during peak river temperatures (Figure V-4), with the TL_m of both species differing by < 3°C over the testing range. The difference between T_a and TL_m varied from approximately 15° to 8°C for white perch and from 17° to 9°C for juvenile striped bass as river temperatures increased from winter to summer respectively. Critical temperatures (T_c) for both species were 1° to 8°C lower than the respective TL_m values.



Vertical bars represent temperature range which the fish school or individuals avoided; the line 45° to each axis represents loci of equal acclimation and avoidance temperature ($\Delta t = 0$)

Figure V-3. Relationship of Upper Avoidance Temperature (T_{ua}) and Acclimation Temperature (T_a) for White Perch and Striped Bass (January through July)

Table V-4

Chronological Summary of Upper Avoidance Temperature Experiments with White Perch during 1974

Date (1974)	No. of Fish	Size Range (mm)	Acclim. Temp. (°C)	Upper Avoidance	
				Temp. (°C)	Temp. Range (°C)
Jan 2	5	168-200	0.8	11.0	10.5-11.5
3	5	170-205	1.0	12.0	11.0-13.0
Feb 15	5	160-195	1.2	12.5	11.0-14.0
Mar 3	6	155-198	2.4	11.0	10.0-12.0
11	8	78-100	3.7	9.5	9.0-10.0
18	7	70- 95	4.0	10.0	9.0-11.0
19	5	155-170	4.2	15.5	14.0-17.0
20	5	170-195	5.0	17.5	17.0-18.0
25	6	75- 90	6.0	12.0	12.0
Apr 18	6	156-186	9.0	24.5	24.0-25.0
22	7	70- 90	9.8	19.7	19.0-20.0
23	6	155-208	10.2	22.2	21.0-23.0
29	6	80-103	11.6	21.8	19.8-23.4
May 2	7	160-185	11.7	26.7	26.0-27.0
6	7	70- 85	12.7	21.9	21.2-23.0
17	7	154-195	15.2	26.0	26.0
21	7	75- 88	16.0	25.2	25.0-26.0
23	7	160-180	17.0	29.0	28.0-30.0
28	9	82-100	17.0	25.4	25.0-25.7
29	10	68- 90	17.0	25.5	25.0-26.0
Jun 6	6	151-159	18.5	29.0	28.0-30.0
12	5	151-174	21.2	30.5	29.0-32.0
18	7	65-115	21.3	27.5	27.0-28.0
25	5	153-167	21.7	32.0	31.0-33.0
Jul 9	7	90-105	24.8	32.0	31.3-32.6

Table V-5

Chronological Summary of Upper Avoidance Temperature Experiments with Striped Bass during 1974

Date (1974)	No. of Fish	Size Range (mm)	Acclim. Temp. (°C)	Upper Avoidance	
				Temp. (°C)	Temp. Range (°C)
Feb 11	6	80- 95	3.0	No avoidance	
Mar 5	6	90-110	4.0	No avoidance	
Apr 11	8	80-100	7.2	No avoidance	
24	7	90-130	10.1	23.5	23.0-24.0
25	7	78-115	9.5	22.5	21.5-23.5
May 1	4	77-115	12.4	27.5	27.0-28.0
8	6	160-210	13.3	29.0	28.0-30.0
20	6	175-205	15.8	29.5	29.0-30.0
24	8	95-110	17.0	29.3	29.0-29.5
30	10	93-110	17.2	27.0	26.0-28.0
Jun 4	10	97-118	17.6	28.5	28.0-29.0
17	7	85-107	21.2	29.5	28.5-30.0

Table V-6

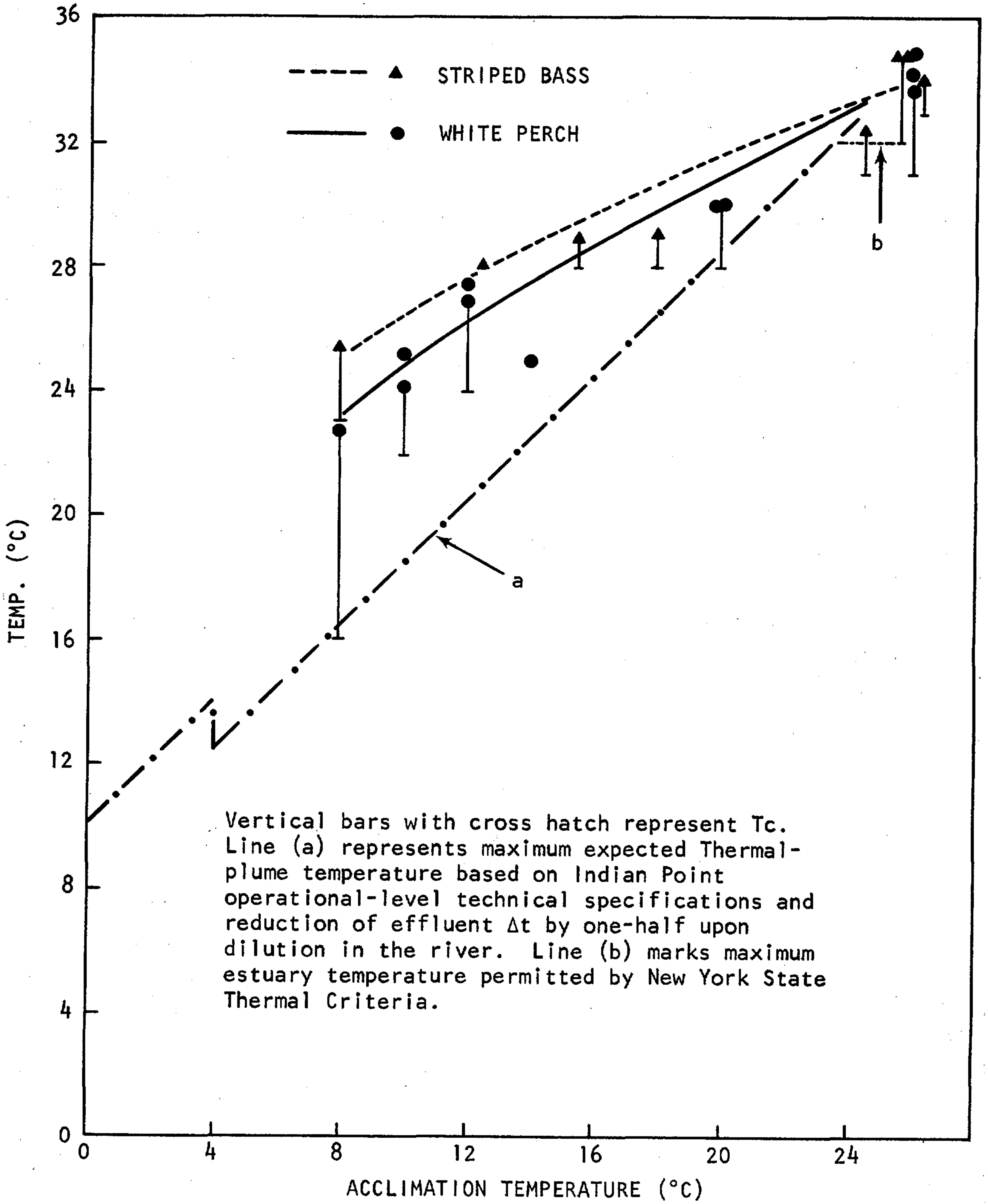
Summary of Thermal-Tolerance Experiments on White Perch during Rising River Temperatures

Date (1973)	No. of Fish	Size Range (mm)	Accl. Temp. (°C)	Test Temperatures						TLm (°C)
				T1		T2		T3		
				(°C)	(% survival)	(°C)	(% survival)	(°C)	(% survival)	
Apr 16	55	130-245	8.0	16.0	100	20.0	66	24.0	44	22.8
24	32	101-168	10.0	22.0	80	26.0	16	28.0	0	24.2
24	30	150-212	10.0	22.0	100	26.0	40	28.0	0	25.3
May 7	30	138-194	12.0	24.0	100	28.0	10	30.0	0	27.5
7	31	109-135	12.0	24.0	100	28.0	50	30.0	0	26.8
14	30	70-130	14.0	26.0	40	30.0	0			25.0
Jun 18	18	56-87	20.0	28.0	100	30.0	50	32.5	0	30.0
18	18	56-76	20.0	28.0	100	30.0	50	32.5	0	30.0
Aug 6	30	31-45	26.0	31.0	90	33.0	90	35.0	0	33.7
11	30	92-138	26.0	32.0	100	34.0	90	36.0	0	34.3
11	30	137-252	26.0	32.0	100	34.0	50	36.0	0	34.0
20	30	153-214	26.0	31.0	90	33.0	90	35.0	0	33.7
20	30	108-170	26.0	33.0	100	35.0	0			34.0
28	28	38-62	26.0	34.0	100	36.0	0			35.0

Table V-7

Summary of Thermal-Tolerance Experiments on Striped Bass during Rising River Temperatures

Date	No. of Fish	Size Range (mm)	Accl. Temp. (°C)	Test Temperatures						TLm (°C)
				T1		T2		T3		
				(°C)	(% survival)	(°C)	(% survival)	(°C)	(% survival)	
1973										
Jul 2	39	75-127	24.3	31.0	100	34.0	0			32.5
30	30	48-68	25.7	32.0	100	34.0	90	36.0	0	34.8
30	30	45-66	25.7	32.0	100	34.0	90	36.0	0	34.8
Aug 6	29	45-73	26.0	33.0	100	35.0	0			34.0
1974										
Apr 18	30	70-106	8.0	23.0	100	25.0	80	27.0	0	25.5
May 6	30	155-213	12.5	28.0	100	28.5	50	29.0	0	28.3
21	30	166-232	15.5	28.0	100	30.0	0			29.0
28	30	160-224	18.0	28.0	100	30.0	10	32.0	0	29.1



Vertical bars with cross hatch represent Tc. Line (a) represents maximum expected Thermal-plume temperature based on Indian Point operational-level technical specifications and reduction of effluent Δt by one-half upon dilution in the river. Line (b) marks maximum estuary temperature permitted by New York State Thermal Criteria.

Figure V-4. Relationship of Median Lethal Tolerance Limit (TL_m) and Acclimation Temperature (T_a) for All Sizes of White Perch and Juvenile Striped Bass from Winter through Summer

4. Cold Tolerance

Striped bass were more susceptible to shock from rapid temperature decreases than were white perch for a given rate of temperature change (Table V-8). A drop from 15° to 2°C caused 100% mortality of striped bass over a 96-hr period, while an entire sample of white perch experiencing identical thermal conditions lost equilibrium within a few minutes but exhibited an apparently normal behavior from 10.5-hr exposure through experiment termination. A temperature decrease from 20° to 2°C resulted in 50% mortality of white perch over 96 hr. Specimens surviving the cold shock displayed equilibrium loss at experiment termination. Neither species incurred loss of equilibrium or death when temperatures were lowered from 10° to 2°C although, as in all tests, activity temporarily increased as water of 2°C was introduced into the aquaria. In both instances in which death occurred, the time to equilibrium loss for striped bass was less than that for white perch.

Table V-8

Summary of Cold-Shock Experiments with White Perch and Striped Bass during 1974

Species	Size Range (mm)	Accl. Temp. (°C)	Test Temp. (°C)	No. of Fish	No. with Equilibrium Loss	No. Dead	Time (hr)
White perch	135-178	10	2	10	0	0	96.0
Striped bass	150-215	10	2	10	0	0	96.0
White perch	135-185	15	2	10	3	0	0.5
					10	0	1.0
					0	0	10.5
					0	0	96.0
Striped bass	135-210	15	2	10	0	0	0.3
					10	0	0.5
					9	1	32.8
					5	5	46.0
					0	10	90.6
White perch	145-190	20	2	10	2	0	0.7
					10	0	4.8
					10	0	45.2
					8	2	69.1
					5	5	96.0
Striped bass	151-220	20	2	10	10	0	0.7
					10	0	4.8
					6	4	45.2
					0	10	69.1

5. Active Respiration

Because data analyses of respiration experiments on white perch and striped bass are incomplete at this time, a later report will present and discuss results.

D. DISCUSSION

1. Thermal Preference

Both species' marked preference for above-ambient temperatures suggests a high potential for their aggregation in warm-water areas, especially during winter and early spring. Intra- and interspecific differences of preferred temperatures at a given acclimation temperature probably reflect age and species-related physiological requirements and abilities to adapt to changing environmental temperatures.

A final report documenting seasonal thermal-selection responses of white perch and striped bass and relation of data to plant operational levels will be presented at a later date.

2. Thermal Avoidance and Heat Tolerance

The occasional failure of white perch and striped bass to avoid lethal temperatures in a laboratory environment was reported by Meldrim and Gift (1971) and was termed low thermal lethal responsiveness (LTR), "... the inability of a fish (or invertebrate) to avoid areas in a thermal gradient (with high or low temperatures) which provide stressful conditions." The ability of juvenile striped bass generally to avoid stressful conditions when acclimated to temperatures of > 7.2°C in this study (Table V-5) seems to exclude the possibility that the apparatus design did not permit their escape to a more suitable environment when acclimated to temperatures of < 9.5°C. These data should be used with caution, however, since they represent a relatively small number of fish acclimated to temperatures of < 9.5°C.

It is not known whether low thermal responsiveness is confined to artificially steep thermal gradients as commonly found in laboratory situations or if it can or does occur in the usually shallower gradients of thermal effluents. The lack of evidence for fish kills near electric-generating stations due solely to upper lethal temperatures suggests that LTR is a laboratory-induced phenomenon. Considering the general torpor of these species during winter, it is possible that they perceive temperature changes relatively slowly; likewise, behavioral responses may be retarted by low metabolic levels. Fish acclimated to low temperatures in this study selected progressively higher temperatures at a slower rate than did warm-acclimated specimens (Tables V-1 and V-2).

Operational procedures for the Indian Point plant allow the ΔT of water in the effluent canal to be reduced by approximately one-half in the river upon mixing through submerged discharge ports (TI, 1972; Dames and Moore, 1974a-c). Present evidence based on discharge-canal water temperature (Indian Point weekly operational data, August 1972-November 1973: impingement water-quality data, November 1973-present) and field studies (TI, 1972 and 1973; Dames and Moore, 1974a-c) indicates that above-ambient river temperatures immediately outside the discharge canal have not exceeded the T_c of either species (Figure V-4) over the acclimation temperature range at which specimens were tested.

Maximum allowable temperature rises above ambient river temperature across condensers during winter are 21.1°C and 18.9°C for 3-unit and 2-unit operation respectively when river temperatures are < 4°C. Reduction of the ΔT by one-half through discharge ports would provide a temperature rise in the river approximately 10°C above ambient river temperature in the immediate vicinity of the discharge ports. Thermal-tolerance information for these species at acclimation temperatures of < 8°C during midwinter is uncommon in scientific literature and was not determined in this investigation because of the limited numbers of each species. Mihursky and McErlean (mimeo) reported TL_m values for white perch and striped bass to be 19° and 20°C respectively above an acclimation temperature of 5°C (approximately 11°C above line a, Figure V-4). Meldrim and Gift (1971) obtained limited information on juvenile white perch responses to sudden temperature increases. Fish acclimated to 3°C were stressed after experiencing an instantaneous ΔT of 10°C (line a); exposure duration was 15-min. Specimens acclimated to 8°C were unaffected by identical thermal conditions (above line a, Figure V-4).

Differences between the TL_m and T_a of 8°C-acclimated yearling and older white perch and juvenile striped bass in the present study were 15° and 17°C respectively. The rate of change of TL_m and T_a was approximately 0.8°C/1°C decrease of acclimation (river) temperature at the lower end of the temperature range in which TL_m tests were performed (Figure V-4). Assuming that the rate of TL_m decrease were to remain constant, the TL_m of striped bass and white perch would be approximately 8° to 9°C above maximum plume temperature (line a, Figure V-4) when river temperatures are 1°C. If extrapolated TL_m values are correct, the potential for LTR to occur seems to be minimal.

Extrapolation of existing data is not necessarily valid and should be used with caution. A later report will contain final analyses of all thermal-avoidance and tolerance data and relate findings to present and expected plant operational levels.

3. Cold Tolerance

Using an instantaneous temperature change, Meldrim et al (unpublished) have provided the only other source of cold-shock information on white perch and striped bass. Based on their data and on results reported by them and on results from the present study, it appears that a temperature decrease of 8°C would probably not cause death or stress of either species, regardless of the rate of temperature change when maximum plume temperatures do not exceed 26°C and river temperatures are not < 2°C. Death or stress of white perch and striped bass from cold shock was apparent in both studies when specimens were subjected to temperatures 12° to 14°C below their acclimation temperatures (15° to 25°C). Percent mortality from such a temperature drop increased as the shock temperature in different experiments approached 0°C and as the rate of temperature change increased (i.e., < 3 hr to instantaneous).

The subtle physiological effects of rapid temperature decreases on white perch and striped bass are unknown, although effects on other species may be indicative. Otto and Rice (1974) reported a decrease in the swimming ability of yellow perch (*Perca flavescens*) for several hours following a rapid sublethal environmental temperature drop of 10°C; Coutant et al (1974) reported an increase in the susceptibility of juvenile channel catfish and largemouth bass to predation by adult largemouth bass following abrupt sublethal temperature decreases.

SECTION VI

PHYSICAL CHEMICAL INFLUENCES ON SELECTED FISH SPECIES

A. INTRODUCTION

Relationships between salinity, temperature, and distribution of selected species were emphasized. Species selection was based on their commercial, recreational, or ecological importance in the Hudson River estuary and their predominance in standard-station catches.

B. METHODS

Catch per unit effort (CPUE) and environmental variables at standard-sampling stations (Figure III-1) in the Indian Point area were considered. Graphical treatments of temporal distributions of environmental variables and CPUE at each standard station were used in this analysis. Beach-seine station catch data for six species (striped bass, white perch, alewife, blueback herring, American shad, and bay anchovy) and bottom-trawl station catch data for three (striped bass, white perch, and Atlantic tomcod) were related to environmental variables.

Only conductivity and temperature data were analyzed because other parameters showed little or no relationship to annual trends in abundance. Short-term trends associated with 2- to 3-day oxygen concentration reductions and variations in turbidity (discussed in Section IV) were not amenable to graphical treatments; pH values do not change appreciably through time (see Section III), so they were not used in these analyses.

C. RESULTS AND DISCUSSION

1. Bottom-Trawl Catches

The most frequently observed trend for all species treated was an apparent bimodal distribution through time (Figure VI-1). With few exceptions, peak catches were made near the time when the summer salt intrusion was beginning or when saltwater was retreating. This relationship suggests spatial catch distribution peaks in the area of Indian Point during peak impingement periods, particularly for the three species treated here (TI, 1974b).

Striped bass catches were low throughout the year at stations; this was apparently a reflection of the low year-class strength observed for this species during 1974 (TI, 1975c). Catches of striped bass were too low to detect any distributional patterns.

Catches of white perch and tomcod exhibited similar spatial patterns. Catches at stations 2, 4, 5, and 7 tended to be greater in magnitude than those at stations 1 and 3, indicating generally greater numbers of white perch and Atlantic tomcod in the eastern portion of the channel near Indian Point.

2. Surface-Trawl Catches

Catches in surface trawls were insufficient to permit detection of patterns in the catch-per-unit-effort data during 1974.

3. Beach-Seine Catches

Catches of striped bass, white perch, and tomcod were considerably greater at beach-seine stations than at trawl stations, reflecting the predominance of young fish in shallow, slightly saline water during most of the year (Figure VI-2). The distribution of striped bass catches seemed to be related to saltwater intrusions more distinctly than did distributions of any other species treated. This is the same general pattern observed in 1973 (TI, 1974c).

Occasional bimodality of temporal distributions was observed for clupeids, especially blueback herring. The CPUE for alewife, American shad, and bay anchovy were usually highest during summer salt intrusions.

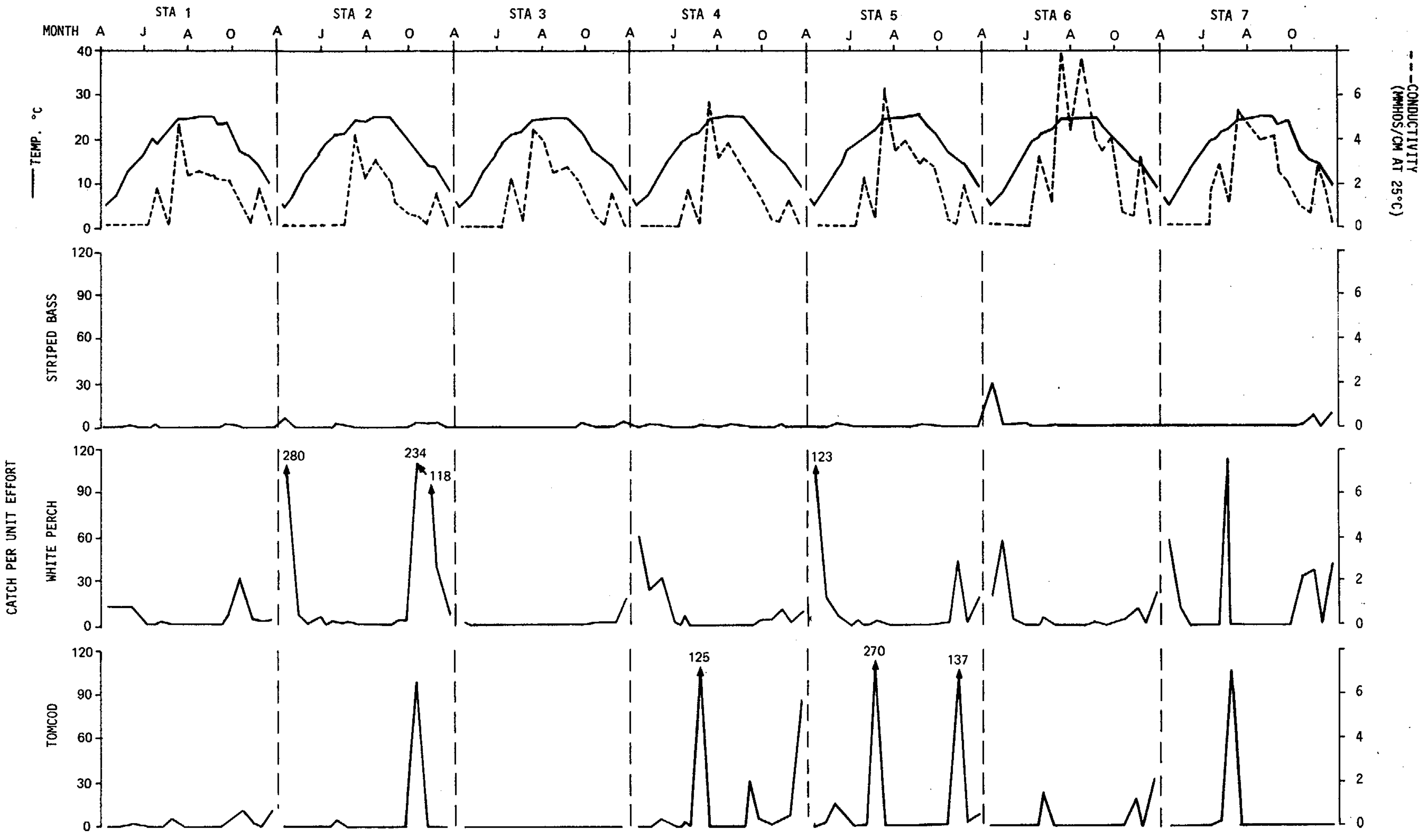


Figure VI-1. Comparison of Temporal Distributions of Environmental Variables and Catch per Unit Effort for Striped Bass, White Perch, and Atlantic Tomcod at Standard Bottom-Trawl Stations near Indian Point during 1974

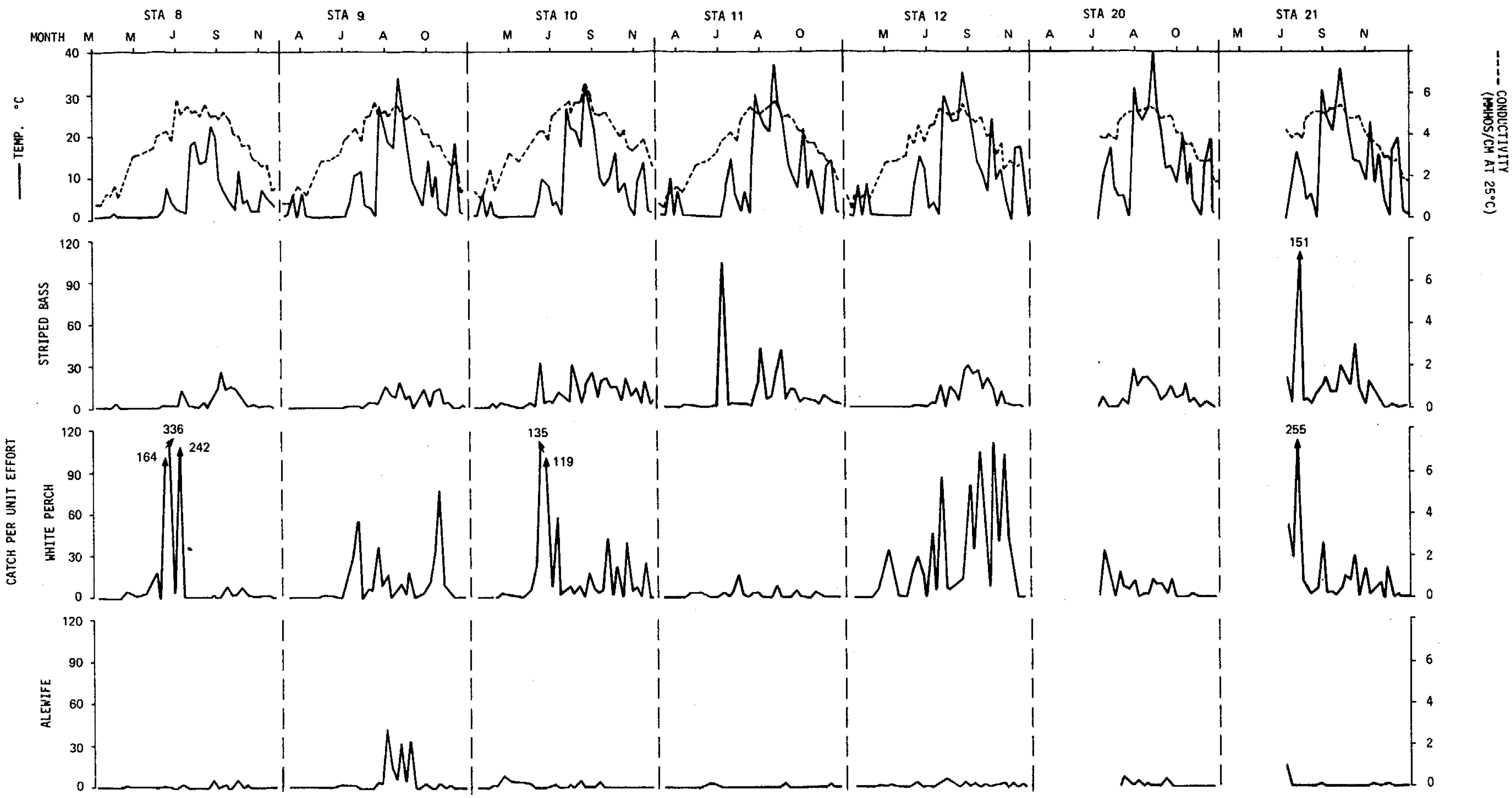


Figure VI-2. Comparison of Temporal Distributions of Environmental Variables and Catch per Unit Effort for Striped Bass, White Perch, and Selected Clupeids at Standard Beach-Seine Stations near Indian Point during 1974

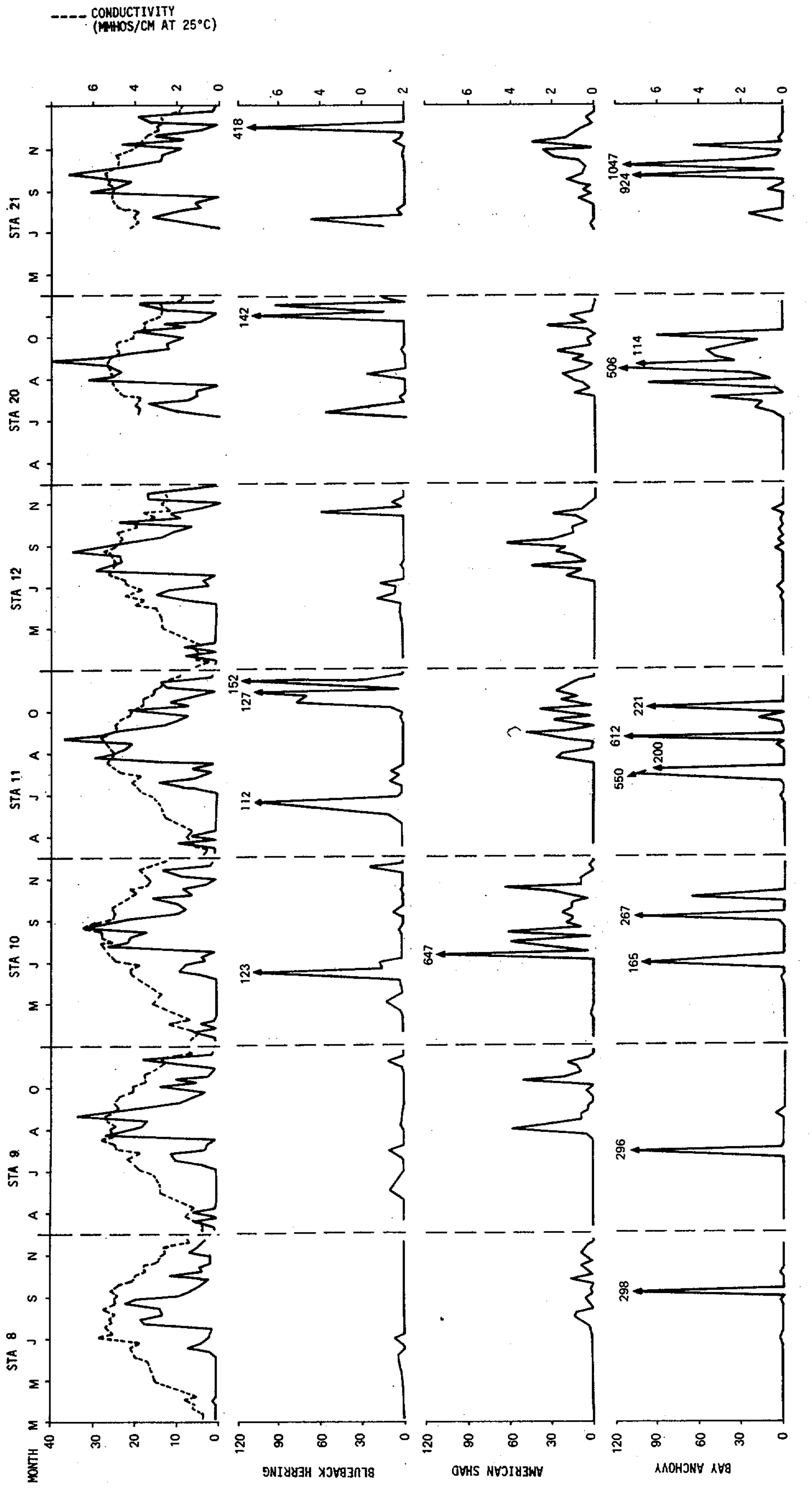


Figure VI-2. (Contd)

SECTION VII
BIOLOGICAL CHARACTERISTICS

A. INTRODUCTION

Biological characteristics such as growth rates, length frequency, age composition of the stock, fecundity, age at maturity, and condition have classically been used as indicators of the dynamics of fish populations. These characteristics generally are labile and may change in response to changes in density. Feeding habits such as prey preference may be used to indicate mechanisms of population regulation and to describe the trophic relationships of a fish population. Documentation of the present biological characteristics of key fish species and detection of changes will aid in defining the operational impact of the Indian Point plants. The data resulting from this part of the total study program will be fully developed and analyzed in later reports.

This section addresses the following biological characteristics of fish of the Hudson River in the vicinity of Indian Point:

- Length-frequency distribution of striped bass *(Morone saxatilis)*, white perch *(Morone americana)*, and Atlantic tomcod *(Microgadus tomcod)*
- Age composition of striped bass, white perch, and Atlantic tomcod populations
- Condition (length/weight relationship) of striped bass and white perch
- Growth rates of striped bass, white perch, and Atlantic tomcod
- Fecundity and age at maturity of striped bass, white perch, and Atlantic tomcod
- Food habits of Atlantic tomcod

B. METHODS

1. Sample Collection

Striped bass, white perch, and Atlantic tomcod were collected by beach seines, box traps, gill nets, otter trawls, Tucker trawls, and epibenthic sleds. Additional striped bass used to determine age at maturity and fecundity were purchased from commercial fishermen. A total of 63 young-of-the-year tomcod used for growth determination were obtained by sampling the lower estuary during July and August 1974.

Striped bass and white perch collected in standard-station gear (Section VI) were preserved in 10% formalin and returned to the laboratory. Weekly (August-October) samples of fresh striped bass and white perch were collected from box traps set within the Indian Point region [RM 39-46 (km 63-75)]. Lengths and weights of striped bass were also taken from those captured in gill nets and purchased from commercial fishermen during the spawning season. Tomcod collected by Tucker trawl and epibenthic sled and by sampling in the lower estuary were preserved in 10% formalin. Tomcod taken in bottom trawls and traps were not preserved in the field but were returned to the laboratory in fresh condition.

2. Laboratory Procedure

The date, location, time of capture, and gear employed were recorded for each sample. Laboratory workup included recording total length, weight, and sex.

Scale samples were removed from striped bass and white perch in an area above the lateral line and below the division of the dorsal fin as defined by Mansueti (1960) and Merriman (1941). Tomcod scales were removed from the area between the middle dorsal fin and the lateral line.

Aging was accomplished by the annulus method using a Tri-simplex microprojector. Striped bass and white perch scales were aged using a wet mount between two microscope slides. Tomcod scales, due to their small size, were originally permanently mounted under cover slips on microscope slides; as the mounting medium was found to crack with time, later samples (after September) were heat-pressed into acetate cards (Koo, 1962).

3. Determination of Growth, Age, and Length Composition

Striped bass and white perch collected in standard-station sampling were subsampled weekly to calculate monthly mean total lengths of young-of-the-year and yearling and older fish. Instantaneous growth rates were calculated by the methods utilized in previous studies (TI, 1974). Weighted percent frequencies by age and length were calculated by month. Age and length distribution of beach-seine and bottom-trawl catches were compared using data from 1972, 1973, and 1974.

Young-of-the-year tomcod used for growth determination were collected from the Hudson River with epibenthic sleds, bottom trawls, box traps, and from lower Long Island Sound (Littleneck Bay, Jamaica Bay, and Manhasset Bay) with the 200-ft haul seine. Mean length and standard deviation of each sample were calculated and are presented graphically by month. December 1974 mean lengths were calculated for tomcod collected from box traps set at RM 51. Age and length-frequency data for the 1973 spawning-run tomcod were also obtained from box traps set at RM 41 and are presented for December 1973 through February 1974.

4. Condition Analysis

Length/weight data for striped bass and white perch samples were collected before rather than after preservation in formalin, because experiments conducted during the past year had indicated that preservation had a significant effect on the length/weight relationship.

Striped bass and white perch collected weekly in box traps during August, September, and October were placed in plastic bags, covered with ice, and returned immediately to the laboratory for workup. Only white perch data are presented, however, since there were insufficient numbers of fresh striped bass with which to calculate the length/weight relationship. White perch length/weight data from summer (June 18-September 14) and fall (September 17-December 29) were used in linear regression analysis. The $\log_{10}$ transformed data were grouped by sex and state of maturity; regression lines were calculated by season for males, females, immatures, and all fish combined. Length/weight regressions were compared for white perch from the river and the Indian Point Unit-1 screens for summer and fall.

5. Determination of Fecundity and Age at Maturity

During May, June, and July, gonads were excised from striped bass and white perch collected in gill nets and standard-station sampling and those purchased from commercial fishermen. The gonads were placed in 10% formalin for later workup. This same procedure was used on tomcod collected during December 1973-February 1974 and May-November 1974. December 1974 ovaries were stored in Simpson's modified version of Gilson's fluid (Ricker, 1971).

Maturity was determined by visual examination, egg-diameter measurements and manual explusion of eggs or milt. Scales were also taken from fish used in the fecundity studies in order to determine ages of individual fish. Age at maturity and percent mature by age were calculated using these data.

To determine fecundity of striped bass and white perch, preserved ovaries were blotted dry and weighed to the nearest 0.1 g. An aliquot was then removed from the medial portion of the right ovary, weighed to the nearest 0.01 g and the total number of eggs in the aliquot counted. For tomcod, eggs were manually separated from the ovarian tissue, washed, drained, and weighed to the nearest 0.01 g. An aliquot of approximately 2 g was removed, weighed to the nearest 0.01 g, and counted. The total number of eggs per fish was then estimated by dividing the number of eggs counted in the aliquot by the weight of the aliquot and then multiplying by the total weight of the ovary. Calculated fecundity estimates were used for regression analysis of $\log_{10}$ transformed data. Mean tomcod gonad weight expressed as a percentage of total body weight is presented graphically for males and females from July 1974 through January 1975.

6. Stomach Analysis

Samples for the tomcod food-habits study were collected from RM 10-58 by box traps and ichthyoplankton gear. Adult tomcod stomachs were injected with 10% formalin to stop further digestion. Young-of-the-year tomcod were taken from ichthyoplankton samples known to or expected to contain eggs and/or larvae of striped bass and white perch.

In the laboratory, the stomachs were removed and the contents placed in a petri dish with a small amount of water. The food items were sorted to the lowest practical taxonomic levels under a dissecting scope and counted; any fish eggs or larvae encountered were identified, and plant and animal remains, detritus, and filamentous algae were noted as being present or absent but were not assigned numerical values. To estimate the total number of identifiable dismembered organisms, either the number of heads or bodies were counted. If large numbers of small organisms were present, they were distributed evenly throughout the petri dish and an aliquot of organisms, based on a gridded petri dish, were counted to estimate the total. Organisms identified and found only occasionally were grouped as "other" organisms for use in calculations.

The frequency of occurrence and percentage frequency of food items were calculated on a monthly basis as follows:

$$\text{Frequency of occurrence of } i^{th} \text{ food item} = \frac{\text{Total number of stomachs containing food item i}}{\text{Total number of stomachs}} \times 100$$

$$\text{Percent frequency of } i^{th} \text{ food item} = \frac{\text{Total number of individuals of food item i}}{\text{Total number of individuals of all food items}} \times 100$$

C. RESULTS

1. Striped Bass

a. Age Composition

Most of the striped bass at the standard stations were yearlings (age I) until July when young-of-the-year (juveniles) were collected and became the dominant fish in the beach-seine catches (Figure VII-1). Juvenile striped bass were collected in bottom-trawl catches in September and dominated them throughout the fall (Figure VII-2). These results are similar to those of 1972 and 1973 although, in both of those years, juvenile bass appeared in bottom-trawl catches during August.

b. Length Frequency

Striped bass collected in beach seines and bottom trawls were typically <150 mm throughout the year (Figures VII-3 and VII-4). Young-of-the-year striped bass were first collected at lengths of 20 to 50 mm in July by beach seine and 2 months later at lengths of 50 to 70 mm by bottom trawls. No striped bass >270 mm were caught by either gear, although fish >200 mm were more commonly collected by bottom trawls. Beach-seine catches included striped bass between 100 and 200 mm with a greater regularity than did bottom trawls and generally produced larger sample sizes. Comparison of 1972, 1973, and 1974 length-frequency data revealed that a smaller percentage of fish >120 mm was collected during 1973, especially by beach seine.

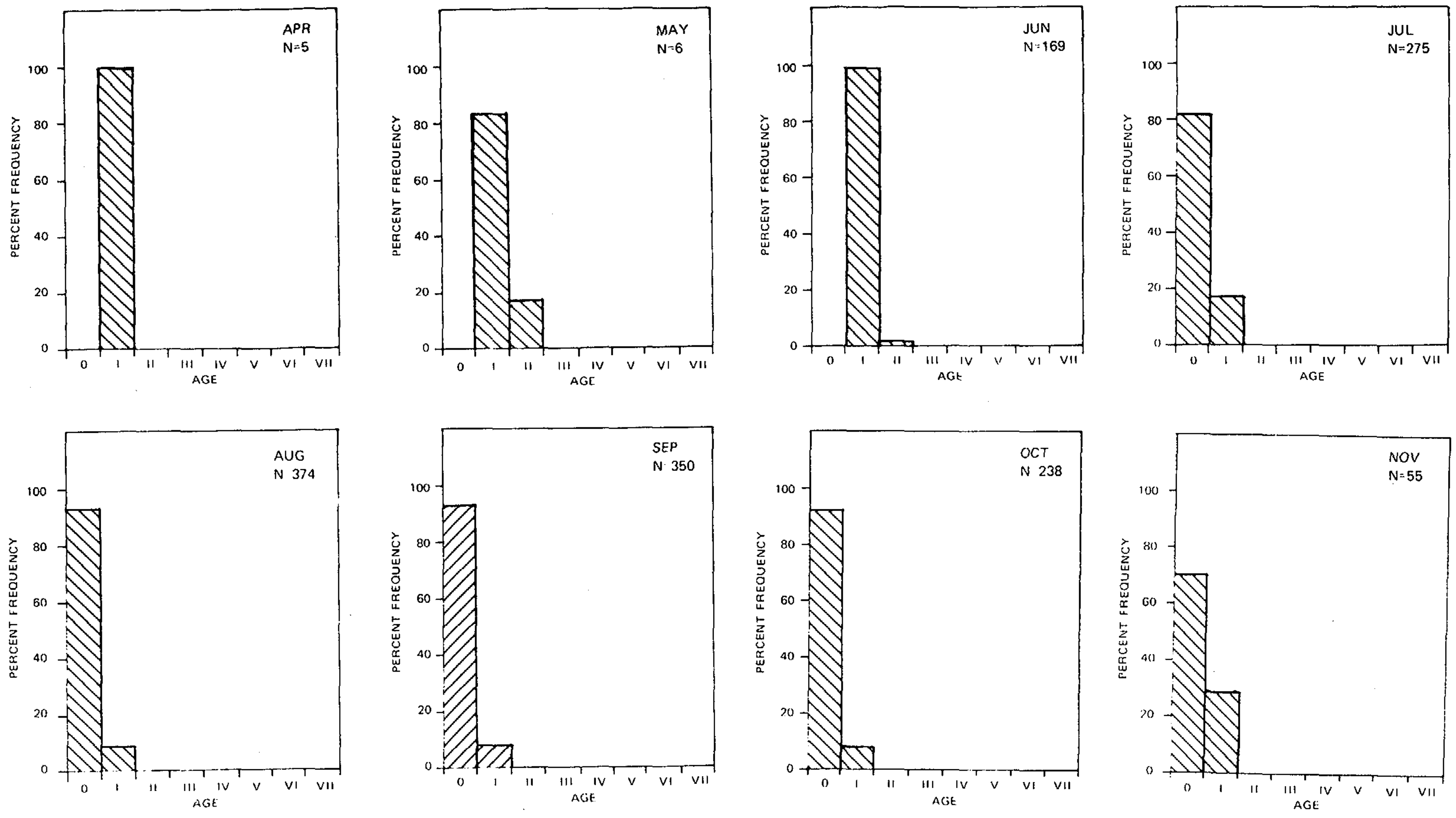


Figure VII-1. Age Composition of Striped Bass Collected by Beach Seines in Indian Point Region, April-November 1974

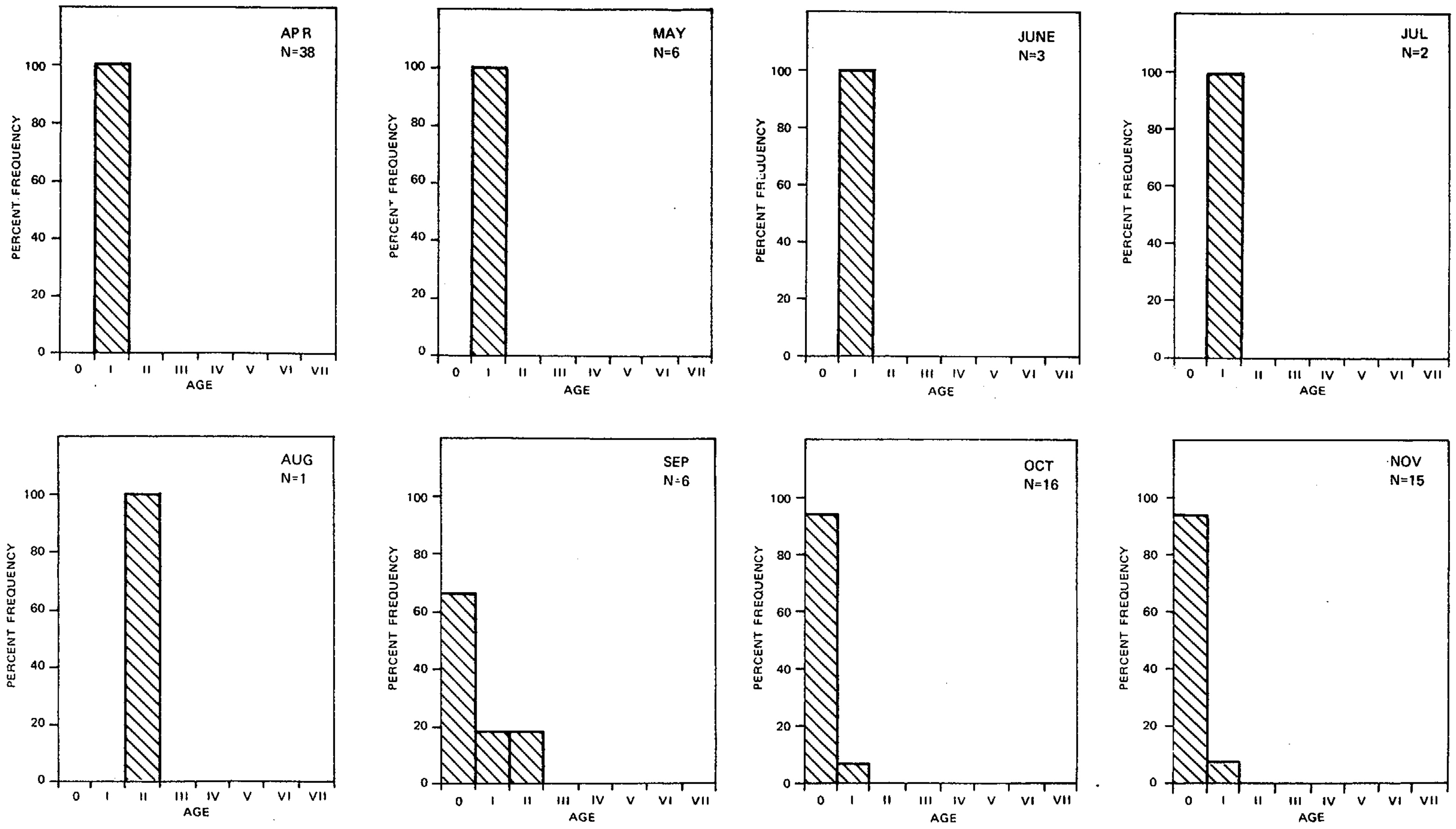


Figure VII-2. Age Composition of Striped Bass Collected by Bottom Trawls in Indian Point Region, April-November 1974

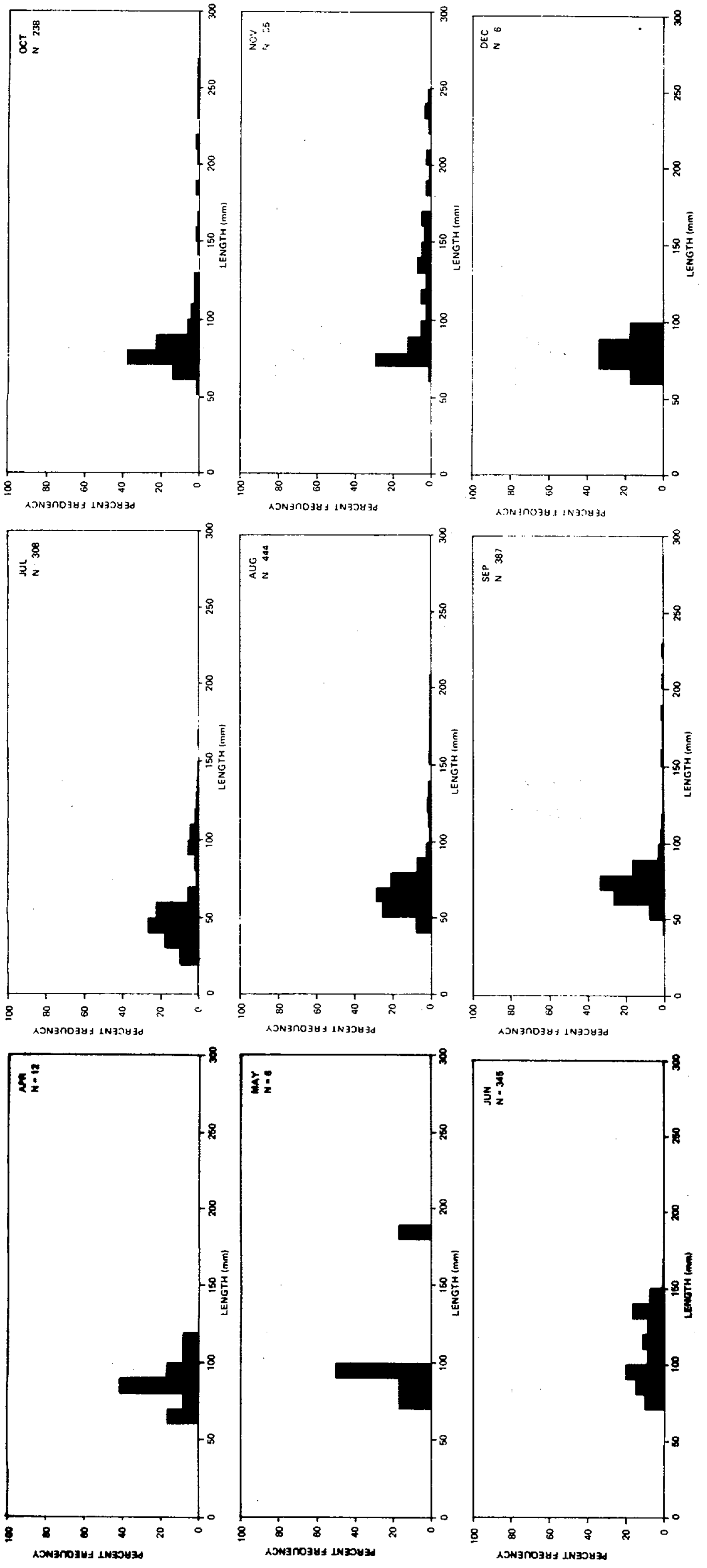


Figure VII-3. Length-Frequency Distribution of Striped Bass Collected in Beach Seines in Indian Point Region, April-December 1974

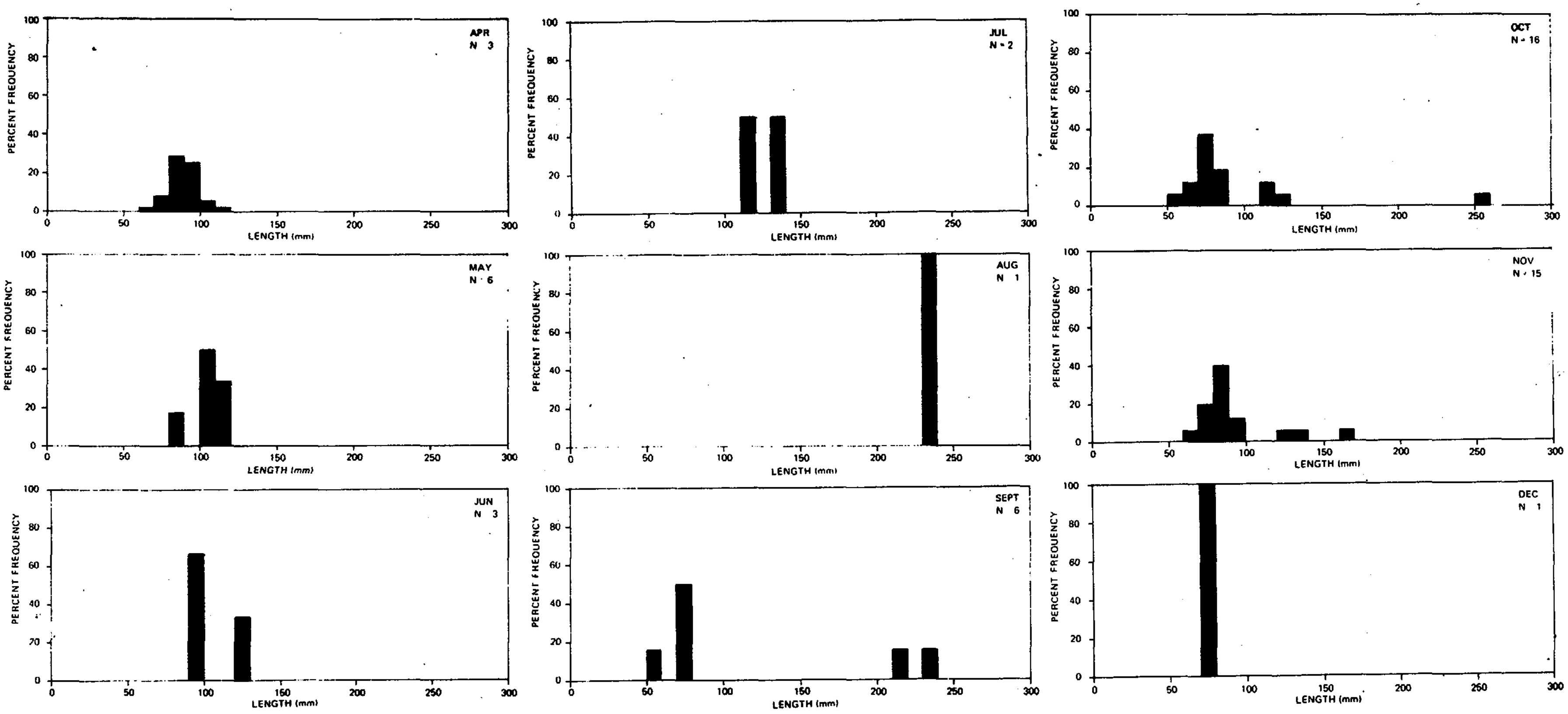


Figure VII-4. Length-Frequency Distribution of Striped Bass Collected in Bottom Trawls in Indian Point Region, April-December 1974

c. Condition

The length/weight relationship for spring 1974 was calculated using 193 striped bass of both sexes ranging in length from 371 to 1085 mm. Regression analyses revealed a higher intercept and a lower slope for immature striped bass when compared to adult males or females (Table VII-1). Small sample sizes of fresh striped bass prevented calculation of a valid regression for the summar and fall periods.

Table VII-1

Total Length/Weight Relationship of Immature, Male, and Female Striped Bass Collected from Commercial Fishery, Spring (March 30-June 15) 1974

($\log_{10}$ transformation of data)

Sex	Sample Size	'Y Intercept a	Slope b	Regression Coefficient r	r^2
Immature	10	-3.329	1.207	0.7764	0.6028
Male	100	-5.750	3.265	0.9785	0.9575
Female	83	-6.180	3.424	0.9773	0.9552
Total	193				

d. Growth

Growth of young-of-the-year striped bass was most rapid during the July-August period (Table VII-2 and Figure VII-5), with a monthly increment of approximately 22 mm in mean length. During August-November, the monthly increment in mean length was < 10 mm; during November-December, mean length appeared to decline slightly. This seasonal pattern of growth is similar to that observed in the 1973 year class (TI, 1974a). The highest rate of growth for yearling striped bass occurred during July-October;

monthly growth increments were approximately 30 mm. Monthly growth increments were <7.0 mm during April-July. During October-November, mean length appeared to decline; however, standard errors were large in both months.

e. Fecundity and Age at Maturity

Samples of striped bass for fecundity analysis in 1974 were collected later in the year than had been the case in 1973; the 1974 fecundity samples were taken concurrently with the spawning season, so they are apt to provide a better measure of percent maturity than did the 1973 samples although more spent fish were encountered. Examination of 82 female striped bass collected from the commercial fishery in 1974 revealed that most Hudson River striped bass females were mature at age V and that all older females were mature; 59 male striped bass (ages IV-XI) were all sexually mature. Fecundity increased with age and size (Table VII-3).

Table VII-2

Monthly Mean Lengths for Young-of-the-Year and Yearling Striped Bass Collected by Bottom Trawls and Beach Seines, Indian Point Region, April-December 1974

Age		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	$\bar{x}$	NC*	NC*	NC*	44.5	66.2	75.4	82.3	91.1	83.9
	2 SE				1.5	1.3	1.2	2.4	5.6	6.8
	n				222	362	395	191	59	13
I	$\bar{x}$	95.2	98.6	104.7	107.8	137.3	164.3	205.2	187.9	NC*
	2 SE	34	8.2	3.2	4.9	9.8	11.0	16.2	16.0	
	n	43	11	175	56	34	31	20	17	

*No catch

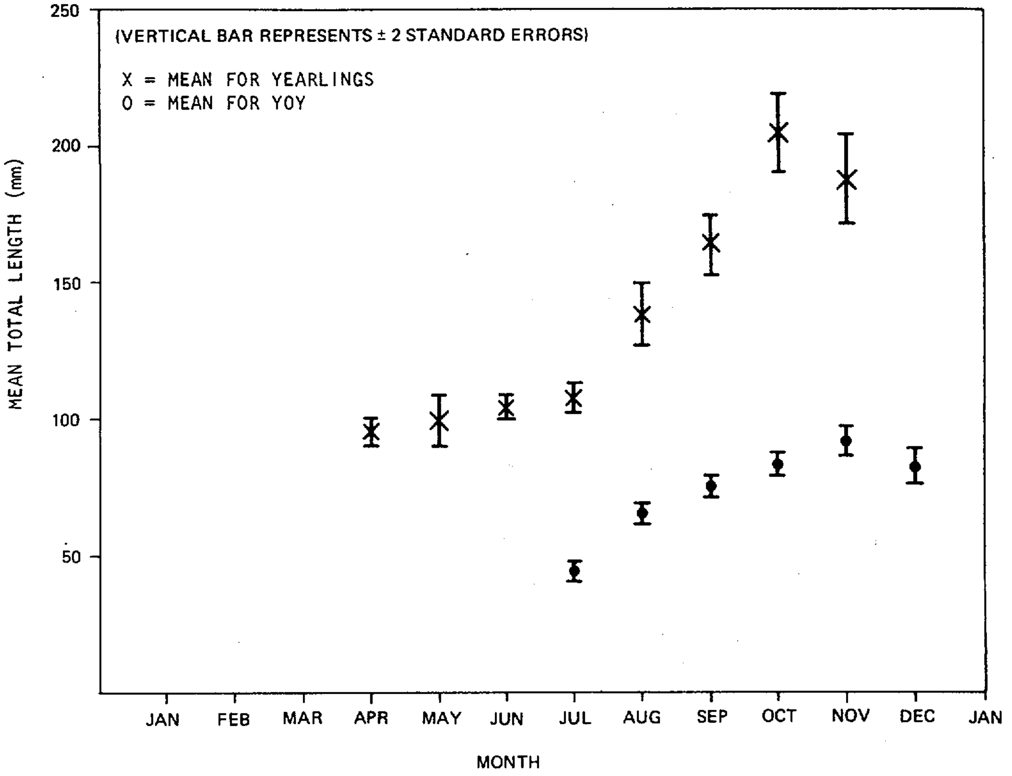


Figure VII-5. Growth of Young-of-the-Year (YOY) and Yearling Striped Bass in Hudson River during 1974

Table VII-3

Percent Maturity and Mean Fecundity by Age for Female Striped Bass Collected in Indian Point Region, May and June 1974

Age	No. Examined	No. Mature	No. Spent	No. Immature	% Mature	$\bar{x}$ Eggs	N	SE	SE$_{\bar{x}}$
IV	9	0	-	9	0	-	-	-	-
V	5	5	1	1	80	778,999	3	392,785	226,775
VI	5	5	0	0	100	726,458	5	257,235	115,039
VII	6	6	3	0	100	984,163	3	536,597	309,804
VIII	16	16	3	0	100	1,184,805	13	304,264	84,388
IX	18	18	3	0	100	1,527,495	15	475,801	122,851
X	16	16	1	0	100	1,800,252	15	613,703	158,457
XI	7	7	2	0	100	1,767,820	5	647,792	323,896

2. White Perch

a. Age Composition

Young-of-the-year (YOY) white perch were first collected by beach seine in July and dominated the catch thereafter (Figure VII-6). First collections of this life stage in bottom trawls were during September, 1 month later than indicated by the 1972 and 1973 data (Figure VII-7). Young-of-the-year white perch also dominated the bottom-trawl catches after September. Although young-of-the-year dominated both gear catches after recruitment in 1974, this dominance was never as great as that observed during 1973. The high percentage of age-I fish in the 1974 catches confirms the previous conclusion of the production of a strong 1973 year class (TI, 1974a).

b. Length Frequency

Throughout the sampling period (May-December), both beach seines and bottom trawls regularly collected white perch 50-200 mm in total length (Figures VII-8 and VII-9). White perch < 50 mm in total length (YOY) were first collected in July by beach seines, while bottom trawls first caught YOY at lengths of 50-80 mm (TL) in September. The 1973 year class (age I) appears in Figure VII-8 as the first three or four bars of the histogram for April, and the growth can be followed through the year. During November and December, the number of beach-seine-caught white perch > 100 mm (TL) declined precipitously, while bottom-trawl catches of this size class greatly increased. This phenomenon was noted also in 1972 and 1973 data (TI, 1973a, 1974a) and was probably due to the white perch moving into deeper water as the water temperature declined (TI, 1973a, 1974a).

c. Condition

During summer, 151 female and immature white perch ranging in total length from 46 to 217 mm were used to calculate the length/weight relationship for the season (Table VII-4); males were not included because of the small number collected during the period.

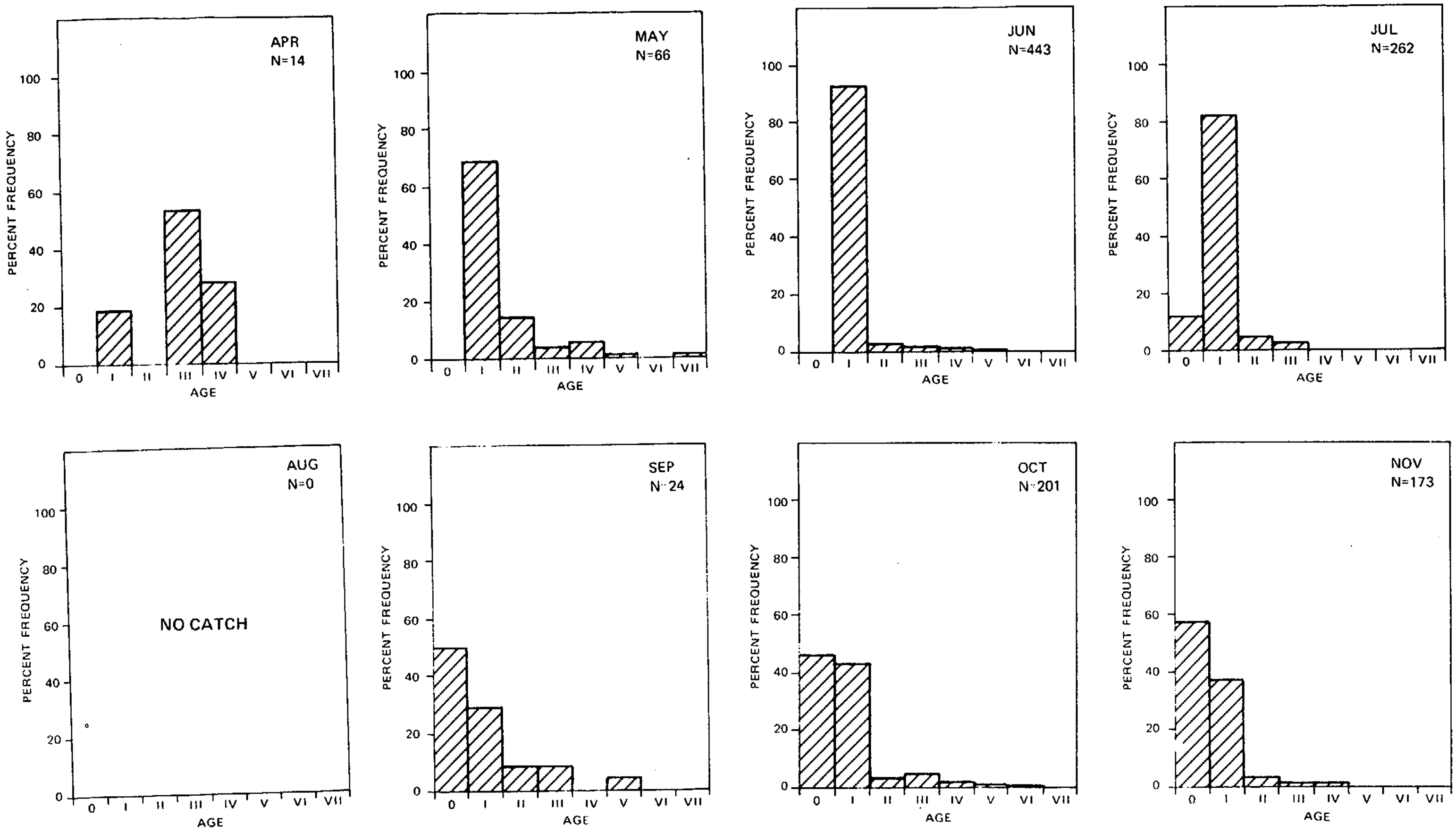


Figure VII-6. Age Composition of White Perch Collected by Beach Seines in Indian Point Region, April-November 1974

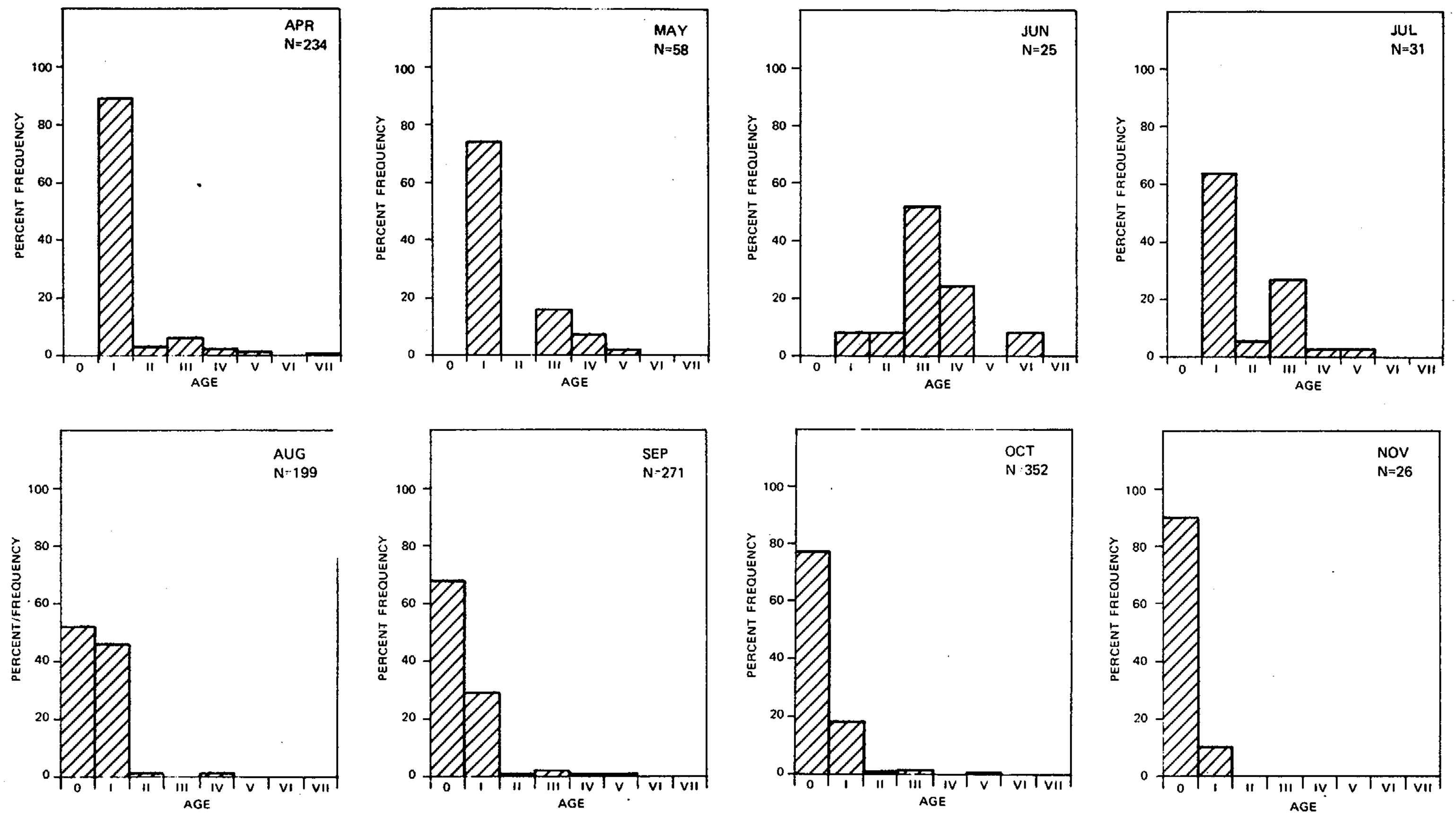


Figure VII-7. Age Composition of White Perch Collected by Bottom Trawls in Indian Point Region, April-November 1974

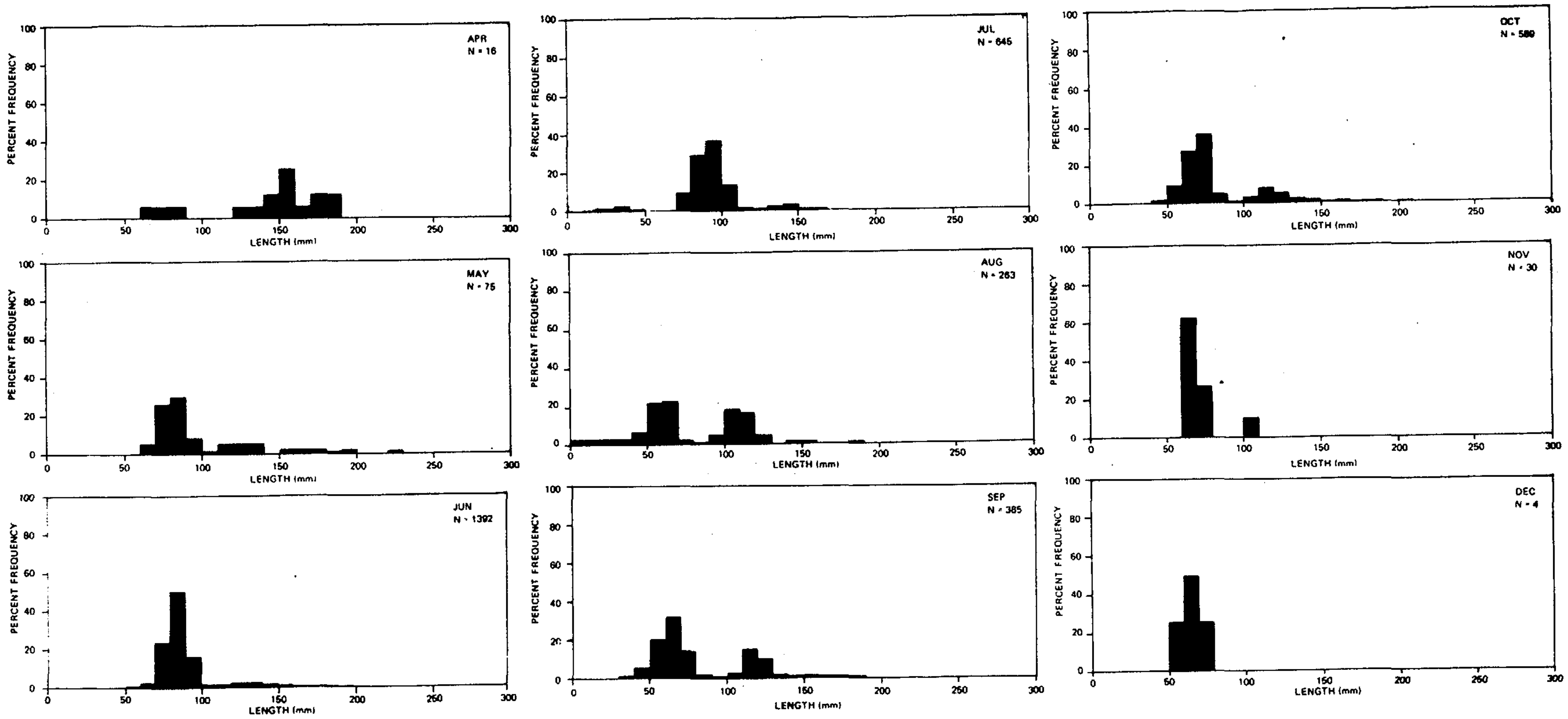


Figure VII-8. Length-Frequency Distribution of White Perch Collected by Beach Seines in Indian Point Region, April-December 1974

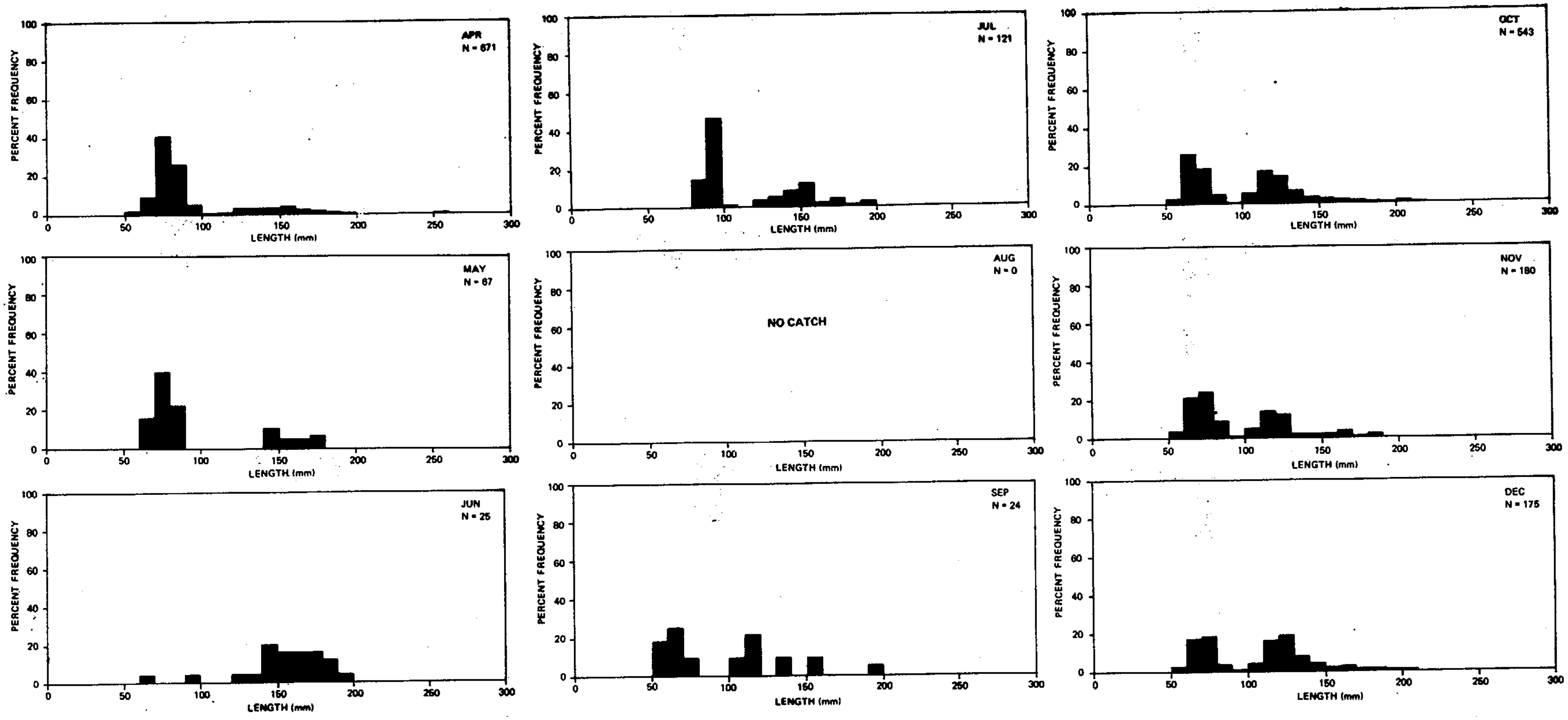


Figure VII-9. Length-Frequency Distribution of White Perch Collected by Bottom Trawls in Indian Point Region, April-December 1974

During fall, box traps captured 127 immature male and female white perch ranging in total length from 49 to 220 mm. Data from these were used to calculate the length/weight relationship for that time period. Regression analysis revealed a similar intercept and slope for immature, male, and female white perch in fall 1974 (Table VII-5).

Table VII-4

Total Length/Weight Relationship of Immature and Female White Perch Collected in Indian Point Region, Summer (June 18-September 14) 1974

Sample Size	Y Intercept a	Slope b	Regression Coefficient r	r^2
151	-5.345	3.224	0.9884	0.9769

Table VII-5

Total Length/Weight Relationship of Immature, Male, and Female White Perch Collected in Indian Point Region, Fall (September 17-December 29) 1974

Sex	Sample Size	Y Intercept a	Slope b	Regression Coefficient r	r^2
Immature	111	-5.344	3.218	0.9925	0.9851
Male	8	-5.194	3.149	0.9879	0.9759
Female	9	-5.889	3.470	0.9956	0.9912
Common Line	128	-5.368	3.230	0.9944	0.9888

d. Growth

Monthly mean lengths showed consistent rates of increase from July through September for young-of-the-year fish, from May through November for fish ages I and II, and from July through December for most of the remaining older fish (Table VII-6). Young-of-the-year white perch were first collected during July at lengths of 30 to 40 mm; thereafter, monthly mean lengths for young-of-the-year white perch increased steadily until October, at which time they stabilized at approximately 70 mm, indicating the end of the growing season during September. A similar trend was noted during the 1972 and 1973 sampling (TI, 1973a, 1974a) and is supported by the calculated instantaneous growth rates, which are near zero (Table VII-7 and Figure VII-10).

Table VII-6

Mean Monthly Total Length (mm) by Age Class for White Perch Collected by Standard-Station Beach Seines and Bottom Trawls in Indian Point Region, 1974

	Age 0		Age I		Age II		Age III	
Month	x̄ ± SE	n	x̄ ± SE	n	x̄ ± SE	n	x̄ ± SE	n
Apr	NA*	NA	77.8 ± 1.268	172	127.8 ± 2.464	29	152.8 ± 2.554	63
May	NA	NA	79.6 ± 1.724	84	127.5 ± 9.460	14	154.6 ± 4.284	14
Jun	NA	NA	83.8 ± 0.9060	356	130.6 ± 1.724	42	152.0 ± 2.594	48
Jul	33.0 ± 2.056	25	94.2 ± 1.276	221	136.0 ± 3.884	16	157.1 ± 4.964	33
Aug	54.0 ± 2.276	90	111.3 ± 1.618	114	166.0 ± 16.00	2	176.3 ± 9.804	8
Sep	66.1 ± 1.250	232	118.5 ± 1.354	139	145.6 ± 4.938	11	165.9 ± 6.012	13
Oct	69.7 ± 0.8700	312	120.5 ± 1.134	252	147.7 ± 3.236	17	165.4 ± 3.648	27
Nov	71.3 ± 1.182	177	119.8 ± 1.946	119	160.0 ± 5.804	10	165.3 ± 15.586	4
Dec	70.4 ± 1.352	151	122.4 ± 1.870	149	160.9 ± 9.566	7	173.1 ± 6.782	11

	Age IV		Age V		Age VI		Age VII	
Month	x̄ ± SE	n	x̄ ± SE	n	x̄ ± SE	n	x̄ ± SE	n
Apr	173.6 ± 4.652	19	183.5 ± 14.388	4	NA	NA	254.0 ± 0.000	1
May	173.4 ± 7.980	9	184.0 ± 26.00	2	NA	NA	225.0 ± 0.000	1
Jun	171.9 ± 4.192	22	189.1 ± 8.134	9	189.0 ± 7.000	2	NA	NA
Jul	174.3 ± 13.776	3	186.3 ± 5.766	6	208.0 ± 0	1	215.0 ± 0	1
Aug	181.9 ± 4.266	8	196.8 ± 8.656	4	NA	NA	NA	NA
Sep	179.8 ± 8.808	4	190.3 ± 7.860	3	NA	NA	NA	NA
Oct	181.7 ± 5.828	10	203.0 ± 2.066	6	215.0 ± 0	1	NA	NA
Nov	178.5 ± 5.000	2	212.0 ± 0	1	NA	NA	NA	NA
Dec	200.0 ± 12.166	3	NA	NA	209.0 ± 0.000	1	NA	NA

*Not available

Table VII-7

Instantaneous Growth Rates of Young-of-the-Year White Perch Collected by Beach Seines in Indian Point Region, 1974

Date (1974)	Initial Weight (g)	Final Weight (g)	Time (days)	Instantaneous Growth Rate (g/day)
8/9-26	0.98 (8)*	3.41 (33)*	17	0.0733
9/5-30	3.25 (56)	5.19 (55)	25	0.0187
10/9-28	4.09 (45)	4.27 (39)	20	0.0023
11/8-11	4.80 (2)	4.59 (21)	3	-0.0149

*Numbers in parentheses represent sample size.

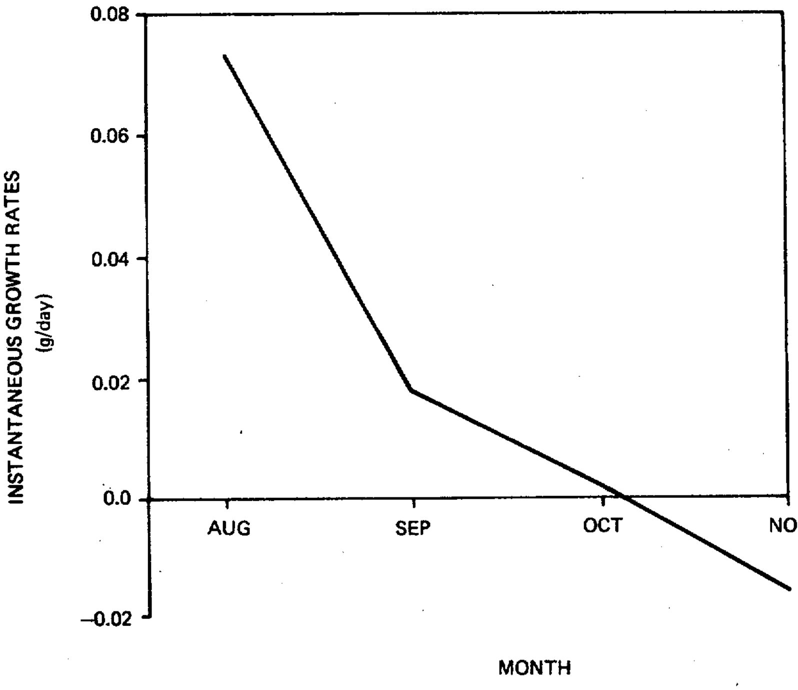


Figure VII-10. Instantaneous Growth Rates of Young-of-the-Year White Perch Collected by Beach Seines in Indian Point Region, 1974

e. Fecundity and Age at Maturity

Examination of 20 male and 73 female white perch subsampled from the May 1973 samples and 36 males and 72 females from the May and June 1974 catches gave results differing from previously reported data (Tables VII-8, VII-9, VII-10, and VII-11). Percent maturity for males differed slightly, with age-II white perch showing a greater proportion of mature fish than indicated in 1973 (TI, 1974a). Percent maturity for age-III males showed a smaller proportion mature than expected from the 1973 data; this is primarily because a larger sample size was used in the 1974 calculation. All age-IV and older male perch were judged mature, which agreed with previous data.

Mean fecundity by age for 1972, 1973, and 1974 was comparable for all ages examined. For percent maturity by age, the 1972 data revealed marked differences when compared to 1973 and 1974 data; previously, no age-II females had been considered mature, but current findings show that approximately 25% of all age-II female white perch are mature and will contribute to spawning. Differences in percent maturity were noted also for age-III female white perch; previous data had indicated that 75% of this age class were mature, but current data show that 95% of all age-III fish are mature. Two age-IV female perch (one each from 1973 and 1974) were considered immature; in both cases, the ovaries showed signs of development, but neither fish showed sufficient egg maturation to spawn. All fish age V and older were mature.

f. River vs Impinged Fish

Preliminary regression analysis of the length/weight relationships of fish impinged on Unit-1 screens and river white perch indicates some differences between the two groups (Tables VII-12 through VII-14). The analysis shown gives some credence to the hypothesis that fall 1974 impinged fish were in poorer condition. This may or may not reflect the actual situation, since the fish taken from the Unit-1 screen had been impinged up to 24 hr before their removal, which may have affected the weight of the impinged fish.

Table VII-8

Percentages of Sexually Mature Male White Perch Ages II-VII Collected in Indian Point Region, May 1973

Age	Total Examined	No. Mature	No. Immature	No. Mature
II	6	3	3	50
III	3	2	1	67
IV	5	5	0	100
V	4	4	0	100
VI	2	1	0	50

Table VII-9

Percent Maturity and Mean Fecundity by Age (II-VI) for Female White Perch Collected in Indian Point Region, May 1973

Age	Total Examined	No. Mature	No. Immature	$\bar{x}$ Eggs	$SE_{\bar{x}}$	% Mature
II	17	4	13	11,856	3,346	24
III	28	27	1	22,093	2,927	96
IV	12	11	1	38,344	6,844	92
V	15	15	0	49,730	5,731	100
VI	1	1	0	62,412	NA*	100

*Not available

Table VII-10

Percentages of Sexually Mature Male White Perch Ages I-VI Collected in Indian Point Region, June 1974

Age	Total Examined	No. Mature	No. Immature	No. Mature
I	2	0	2	0
II	13	10	3	77
III	13	12	1	92
IV	5	5	0	100
V	1	1	0	100
VI	2	2	0	100

Table VII-11

Percent Maturity and Mean Fecundity by Age (I-V and VII) for Female White Perch Collected in Indian Point Region, May and June 1974

Age	Total Examined	No. Mature	No. Immature	$\bar{x}$ Eggs	SE$_{\bar{x}}$	% Mature
I	1	0	1	-	-	0
II	26	5 (5)	21	11,853	2,599	23
III	18	17 (5)*	1	32,602	7,057	95
IV	20	19 (5)*	1	37,668	2,414	95
V	6	6 (5)*	0	49,509	12,230	100
VII	1	1	0	63,047	-	100

*Due to protracted spawning period, higher probability of catching partially spent fish as spawning season progressed was expected; therefore, only fish collected before June 10, 1974, were used for calculating mean fecundity. This number appears in parentheses.

Table VII-12

Length/Weight Regressions of River and Impinged White Perch in 1974

($\log_{10}$ transformed data)

		Regression Equation ($\log_{10}$ weight = a + b $\log_{10}$ length)	Correlation Coefficient	Sample Size
Summer	River	$-5.44848 + 3.27278 \log_{10}$ length	0.988952	75
	Impinged	$-5.02648 + 3.05654 \log_{10}$ length	0.987852	69
Fall	River	$-5.51711 + 3.30751 \log_{10}$ length	0.987915	90
	Impinged	$-5.14860 + 3.12985 \log_{10}$ length	0.986611	87

Table VII-13

Mean Square Errors of Length/Weight Regression Lines

		Mean Square Error	Prob. of Variance Heterogeneity
Summer	River	0.2879577×10^{-2}	1.0000
	Impinged	0.8309485×10^{-2}	
Fall	River	0.5545271×10^{-2}	0.8573
	Impinged	0.4664391×10^{-2}	

Table VII-14

Regression Line ANOVA for Fall 1974 River Vs Impinged White Perch

Source	DF	SS	MS	F	Prob.
Common line	2	$0.34769768436 \times 10^{-1}$	$0.17384884218 \times 10^{-1}$	3.400487	0.96440
Error	173	0.88445705884	$0.51124685482 \times 10^{-2}$		

Table VII-15

Frequency of Occurrence and Percent Frequency of Principal Food Items Found in 41 Adult Tomcod Captured during December 1973 in Box Traps between RM 0 and 60

Food Items	Frequency of Occurrence	Percent Frequency
Gammarus	63.41	76.94
Calanoid	0	0
Cyclopoid	0	0
Harpacticoid	0	0
Polychaete	2.44	0.13
Cladocera	0	0
Neomysis	36.59	11.52
Monoculodes	4.88	4.02
Chironomid (larvae)	9.76	0.54
Chironomid (pupae)	0	0
Chaoborus	0	0
Leptocheirus	0	0
Cyathura	4.88	0.27
Crangon	17.07	2.94
Chirodotea	7.32	2.01
Striped Bass	2.44	0.40
Unidentified *Morone*	4.88	0.27
Fish eggs	2.44	0.40
Unidentified fish	2.44	0.13
Other	7.32	0.40

*One fish (TL = 208 mm) contained three striped bass.

3. Atlantic Tomcod

a. Food Habits

Stomachs from 46 adult Atlantic tomcod were examined. One contained three striped bass. Remaining adult stomachs contained two unidentified *Morone* one unidentified fish, and fish eggs which, because of the time of year, were thought to be tomcod eggs. Stomachs from 486 young-of-the-year (YOY) fish were examined. One white perch larvae (June) and one unidentified fish (July) were found. Five adult and 12 young-of-the-year stomachs were empty.

Invertebrates comprise the majority of the food items for both adult and YOY tomcod (Tables VII-15, VII-16, and VII-17). Calanoid copepods were numerically very important food items in May for both regions but rapidly decreased in importance by July in region I (RM 0-30) and August in region II (RM 31-60), decreasing to approximately 3% of total numbers. The percent frequency of *Gammarus* in YOY stomachs from region I increased from 5% in May to 17% in July; the increase in region II was higher (10% in May to 90% in October), which was approximately the same frequency observed in the December 1973 stomachs (77%). The 1974 young-of-the-year data appear to indicate that tomcod prey on *Morone* eggs and larvae at a very low level. The December 1973 data suggest that adult tomcod are more piscivorous than the young.

b. Age Composition

Length-frequency distributions of the adult tomcod captured during the spawning season of 1973-1974 are unimodal (Figure VII-11). Analysis of scales collected during December initially indicated two age classes; however, after the growth-pattern and scale morphology of 1974 YOY tomcod were examined, results of age studies on adult fish were reevaluated. Scales from the 1974 YOY had a distinct check or false annulus which acquired the characteristics of an annulus upon resumption of growth at the end of September. Reexamination of the 1973-1974 adult scales revealed that the first

Table VII-16

Frequency of Occurrence and Percent Frequency by Month of Principal Food Items Found in Young-of-the-Year Atlantic Tomcod Captured in Region I (RM 0-30) during 1974

Food Item	May n = 133 Frequency of Occurrence	Percent Frequency	Jun n = 25 Frequency of Occurrence	Percent Frequency	Jul n = 47 Frequency of Occurrence	Percent Frequency
Gammarus	49.62	5.08	72.0	6.32	23.4	17.08
Calanoid	82.70	86.31	64.0	53.06	6.38	2.91
Cyclopoid	12.03	1.65	28.0	11.73	6.38	2.08
Harpacticoid	10.52	0.99	44.0	8.12	17.02	7.92
Polychaete	34.58	2.50	44.0	5.72	6.38	3.33
Cladocera	5.26	0.40	52.0	10.93	4 .25	0.83
Neomysis	15.78	2.45	0	0	21.27	7.92
Monoculodes	12.03	0.40	20.0	0.70	38.29	12.91
Chironomid (larvae)	0	0	32.0	1.80	10.63	2.91
Chironomid (pupae)	2.25	0.07	8.0	0.20	10.63	2 91
Leptocheirus	0	0	8.0	0.40	0	0
Cyathura	1.50	0.09	8.0	0.20	12.76	3.33
Gastropod	0	0	0	0	0	0
Chirodotea	0	0	0	0	0	0
Chaoborus	0	0	4.0	0.10	14.89	20.83
Other	0.75	0.02	24.0*	0.70	38.29**	15.0

*Includes one white perch larvae.

**Includes one unidentified fish.

check or false annulus was present on nearly all scales. It was also noted that circulus densities from the focus of the scale to the area of the first check were higher than from the check to the edge of the scale. On most scales, there is an obvious demarcation between the two density zones; this demarcation may be coincident with, but is frequently located one or more circuli beyond, the check. It is currently hypothesized that the higher densities result from growth within the river, that the less dense circuli zone results from growth in a more saline environment and that the area of demarcation is a result of the change in environment. If this hypothesis is correct and the initial growth rates observed from river samples can be approximately maintained in a more saline environment (i.e., Long Island Sound), it would help to explain not only the scale morphology but the wide range of lengths encountered during the spawning season.

Table VII-17

Frequency of Occurrence and Percent Frequency by Month of Principal Food Items Found in Young-of-the-Year Atlantic Tomcod Captured in Region II (RM 31-60) during 1974

Food Item	May n = 98		Jun n = 50		Aug n = 49		Sep n = 48		Oct n = 24	
	Frequency of Occurrence	Percent Frequency	Frequency of Occurrence	Percent Frequency	Frequency of Occurrence	Percent Frequency	Frequency of Occurrence	Percent Frequency	Frequency of Occurrence	Percent Frequency
Gammarus	79.59	10.16	86.0	21.95	89.79	70.35	81.25	55.10	100.0	89.94
Calanoid	90.82	83.76	60.0	64.74	14.25	2.96	2.08	0.25	0	0
Cyclopoid	14.28	2.20	16.0	2.66	2.04	0.27	0	0	0	0
Harpacticoid	40.82	2.63	2.0	0.77	20.4	5.39	2.08	0.76	0	0
Polychaete	14.28	0.47	62.0	8.75	0	0	2.08	0.76	4.16	0.57
Cladocera	1.02	0.04	2.0	0.11	2.04	0.27	0	0	0	0
Neomysis	0	0	0	0	0	0	0	0	8.33	0.86
Monoculodes	5.1	0.12	0	0	24.48	5.66	52.08	35.71	25.0	7.18
Chironomid (larvae)	13.26	0.35	6.0	0.33	2.04	0.27	2.08	0.25	0	0
Chironomid (pupae)	0	0	0	0	2.04	0.27	0	0	0	0
Chaoborus	8.16	0.16	0	0	24.48	12.39	2.08	0.25	8.33	0.57
Leptocheirus	1.02	0.02	0	0	0	0	14.58	2.04	4.16	0.29
Cyathura	0	0	6.0	0.33	6.12	0.80	14.58	3.31	4.16	0.29
Gastropod	3.06	0.06	0	0	0	0	4.16	0.76	0	0
Chirodotea	0	0	4.0	0.22	6.12	0.80	2.08	0.76	0	0
Other	0	0	2.0	0.11	4.08	0.54	0	0	4.16	0.29

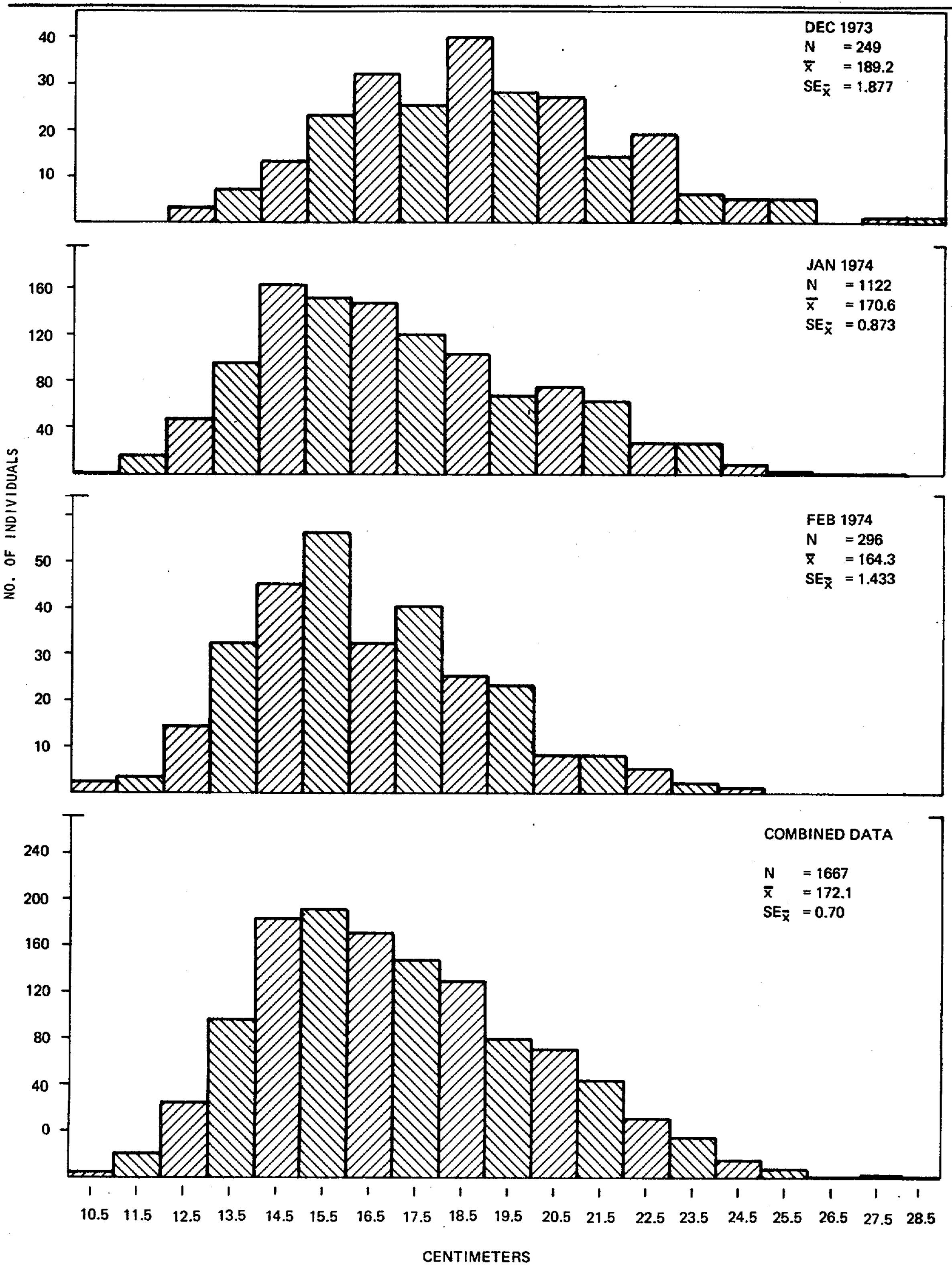


Figure VII-11. Length-Frequency Distributions of Adult Tomcod Caught in Traps in Vicinity of Indian Point, December 1973-February 1974

c. Growth

Young-of-the-year tomcod were first caught on May 4 and averaged 26.1 mm in total length. Mean lengths of Hudson River samples increased until the end of June when lengths stabilized at about 74 mm (Figure VII-12 and Table VII-15). Growth resumed at the end of September and continued to December. Five lower Long Island Sound samples totaling 63 specimens suggest that growth continued through the summer and did not reach a plateau as observed in the river samples (Table VII-18). If the growth rate observed in the river during May and June is continued by fish in the Sound, it is reasonable to expect tomcod approximating 250 mm in December river samples.

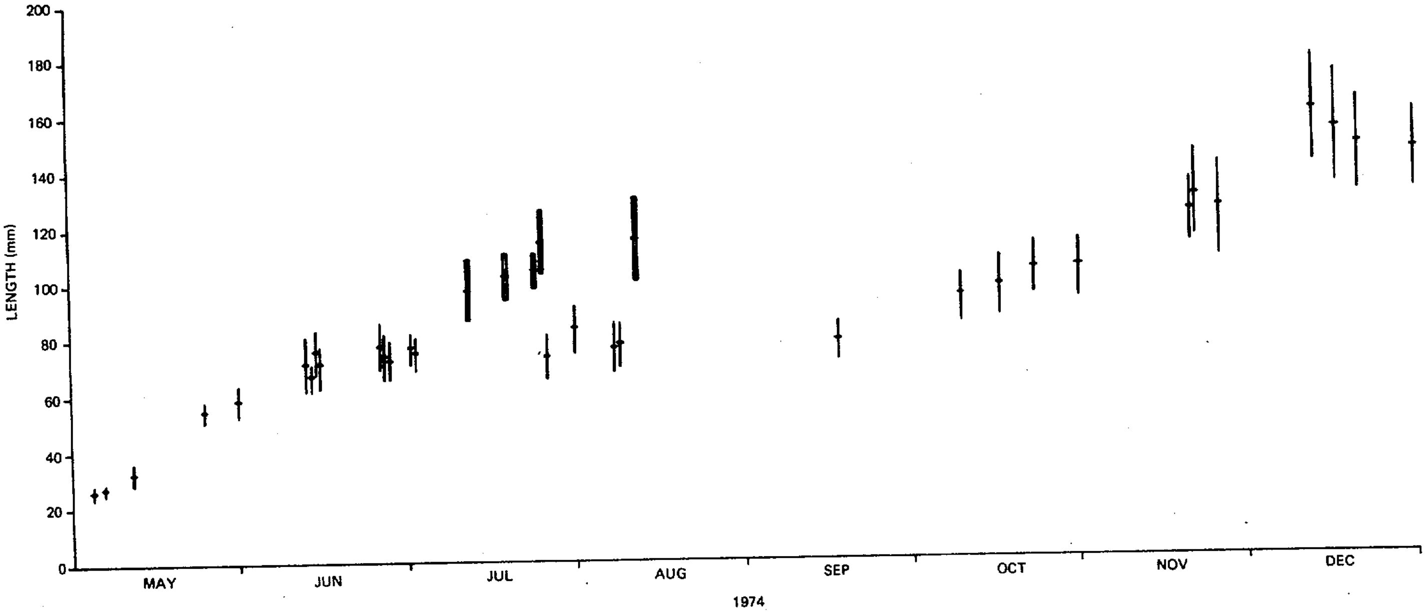


Figure VII-12. Mean Lengths ±1 Standard Deviation of 1974 Young-of-the Year Tomcod Caught in Hudson River (Solid Vertical Bars) and Lower Long Island Sound (Hollow Vertical Bars)

Table VII-18

Date, Sample Size, Mean Length, Standard Deviation, Gear, and Capture Location of 1974 Young-of-the-Year Atlantic Tomcod Caught in Hudson River and Western Long Island Sound (LIS)

Date	N	$\bar{x}$	S.D.	Gear	RM
May 4	50	26.08	2.44	Epibenthic sled	29
6	104	26.59	2.65	Bottom Trawl	25
11	50	32.02	4.12	Epibenthic sled	24
24	50	55.30	4.47	Epibenthic sled	25
30	109	58.32	6.02	Epibenthic sled	33
Jun 12	28	70.85	10.52	Bottom trawl	31
13	40	66.55	5.33	Bottom trawl	42
14	48	75.71	7.97	Bottom trawl	42
14	32	70.28	8.20	Bottom trawl	42
26	124	77.77	8.96	Bottom trawl	33
26	50	73.63	8.59	Bottom trawl	37
27	100	72.68	7.68	Bottom trawl	44
Jul 1	104	75.71	5.71	Bottom trawl	42
1	215	74.21	7.78	Bottom trawl	42
11	19	98.00	9.77	Haul seine	LIS
18	11	102.00	8.22	Haul seine	LIS
23	10	104.60	6.62	Haul seine	LIS
24	12	114.38	11.27	Haul seine	LIS
25	227	73.69	8.35	Bottom trawl	45-49
31	200	83.09	9.49	Bottom trawl	42
Aug 7	34	76.21	9.47	Bottom trawl	54
8	200	77.61	8.20	Bottom trawl	42
11	11	115.55	15.10	Haul seine	LIS
Sep 17	114	77.99	6.86	Bottom trawl	46
Oct 9	100	93.88	8.49	Bottom trawl	42
16	93	97.27	11.25	Bottom trawl	42
22	133	103.56	9.53	Bottom trawl	42
31	53	101.20	10.69	Bottom trawl	48
Nov 20	88	124.79	12.83	Bottom trawl	42
20	30	129.90	17.01	Bottom trawl	40
25	29	125.38	16.75	Bottom trawl	33
Dec 12	458	159.64	19.21	Box trap	51
16	372	153.24	19.99	Box trap	51
20	384	147.85	16.63	Box trap	51
31	428	145.57	14.25	Box trap	51

A possible explanation of the summer growth plateau in the river and the larger tomcod in Long Island Sound is that growth did not terminate in the river but only appeared to do so as a result of emigration of larger river fish. This possibility is rejected, however, since the length-frequency distributions from the river remained essentially unchanged throughout the summer.

d. Fecundity and Age at Maturity

The gonad-weight/body-weight ratio for 1974 YOY tomcod remained essentially static until the end of October when both sexes began to show signs of maturation (Figure VII-13 and Table VII-19). The November-January data are considered to be preliminary at present due partly to small sample sizes and to altered handling procedures during collection; however, the trend of a rapid increase in the state of maturity during November-December was consistent with qualitative observations. The apparent decline in gonad-weight/body-weight ratio in December and January is currently under investigation and will be included in a later report.

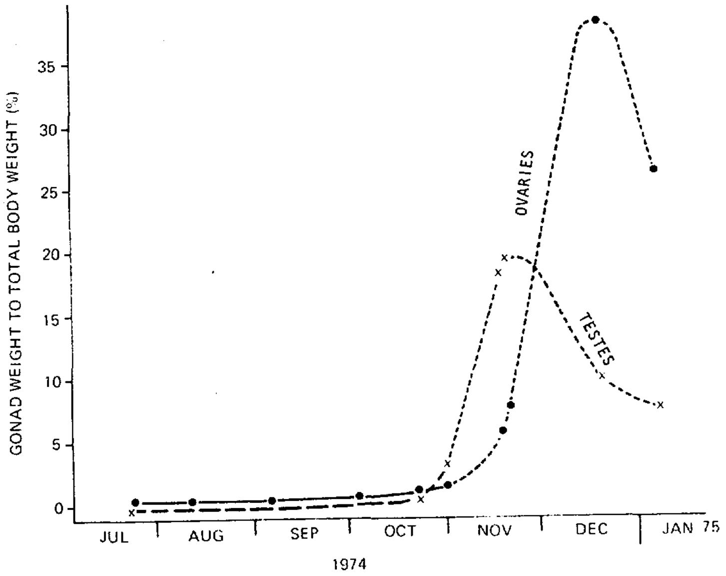


Figure VII-13. Mean Gonad Weights Expressed as Percentage of Total Body Weight for Young-of-the-Year Atlantic Tomcod in Hudson River, July 1974-January 1975

Table VII-19

Sample Sizes and Means by Date of Gonad Weights as Percent of Total Body Weights for Atlantic Tomcod Caught during July 1974-January 1975

Date	Female	Sample Size	Males	Sample Size
1974				
Jul 25	0.226	20	0.064	12
Aug 11	0.161	7	NC*	NC
Sep 5	0.344	21	NC	NC
Oct 3	0.481	4	NC	NC
Oct 22	0.874	17	0.731	19
Oct 31	1.287	16	3.05	14
Nov 18	5.58	3	18.33	14
Nov 20	7.47	9	19.37	17
Dec 19	38.15	6	9.85	8
1975				
Jan 6	26.10	16	7.60	10

*No catch

Assuming that the average 1974 year-class tomcod was spawned in January 1974, this year class is spawning at the age of 11-13 months. Based on the rate of sexual maturity of the 1974 young-of-the-year tomcod, the 1973 fecundity estimates were considered to be from one year class. Fecundity was found to increase with length (Figure VII-14), with a correlation coefficient of 0.8509 ($r^2 = 0.7240$).

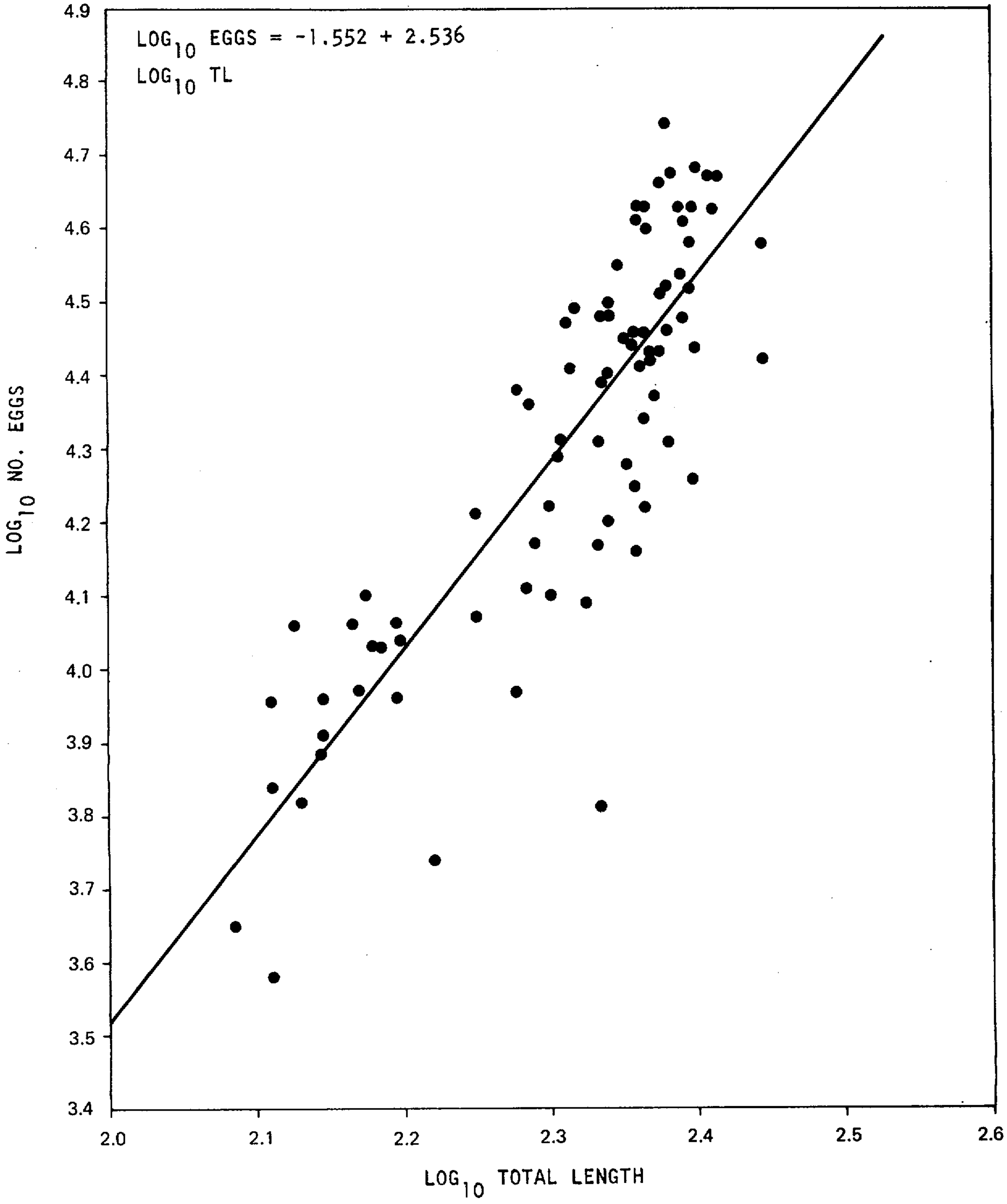


Figure VII-14. Regression of Number of Eggs on Total Length for Atlantic Tomcod from Hudson River, December 1973

SECTION VIII

CONTRIBUTION OF HUDSON RIVER STRIPED BASS TO ATLANTIC FISHERY

A. INTRODUCTION

Most works on striped bass tagging data conclude that the Chesapeake Bay system is the major source of striped bass taken in the mid-Atlantic fishery (Merriman, 1941; Vladykov and Wallace, 1952; Alperin, 1966; Schaefer, 1968; Porter and Saila, 1969). At hearings related to licensing of Consolidated Edison's Indian Point Unit 2 (AEC Docket 50-247), testimony was given in support of this view (Raney, 1972; Lawler, 1973). Additional information on the range of Hudson River striped bass has been provided by tagging studies conducted by TI (Section IX), but tagging data alone cannot be used to determine the relative contribution of the Hudson River to the Atlantic fishery. Assessment of the Hudson River contribution requires positive identification of individual fish from the Hudson River. Assumptions that are important in this approach are that striped bass return to their natal river to spawn and that the fish spawning in a given river are somehow different from those returning to spawn in other rivers.

Earlier studies (Raney and deSylva, 1953; Raney et al, 1954) demonstrated that, by using meristic characteristics, approximately 70% of the striped bass from the Hudson River could be separated from fish originating in the Chesapeake Bay system. Morgan et al (1973) demonstrated that the populations in several Chesapeake Bay tributaries differed biochemically.

In February 1974, a study was begun to determine the contribution of the Hudson River to the mid-Atlantic striped bass fishery. This program was divided into two phases:

- Feasibility study for determining the potential use of a combination of meristic, morphometric, and biochemical characteristics as an innate mark to identify individual striped bass from the major spawning populations

- Design and implementation of a study to determine the relative contribution of the Hudson River to the Atlantic fishery for striped bass (if techniques identified in the first phase prove feasible)

B. 1974 PROGRAM SUMMARY

1. Texas Instruments Program

During the spring 1974 spawning season, 150 to 250 adult striped bass were collected from the spawning areas of the Rappahannock, Potomac, Elk, Choptank, and Hudson Rivers. Twelve characteristics that could potentially characterize the spawning populations of those rivers were identified. Using a discriminant analysis of the basic meristic and morphometric data, it was possible to separate the Hudson River population from those within the Chesapeake Bay system. The probability of correctly identifying the origin of an individual fish from a mixed sample of Chesapeake and Hudson striped bass was 80-83%. The four best discriminant characteristics were lateral line scale count, snout/head-length ratio, internostril/head-length ratio, and first annulus-to-second annulus/focus-to-first annulus measure ratio. TI's 1974 program also included a preliminary analysis of biochemical variation among the striped bass populations of the eastern United States. This effort was directed toward locating and identifying variant proteins that might be useful in assigning individual fish to particular spawning populations. Isozymes representing several genetic loci were found to offer some potential in this regard.

The details of this program will appear in a separate report entitled *A Report on the Feasibility of Using Innate Tags to Identify Striped Bass (Morone saxatilis) from Various Spawning Rivers* (TI, 1975b).

2. University of Rhode Island Program

A surface profile analyzer was used to detect differences in height and spacing of circuli on scales from samples provided by Texas Instruments. Results indicated that intercirculus spacing does not appear to be useful in discriminating Hudson and Chesapeake fish. Circulus height varied significantly between Hudson and Chesapeake groups, although confounded by differences in sizes of fish in the samples from the two areas. The probability of correctly identifying an individual fish from a mixed sample of Chesapeake and Hudson striped bass was 65% to 70%. Details of this study were reported by Taub and Saila (1975).

SECTION IX

MOVEMENTS OF STRIPED BASS TAGGED IN HUDSON RIVER

A. INTRODUCTION

The migratory patterns of Hudson River striped bass (*Morone saxatilis*) have been a matter of considerable conjecture for some time. Several investigators (Neville, 1940; Raney and deSylva, 1953; Raney et al, 1954; Clark, 1968; Clark and Smith, 1969) have discussed the movements of fish tagged in the Hudson and have reported that the majority of these fish were recovered either within the Hudson or in western Long Island Sound. These previous studies were limited almost entirely to small fish (<500-620 mm). Some workers (Clark, 1968; Raney et al, 1954; Alperin, 1966; Schaefer, 1968) have attempted to describe the movements of Hudson River striped bass based on recaptures within the Hudson of fish tagged primarily outside the river.

Two major generalizations about migratory patterns have been made from this body of data. The first is that Hudson River striped bass are relatively nonmigratory, being restricted largely to the western end of Long Island Sound and the extreme southwestern end of Long Island (Raney and deSylva, 1953; Raney et al, 1954; Alperin, 1966). The second is that Hudson River striped bass may exist as three "contingents or groups...of fish that engage in a common pattern of seasonal migration between feeding areas, wintering areas, and spawning areas" (Clark, 1968) which can be identified as (1) the Hudson Estuary Contingent, (2) the Hudson-West Sound Contingent, and (3) the Hudson-Atlantic Contingent.

This paper, which contributes additional information on the movements of striped bass tagged further upstream in the Hudson River than had been the case in earlier studies, indicates that the generalizations made previously may have resulted from a lack of information on the migratory patterns of large individuals.

B. MATERIALS AND METHODS

From April 1972 through June 1973, 891 striped bass were tagged and released in the Hudson River between George Washington Bridge [river kilometer 19 (measured from the southern most tip of Manhattan)] and the Troy Lock (river kilometer 245). Several large fish were tagged before and during the spawning season (May-June) in the major reported spawning area between river kilometers 74 and 96 (Rathjen and Miller, 1957). Most of the larger fish were taken in gill nets. Smaller fish were generally taken in beach seines and box traps. Tag number, date, time, location, and capture gear were recorded for each tagged fish. Total length was recorded for most tagged fish and a scale sample taken from the majority of large fish for age determination by the annulus method (Mansueti, 1961).

Four types of tags were used during the study. The majority of all fish were tagged with either fingerling tags (Floy No. FTF-69) or nylon internal anchor tags (Floy No. FD-67C), depending on fish length: fingerling tags were applied primarily to fish ≤150 mm in 1972-73 and to fish ≤200 mm in 1974, while larger fish received internal anchor tags. All tags were applied through the back of the fish between the first and second dorsal fins. Return address, serial number, and indication of reward were printed on each tag and a reward of $1 paid for each tag returned.

C. RESULTS

The most frequently tagged length category was 101-200 mm total length (Table IX-1); however, 23% of all measured tagged fish were >500 mm. The seasonal distribution of tagging effort and fish abundance in the river produced approximately four times as many releases in spring and fall as in winter and summer. There were no releases in winter 1972, and releases from summer and fall 1974 were not included in this analysis.

Table IX-1

Summary by Length and Season of Striped Bass Tagged during 1973

Total Length (mm)	Number of Fish Tagged in Each Season				Totals*
	Winter (Jan-Feb-Mar)	Spring (Apr-May-Jun)	Summer (Jul-Aug-Sep)	Fall (Oct-Nov-Dec)	
≤100	-	95	1	28	124
101-200	-	145	70	165	380
201-300	-	36	2	34	72
301-400	-	12	2	12	26
401-500	18	6	-	24	48
501-600	34	1	-	35	70
601-700	34	7	-	8	49
701-800	6	19	-	4	29
801-900	2	18	-	-	20
901-1000	-	17	-	-	17
>1000	1	7	-	-	8
TOTALS	95	363	75	310	843

*Length data not available for 48 tagged individuals.

During the recapture period of April 1, 1972 through December 31, 1974, 23 tags (2.6% return rate) were returned from the tagging period of April 1, 1972 to June 1974 (Table IX-2). Return rates were higher for the larger size classes:

Length group (mm)	≤200	201-400	401-600	601-800	801-1000	>1000
Percent return	0.2	0	5.9	11.5	10.8	25.0

Table IX-2

Release and Recovery Data for Recaptured Striped Bass Tagged in Hudson River, 1972-74

Release Data				Recovery Data				
Date	Location (river km)	Total Length (mm)	Age (years)	Date	Location	Days at Large	Approximate Distance (km) from Tagging Site	Recapture Gear*
12/28/72	54	555	-	4/1/73	Long Island Sound Rye, N.Y.	94	104	SF
12/28/72	54	605	-	5/25/73	Long Island Sound Greenwich, Conn.	147	112	SF
1/3/73	54	567	-	4/23/74	Hudson River km 54	110	<1	CF
1/3/73	54	588	-	3/30/73	Long Island Sound Little Neck Bay, N.Y.	86	96	SF
3/9/73	53	645	VI	4/23/73	Hudson River km 54	45	1	CF
3/9/73	53	570	V	4/27/73	Hudson River km 62	49	9	PS
3/9/73	53	670	V	7/21/73	Long Island Sound Mamaroneck, N.Y.	134	96	SF
3/13/73	51	610	V	5/1/73	Hudson River km 62	49	11	PS
3/13/73	51	650	V	6/20/73	Long Island Sound Glen Cove, N.Y.	99	104	SF
3/13/73	51	650	V	7/27/73	Long Island Sound Stamford, Conn.	136	112	SF
3/14/73	54	552	-	3/14/73	Hudson River km 54	<1	<1	SF
3/15/73	53	870	VIII	7/5/73	Nantucket Sound Nantucket, Mass.	112	400	SF
3/26/73	54	575	-	6/7/73	Great South Bay R. Moses Bridge, N.Y.	73	136	SF
3/26/73	54	660	-	9/5/74	Long Island Sound Stamford, Conn.	528	112	SF
4/3/73	53	492	IV	4/13/73	Hudson River km 50	10	3	CF
4/19/73	96	903	VII	10/12/73	Long Island Sound Montauk Pt., N.Y.	174	296	SF
4/20/73	94	975	IX	6/19/73	Buzzards Bay New Bedford, Mass.	60	392	SF
4/20/73	91	1040	VIII	7/15/74	Boston Harbor Boston, Mass.	451	512	SF
4/26/73	94	745	VII	9/17/73	Lower N.Y. Bay Rockaway Pt., N.Y.	145	128	SF
11/12/73	62	645	VI	5/10/74	Stockport Creek Tributary to Hudson River - km 192	179	144	SF
4/23/74	67	980	-	5/2/74	Hudson River km 53	9	14	SF
4/24/74	22	120	I	8/1/74	Hudson River km 46	100	24	SF
5/16/74	67	1035	X	6/27/74	Cape Cod Bay Orleans, Mass.	42	416	SF

*SF = sport fishing
CF = commercial fishing
PS = project sampling

Fourteen (58%) of the returns were from outside the Hudson River and its tributaries (Figure IX-1). The most distant recapture occurred in Boston Harbor, Massachusetts; this was also the largest fish recaptured. For the fish recaptured outside the Hudson River (Figure IX-2), there was a strong relationship between length at time of tagging and distance traveled ($r = 0.943$, $P<0.001$). All of the five fish greater than 800 mm in total length which were recovered outside the Hudson had traveled more than 240 km.

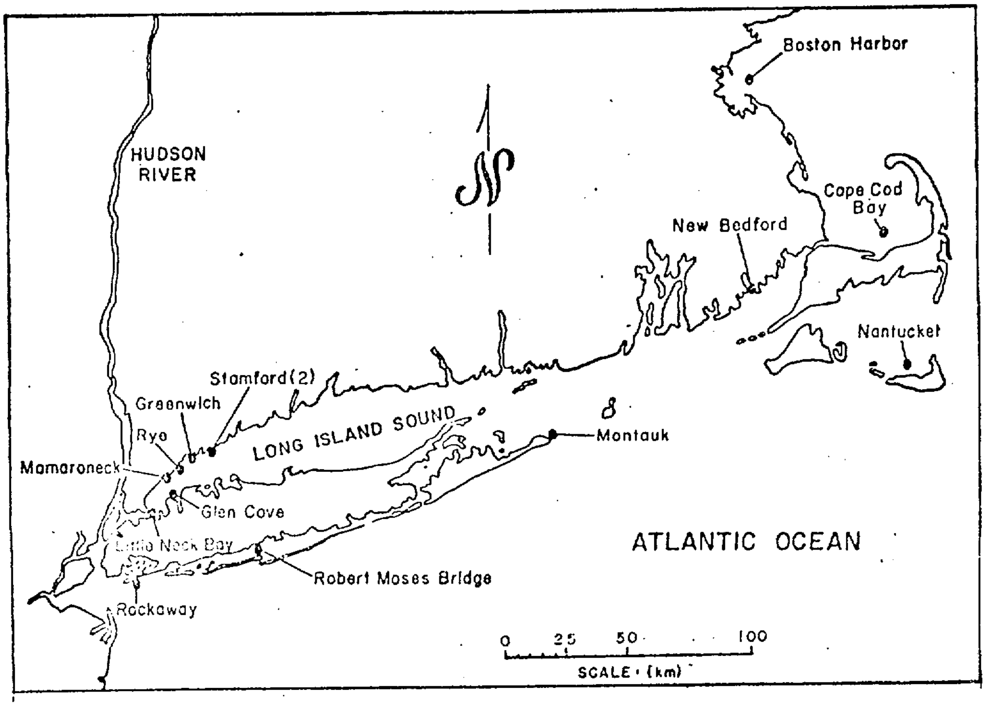


Figure IX-1. Recovery Locations Outside Hudson River and Tributaries of Striped Bass Tagged in Hudson, 1972-74

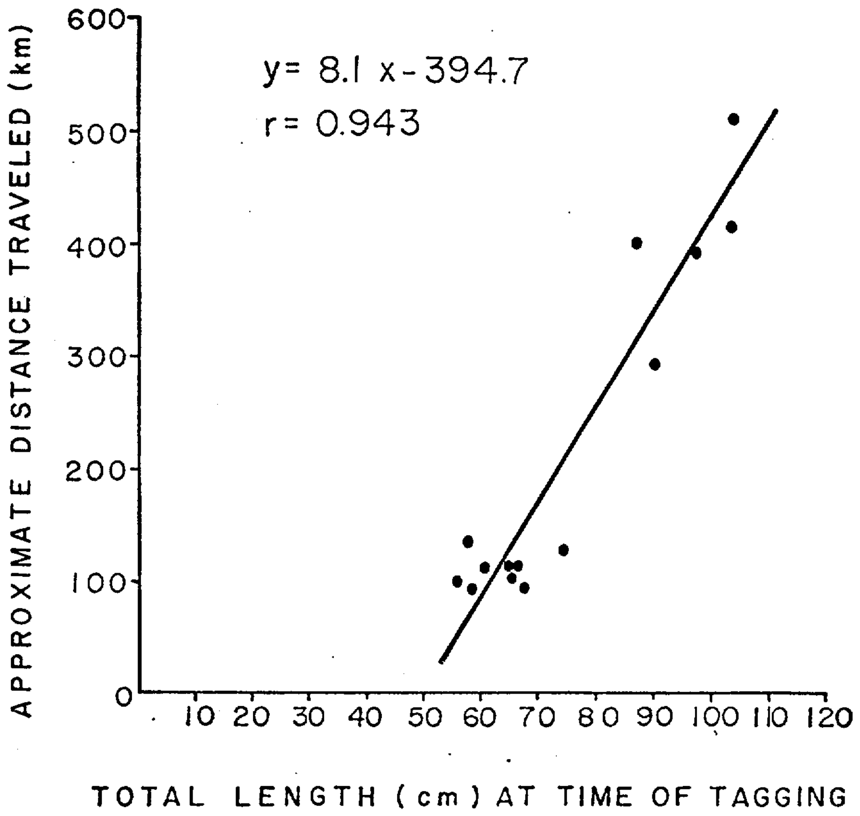


Figure IX-2. Relationship of Fish Length to Distance Traveled for Striped Bass Recaptured Outside Hudson River and Tributaries

D. DISCUSSION

Our data on striped bass migration from wintering-spawning areas in the Hudson River to areas outside the river indicate that some large striped bass tagged in the Hudson make extensive northward migrations into New England waters. Distances traveled are directly related to size, with larger fish migrating farther. The hypothesized contingents of Hudson River striped bass (Clark, 1968) may simply represent size groups rather than any other type of association. Clark's Hudson Estuary Contingent, for example, may represent smaller fish ≤age II, which are reported to be relatively nonmigratory in other estuarine systems (Vladykov and Wallace, 1938, 1952; Merriman, 1941; Raney, 1952, 1957; Mansueti, 1961; Massman and Pacheo, 1961; Nichols and Miller, 1967) and could be expected to remain within the Hudson estuary. Conversely, large striped bass often make extensive oceanic migrations (Chapoton and Sykes, 1961; Schaefer, 1968). Clark (1968) recognized the limitations inherent in the tagging data which he analyzed, and he stated clearly that his conclusions were based on the recovery of primarily small fish (<500 mm in fork length) within 1 year after tagging. Our conclusions are based on the recovery of predominantly large fish (91% >500 mm in total length, 51% >600 mm).

Size is not the only factor which could influence the spatial distribution of tag returns. As a general rule in tagging studies of this nature, the spatial distribution of fishing effort also can affect the spatial distribution of tag returns. Clusters of returns may represent clusters of fishermen rather than fish. Such clustering of returns is apparent in our data (Figures IX-1 and IX-2). Size selectivity of recovery gear and differential age-group mortality rates may further influence the interpretation of tagging data. Our data suggest that striped bass tag-return rates increase with size (age) of the fish, a pattern also noted by Grant et al (1969).

A recurring question of fundamental importance in a study such as this is the heritage of tagged fish; i.e., are these fish of Hudson River stock? It has never been established that striped bass return unerringly to their native river system, but there is some evidence that Hudson River fish are genetically distinct from those found in more southerly waters (Raney and deSylva, 1953). However, there is also evidence (Raney and deSylva, 1953; Raney et al, 1954) that striped bass of other stocks may overwinter in the

Hudson River, particularly in the area south of Stony Point (river kilometer 64). Hence, fish tagged during winter (January, February, and March) are of questionable origin; those tagged in spring (April, May, and June) on known spawning grounds (Rathjen and Miller, 1957) are most likely to be of Hudson River stock. Of the five spring-tagging returns recaptured outside the Hudson, four were tagged on important spawning grounds (river kilometer 91-96) and were recovered 128, 296, 392, and 512 kilometers from the point of release, indicating that some large striped bass of the Hudson River stock do indeed undertake extensive migrations into New England waters. Smaller individuals appear to restrict their movements outside the Hudson to western Long Island Sound and the southwestern shore of Long Island.

SECTION X

IMPACT OF UNIT-2 OPERATION ON HUDSON RIVER STRIPED BASS AND WHITE PERCH POPULATIONS

A. INTRODUCTION

The use of very large quantities of water for once-through cooling systems is potentially damaging to organisms exposed to passage through the cooling system or to impingement on the system's protective screens. The impact on a year class of a given fish is determined by several factors, the most important being the fraction of the population in the vicinity of the plant, the volume of water circulated, the density of organisms in the cooling water, and the mortality rates of organisms passing through the plant or impinged on its screens.

The impact of plant operations is equivalent to the exploitation due to entrainment and impingement or the probability of death from these causes of mortality. In the absence of compensatory changes in survival, impact can be defined as the proportional reduction in survival rate which is equivalent to the proportional reduction of the final population size.

Mortality due to entrainment or impingement is essentially analogous to the cropping of a fish population through fishing; therefore, evaluation of power-plant impact is, to some extent, parallel to evaluation of the effects of fishing mortality on a population. In the case of impingement, the same analytical procedures can be used. However, the cropping of young fish probably has a lesser effect on the population than does the cropping of adults because the population remaining after the cropping of some young may compensate to some extent before reproducing.

The impact estimates are determined from the numbers of fish entrained and impinged and are expressed as the proportion of the population cropped. Actual numbers of organisms cropped were determined by TI for this assessment from data analyzed. However, three parameters (withdrawal ratios, mortality, and recirculation) needed for estimating the number of ichthyoplankton cropped were evaluated theoretically and by reviewing data from other contractors.

The impact assessment presented in this report considered entrainment and impingement for striped bass and white perch. The numbers of striped bass and white perch impinged at post-1972 power plants were estimated by 3-month intervals from January 1973 through September 1974. Impingement impact was evaluated for the year from July 1973 through June 1974 and reflects impact on the 1973 year class of striped bass; estimation of impingement impact on the 1974 year class of these species will not be completed until impingement through June 1975 has been evaluated. The combined impact of entrainment and impingement is presented only for the 1973 year class of striped bass.

B. ENTRAINMENT IMPACT ASSESSMENT

1. Introduction

Entrainment impact assessment is an estimation of the percent of a year class of ichthyoplankton cropped by entrainment. It is a function of the temporal and spatial distribution and abundance of the ichthyoplankton and the temporal distribution and magnitude of the volumes of water withdrawn by the power plants and can be expressed as the proportion of ichthyoplankton cropped by entrainment from the time of egg recruitment until the juveniles are no longer vulnerable to entrainment. This estimate is calculated from population sizes and numbers cropped throughout the entrainment season.

In assessing entrainment impact, the population size of the year class of ichthyoplankton entrained was determined from the empirically estimated standing crop adjusted for the proportion of eggs of that year class which were spawned later in the spring. The proportion of eggs producing the year class that were still in the ovaries of the parent stock during estimation intervals in the early part of the entrainment season (May-June) were determined from the proportion of the year class of eggs present in the river after that estimation interval.

The numbers of ichthyoplankton cropped by entrainment were determined from both empirical estimates and approximations. Using 13-mi regions centered at each plant in order to allow for movement of the ichthyoplankton by tidal action, densities in the vicinity of each plant were estimated biweekly in 1973 and weekly in 1974. The volumes of water withdrawn by each plant were obtained from plant operation logs. Because the ratios of ichthyoplankton density in the withdrawn water to the density in the water in the plant river regions have not been empirically defined, the parameter was determined on the basis of theoretical considerations.

The survival of the entrained ichthyoplankton through the plant was estimated from data collected by NYU at Indian Point in 1973 (NYU, 1974; NRC, 1975).

The proportion of ichthyoplankton recirculated after initial entrainment was determined from theoretical considerations and on the basis of indirect empirical evidence for the existence of some recirculation of heated water in the Alden Laboratories physical model of Indian Point (Larson, 1969).

The proportion of striped bass ichthyoplankton cropped by entrainment in 1973 was estimated for biweekly intervals. The proportion of striped bass and white perch ichthyoplankton cropped by entrainment in 1974 was estimated for weekly intervals using the same methods. Only impact values for Indian Point Unit 2, Bowline, and the two combined (post-1972 plants) are reported here; values for other units and plants and methods of calculation are presented in the *First Annual Report for the Multiplant Impact Study of the Hudson River Estuary* (TI, 1975c).

2. Methods

a. Ichthyoplankton Standing Crop and Population Estimation

To estimate the effective population size of the year class of ichthyoplankton during each sampling interval, the standing crop was estimated and then adjusted for the recruitment to the year class that occurred subsequently. Before all the eggs producing a year class have been spawned (through June), the effective size of that year class is greater than the standing crop; thus, the entrained proportion of the entire river standing crop is greater than the corresponding effect on the eventual population. For example, if only 10% of the eggs were spawned up to and including an interval during which 10% of the ichthyoplankton present was entrained, the effective impact on the population would be only 1% and not 10%.

b. Procedures for Estimating Ichthyoplankton Cropped by Entrainment

1) Density Estimates

Ichthyoplankton densities were estimated by life stage for each time interval for 13-mi regions centered at each plant. The densities in these 13-mi plant regions were estimated from a weighted average of the densities in the portions of the geographic regions which are the basis for sampling stratification in the ichthyoplankton sampling program (TI, 1975c).

2) Volume of Water Withdrawn

The actual volume of water withdrawn by each plant was obtained from the respective plant operational logs. These volumes reflect the water withdrawn by the plants during their actual operation and are not the volumes that would have been withdrawn if the plants had been operating at maximum output.

3) Estimation of Number of Ichthyoplankton Entrained

The number of ichthyoplankton entrained during an entrainment interval were estimated for each plant. Each of the plant-region mean densities of ichthyoplankton was multiplied by the volume of water pumped during the interval of estimation (2 weeks in 1973 and 1 week in 1974) to estimate the number entrained.

Because ichthyoplankton are not uniformly distributed laterally or vertically in the river (TI, 1974), the density of ichthyoplankton in entrained water is probably not the same as the average density in river water. The ratio of the ichthyoplankton density in the entrained water to ichthyoplankton density in the plant region was represented by W; values of 0.5 and 1.0 were used for W_p in estimating entrainment to test the sensitivity of the estimates to the parameter, with 0.5 being the value we considered to be the more reasonable estimate.

4) Effects of Recirculation and In-Plant Survival

More realistic estimates may be obtained by considering the effects of various recirculation (reentrainment of previously entrained organisms) factors and in-plant survival regimes. The degree to which entrainment cropping is reduced by recirculation of ichthyoplankton through the plants and by survival of entrained organisms can only be approximated with present information.

Evidence for recirculation of water (Larson, 1969) indicates that the amount is low, although some does occur at Indian Point during flood tides. We have chosen a value of 10% recirculation as our working estimate but have also used 0% recirculation as an alternate value.

Data for survival through the plant from NYU's 1973 study of entrainment survival at Indian Point (NYU, 1974) indicated in-plant survival of approximately 20% for eggs, 40% for yolk-sac and post yolk-sac larvae, and 30% for early juveniles (NRC, 1975). Studies of entrainment of various species at other plants (Marcy, 1975) indicated in-plant survival to be very low, so a second value of no in-plant survival was used as an alternative to examine the sensitivity of this parameter. This is undoubtedly too low, but the maximum entrainment estimates without these adjustments provide an estimate that can be modified using the functional relationship of recirculation and in-plant mortality to derive an estimate of proportion cropped at other intermediate values of in-plant survival and recirculation.

c. Entrainment Impact Estimation

Because of natural mortality, organisms entrained at an early life stage do not contribute to the proportional reduction of the population to as great an extent as do the organisms entrained at a later life stage. Thus, the proportion cropped cannot be estimated by summing the numbers cropped across time.

Estimation of the proportion entrained within each time interval (2 weeks in 1973 and 1 week in 1974) permitted an estimate of proportion entrained over the season, allowing for unequal probabilities of natural survival of ichthyoplankton of different ages. Combination of proportions rather than numbers across time accounted for natural mortality without requiring an estimate of natural mortality during each life stage. Proportions were combined by finding the products of the proportion of organisms surviving ($1-q$, where q is mortality) during each time interval; i.e., $(1-q_a)(1-q_b)(1-q_c)$, where a, b, and c are separate time intervals. The changes in the estimates of density and population size taken biweekly (1973) or weekly (1974) included natural mortality. The proportion cropped (all entrainable life stages combined) during each time interval was the ratio of the number cropped to the adjusted population during each time interval. Since the plants are competing sources of mortality during any given time interval, all estimates of proportion cropped by any plant were made against the background of all other sources of existing mortality including other operating plants. Within each time interval, the effects of the various plants were therefore additive. The proportion cropped by a plant during a time interval was the sum of proportions cropped by each of the units of the plant during the time interval.

3. Results

a. Striped Bass

1) Entrainment Impact in 1973

Estimates for the proportion of the striped bass ichthyoplankton population cropped by entrainment varied among plants as well as among the biweekly intervals (Table X-1). Based on our estimates of recirculation, mortality, and withdrawal, 1.04% of the striped bass ichthyoplankton were cropped by the entrainment at Indian Point Unit 2 in 1973. The post-1972 power plants (Bowline Unit 1 and Indian Point Unit 2) cropped 2.2% of the population.

In 1973, the biweekly time periods having the highest entrainment cropping were May 13-26 and June 10-23. Entrainment after mid-July was probably negligible, as indicated by the length-frequency distribution of entrained ichthyoplankton after this time at Indian Point (NYU, 1974). There may be an overestimate of impact during the interval between June 24 and July 21, because some of the juveniles estimated to be entrained might actually have been impinged and thus included in the impingement impact analysis.

In addition to the estimates just discussed, other estimates were made using alternative values of withdrawal, recirculation, and in-plant survival to determine the sensitivity of the estimates to these parameters

Table X-1

Estimates* of Proportion of Striped Bass Ichthyoplankton Entrained during Each 2-Week Sampling Interval in 1973 Using Best Working Estimates of Parameters (withdrawal = 0.5, recirculation = 0.1, mortality of eggs, larvae and juveniles = 0.8, 0.6, and 0.7 respectively)

Date	Post-1972 Plants (all units)	Bowline (Unit 1)	Indian Point (Unit 2)
4/29-5/12	0.0002	< 0.0001	0.0001
5/13-26	0.0072	0.0053	0.0019
5/27-6/9	0.0020	0.0008	0.0012
6/10-23	0.0065	0.0029	0.0036
6/24-7/7	0.0034	0.0013	0.0020
7/8-21	0.0034	0.0011	0.0022
Total Proportion Entrained	0.0224	0.0115	0.0104

*Estimates based on alternate values of in-plant mortality, recirculation, and withdrawal are given as a test of the sensitivity of these parameters.

(Table X-2). Of these three parameters, the effect of using the alternative estimate rather than the more realistic estimate is greatest in the case of withdrawal because of the relatively larger difference between the estimate and the alternative value. Setting withdrawal to 1.0 almost doubles the estimate; for example, the 1973 entrainment impact estimate for the post-1972 plants goes from 2.2% to 4.4%. The value assigned to in-plant survival has a lesser effect but, in the alternative case of no in-plant survival, it would increase the estimate of the proportion cropped by entrainment by slightly < 50%. The alternative value of no recirculation would increase the estimate of the proportion cropped by < 10%, which means that the 1973 impact of the post-1972 plants goes from 2.2% to 2.4%.

Table X-2

Estimates* of Entrainment Impact on Striped Bass during 1973 Using Various Combinations of Parameters of Withdrawal, Recirculation, and Mortality Rates

IN-PLANT MORTALITY (q_p)	EGGS = 0.8 LARVAE = 0.6 JUVENILES = 0.7				ALL LIFE STAGES = 1.0 (q_p = 1.0)			
RECIRCULATION	0.1		0.0		0.1		0.0	
PLANT \ W	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0
Bowline (Unit 1)	0.0115	0.0230	0.0124	0.0247	0.0165	0.0327	0.0183	0.0363
Indian Point (Unit 2)	0.0109	0.0218	0.0117	0.0233	0.0164	0.0326	0.0182	0.0362
Post-1972 Plants (All Units)	0.0224	0.0443	0.0240	0.0476	0.0326	0.0645	0.0362	0.0714

*Estimates based on alternate values of in-plant mortality, recirculation, and withdrawal are given as a test of the sensitivity of these parameters.

2) Entrainment Impact in 1974

The proportion of striped bass cropped by entrainment during each week of the 1974 season was fairly constant from May 20 through July 14 (Table X-3). The proportion of striped bass ichthyoplankton population cropped by entrainment at Bowline Unit 1 was similar to that cropped in 1973 (Tables X-1 through X-4). The proportion cropped by entrainment at Indian Point Unit 2, however, increased fivefold from 1973 to 1974; the proportion entrained and cropped at Indian Point Unit 2 was 1.1% in 1973 and 5.7% in 1974, but only about half of this increase is attributable to the increase in flow through the plant. The remaining increase is due to differences in distribution of the striped bass ichthyoplankton population in 1974 relative to distribution in 1973 (TI, 1975c). In 1974, the post-1972 plant entrainment cropping was estimated at 8.1% of the striped bass population.

Table X-3

Estimates* of Proportion of Striped Bass Ichthyoplankton Entrained during Each Weekly Interval in 1974 Using Best Working Estimates of Parameters (withdrawal = 0.5, recirculation = 0.1, mortality of eggs, larvae and juveniles = 0.8, 0.6, and 0.7 respectively)

Date	Post-1972 Plants (all units)	Bowline (Unit 1)	Bowline (all units)	Indian Point (Unit 2)
4/29-5/5	<0.0001	0.0	0.0	<0.0001
5/6-12	0.0005	0.0	<0.0001	0.0005
5/13-19	0.0037	0.0	0.0012	0.0026
5/20-26	0.0083	0.0	0.0	0.0083
5/27-6/2	0.0042	0.0	0.0	0.0042
6/3-9	0.0083	0.0005	0.0028	0.0055
6/10-16	0.0115	0.0010	0.0031	0.0084
6/17-23	0.0102	0.0016	0.0033	0.0069
6/24-30	0.0121	0.0020	0.0045	0.0075
7/1-7	0.0108	0.0020	0.0042	0.0065
7/8-14	0.0143	0.0032	0.0066	0.0076
Total Proportion Entrained	0.0808	0.0103	0.0255	0.0566

*Estimates based on alternate values of in-plant mortality, recirculation, and withdrawal are given as a test of the sensitivity of these parameters.

Table X-4

Estimates* of Entrainment Impact on Striped Bass during 1974 Using Various Combinations of Parameters of Withdrawal, Recirculation, and Mortality Rates

IN-PLANT MORTALITY (q_p)	EGGS = 0.8 LARVAE = 0.6 JUVENILES = 0.7				ALL LIFE STAGES = 1.0 (q_p = 1.0)			
RECIRCULATION	0.1		0.0		0.1		0.0	
PLANT \ W	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0
Bowline (Unit 1)	0.0103	0.0204	0.0109	0.0218	0.0161	0.0321	0.0179	0.0356
Bowline (All Units)	0.0255	0.0504	0.0272	0.0538	0.0396	0.0779	0.0439	0.0863
Indian Point (Unit 2)	0.0566	0.1103	0.0605	0.1177	0.0853	0.1641	0.0944	0.1803
Post-1972 Plants (All Units)	0.0808	0.1558	0.0862	0.1658	0.1219	0.2307	0.1346	0.2532

*Estimates based on alternate values of in-plant mortality, recirculation, and withdrawal are given as a test of the sensitivity of these parameters.

b. White Perch Entrainment Impact in 1974

In contrast to the entrainment cropping estimates for striped bass, the proportion of the white perch ichthyoplankton population cropped by entrainment increased from May 6 through June 30 (Tables X-5 and X-7), peaking during the week of June 24-30 and then decreasing for the remainder of the entrainment season (May through mid-July). The impact was < 5% at the post-1972 plants (Bowline and Indian Point Unit 2).

Table X-5

Estimates* of Proportion of White Perch Ichthyoplankton Entrained (Eggs Not Entrainable) during Each Weekly Interval in 1974 Using Best Working Estimates of Parameters (withdrawal = 0.5, recirculation = 0.1, mortality of eggs, larvae and juveniles = 0.8, 0.6, and 0.7 respectively)

Date	Post-1972 Plants (all units)	Bowline (Unit 1)	Bowline (all units)	Indian Point (Unit 2)
4/29-5/5	0.0	0.0	0.0	0.0
5/6-12	<0.0001	0.0	<0.0001	<0.0001
5/13-19	<0.0001	0.0	< 0.0001	<0.0001
5/20-26	0.0002	0.0	0.0	0.0002
5/27-6/2	0.0003	0.0	0.0	0.0003
6/3-9	0.0005	<0.0001	0.0002	0.0003
6/10-16	0.0030	0.0003	0.0010	0.0020
6/17-23	0.0096	0.0015	0.0030	0.0066
6/24-30	0.0162	0.0026	0.0057	0.0105
7/1-7	0.0104	0.0017	0.0037	0.0067
7/8-14	0.0048	0.0010	0.0020	0.0028
Total Proportion Entrained	0.0443	0.0071	0.0155	0.0292

*Estimates based on alternate values of in-plant mortality, recirculation, and withdrawal are given as a test of the sensitivity of these parameters.

The values assigned to recirculation, in-plant survival, and withdrawal (W) were the same as those used in the striped bass estimation. Because of this, the relative effect of these parameters on the entrainment cropping estimate was similar to the effects in the striped bass entrainment cropping estimate (Tables X-6 and X-8)

Table X-6

Estimates* of Entrainment Impact on White Perch during 1974 (Eggs Not Entrainable) Using Various Combinations of Parameters of Withdrawal, Recirculation, and Mortality Rates

IN-PLANT MORTALITY (q_p)	EGGS = 0.8 LARVAE = 0.6 JUVENILES = 0.7				ALL LIFE STAGES = 1.0 (q_p = 1.0)			
RECIRCULATION	0.1		0.0		0.1		0.0	
PLANT \ W	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0
Bowline (Unit 1)	0.0071	0.0141	0.0076	0.0151	0.0113	0.0225	0.0126	0.0250
Bowline (All Units)	0.0155	0.0308	0.0165	0.0328	0.0246	0.0488	0.0273	0.0541
Indian Point (Unit 2)	0.0292	0.0577	0.0311	0.0614	0.0463	0.0910	0.0513	0.1007
Post-1972 Plants (All Units)	0.0443	0.0871	0.0472	0.0927	0.0701	0.1364	0.0776	0.1506

*Estimates based on alternate values of in-plant mortality, recirculation, and withdrawal are given as a test of the sensitivity of these parameters.

C. IMPINGEMENT IMPACT

1. Introduction

Impingement impact can be viewed as the annual reduction of the fish population due to impingement, assuming the absence of other sources of mortality and not including the ameliorating effects of compensation. The impingement impact was estimated by a method derived from those described by Ricker (1958, page 24) for analyzing mortality in a fishery. Impingement is a function of the temporal and spatial distribution and abundance of the fish, the volumes of water withdrawn, the intake velocities at the plants, and swim speed and diel movements of the fish. Impingement impact is expressed as

Table X-7

Estimates* of Proportion of White Perch Ichthyoplankton Entrained (Eggs Entrainable) during Each Weekly Interval in 1974 Using Best Working Estimates of Parameters (withdrawal = 0.5, recirculation = 0.1, mortality of eggs, larvae and juveniles = 0.8, 0.6, and 0.7 respectively)

Date	Post-1972 Plants (all units)	Bowline (Unit 1)	Bowline (all units)	Indian Point (Unit 2)
4/29-5/5	0.0	0.0	0.0	0.0
5/6-12	<0.0001	0.0	<0.0001	<0.0001
5/13-19	<0.0001	0.0	<0.0001	<0.0001
5/20-26	0.0003	0.0	0.0	<0.0003
5/27-6/2	0.0008	0.0	0.0	0.0008
6/3-9	0.0069	0.0005	0.0029	0.0040
6/10-16	0.0067	0.0009	0.0028	0.0039
6/17-23	0.0097	0.0015	0.0031	0.0066
6/24-30	0.0166	0.0026	0.0058	0.0108
7/1-7	0.0105	0.0017	0.0037	0.0068
7/8-14	0.0048	0.0010	0.0020	0.0028
Total Proportion Entrained	0.0549	0.0082	0.0202	0.0354

*Estimates based on alternate values of in-plant mortality, recirculation, and withdrawal are given as a test of the sensitivity of these parameters.

Table X-8

Estimates* of Entrainment Impact on White Perch during 1974 (Eggs Entrainable) Using Various Combinations of Parameters of Withdrawal, Recirculation, and Mortality Rates

IN-PLANT MORTALITY (q_p)	EGGS = 0.8 LARVAE = 0.6 JUVENILES = 0.7				ALL LIFE STAGES = 1.0 (q_p = 1.0)			
RECIRCULATION	0.1		0.0		0.1		0.0	
PLANT \ W	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0
Bowline (Unit 1)	0.0082	0.0164	0.0088	0.0175	0.0127	0.0252	0.0141	0.0280
Bowline (All Units)	0.0202	0.0400	0.0216	0.0428	0.0303	0.0599	0.0337	0.0664
Indian Point (Unit 2)	0.0354	0.0697	0.0378	0.0745	0.0538	0.1052	0.0596	0.1163
1972 Plants (All Units)	0.0549	0.1074	0.0587	0.1147	0.0828	0.1599	0.0916	0.1764

*Estimates based on alternate values of in-plant mortality, recirculation, and withdrawal are given as a test of the sensitivity of these parameters.

the probability of a fish being impinged during a year and is analogous to the entrainment impact estimated earlier. The interval between July 1973 and June 1974 was chosen in order to include a year of impact on the 1973 year class.

The estimate of impingement impact was calculated from the estimated population sizes in the fall of 1973 and the number of fish impinged between July 1973 and June 1974. The fall population sizes of white perch and striped bass were estimated from a mark/recapture study. Fish impinged at Indian Point were counted daily; thus, no estimation was needed. The numbers of fish impinged at other power plants were estimated from counts on sample days and the volumes of water withdrawn, using a ratio estimation method (TI, 1975c).

2. Methods

a. Population Estimation

Petersen estimates of the size of the fall 1973 populations of young-of-the-year, yearling, and older white perch and young-of-the-year striped bass were derived from a mark/recapture program which has been in continuous operation since April 1972 (TI, 1974b, 1975c). An interval of about 6 months was allowed between the time of release of the majority of marked fish and their recovery; the long separation between release and recovery periods helped to insure random mixing of marked and unmarked individuals in the population. The population was stratified by size to avoid differential recapture rates due to gear selectivity, marking methods, or fish distribution. Young-of-the-year and older fishes were estimated separately.

Petersen estimates of the fall 1973 populations of young-of-the-year, yearling, and older white perch and young-of-the-year striped bass were made using the following spring as a recovery period. The estimates were compared to earlier estimates of the same fall 1973 populations (TI, 1974b) based on recapture of fish both marked and recovered in fall 1973; these earlier estimates had been made using the Petersen and Schumacher-Eschmeyer methods.

b. Impact Estimation

Impingement impact is expressed as the annual probability of a fish being killed by impingement or the annual mortality rate from impingement. In this analysis, the natural mortality rate is assumed to be constant; i. e., no changes in natural mortality rate occur as the mortality rate from impingement changes.

The expectation of death due to impingement at each power plant was calculated for striped bass and white perch from the impingement estimates and the population estimates. Since no estimates of the annual probability of dying from all causes are presently available for any species in the Hudson River, the annual probability of dying from nonimpingement causes was calculated at various levels of mortality from all causes over the range of 0.10-0.90. The resultant values of nonimpingement mortality and their corresponding values of combined mortality were used to calculate the percent impact.

3. Results

a. Impingement Estimates

Seasonal trends in the impingement of striped bass and white perch were noted, with impingement generally heavier at Indian Point in the fall and becoming heavier at Bowline in winter and early spring. This pattern may reflect a downriver movement of juvenile striped bass and white perch with the approach of winter. An upriver movement of both species probably occurred in the spring after they overwintered in Haverstraw Bay and the

Indian Point regions. Impingement increased at Indian Point from January-March to April-June in both 1973 and 1974. From July-September through October-December 1974, there was an apparent increase of impingement of both striped bass and white perch at both post-1972 plants.

b. Population Estimates

Petersen estimates of young-of-the-year and yearling and older white perch calculated from spring 1974 recaptures of fall marks were four to five times larger than Petersen and Schumacher-Eschmeyer estimates of the same populations in fall 1973 (Table X-9). Although the fall 1973 estimates were not made for the entire estuary, the majority of young-of-the-year white perch occurred between RM 12 and 62 after mid-August; therefore, the fall 1973 and spring 1974 estimates of the fall population are roughly comparable. The differences in estimates can be examined in terms of the assumptions that must be met for valid estimates by mark/recapture techniques (Ricker, 1958).

The final assumption of random mixing of marked and unmarked fish in the population appeared to be the most probable source for the difference between fall and spring estimates of the fall 1973 populations. The 6-month interval between the release and recovery of the majority of the marked fish in the spring recapture period allowed sufficient time for mixing within the population and between river regions. Recoveries of fin-clipped and tagged white perch throughout this time indicated considerable movement of all age groups. Insufficient mixing probably occurred during the fall estimation period, causing an underestimate of the population size.

The spring estimate of the young-of-the-year striped bass population was not greater than the fall estimate (Table X-10) as was the case with the white perch estimates. There are at least two possible explanations for this: either the marked and unmarked striped bass were more randomly

Table X-9

Population Estimates of White Perch in Hudson River Estuary, Fall 1973

Population	River Miles[*]	Estimate	95% Confidence Interval	Type Estimate	Marking Period	Recapture Period
Young-of-the-year	12-153 (19-245)	7,824,000[†]	5,652,000 - 12,704,000	Petersen	Mid-Aug - Nov 1973	Jan - June 1974
Young-of-the-year	12-62 (19-99)	1,992,000[‡]	1,579,000 - 2,773,000	Petersen	Sep - Oct 1973	Nov - Dec 1973
Young-of-the-year	12-62 (19-99)	1,549,000[‡]	906,000 - 5,345,000	Schumacher -Eschmeyer	Mid-Aug - Oct 1973	Mid-Aug - Oct 1973
Young-of-the-year	12-62 (19-99)	2,340,000[†]	1,731,000 - 3,609,000	Petersen	Mid-Aug - Sep 1973	Mid-Oct - Dec 1973
Yearling and older	12-153 (19-245)	7,225,000[†]	4,615,000 - 16,631,000	Petersen	Mid-Aug - Nov 1973	Jan -June 1974
Yearling and older	12-62 (19-99)	1,467,000[‡]	995,000 - 2,801,000	Petersen	Mid-Aug - Oct 1973	Nov - Dec 1973
Yearling and older	12-62 (19-99)	1,367,000[‡]	764,000 - 6,501,000	Schumacher -Eschmeyer	Sep - Nov 1973	Sep - Nov 1973

[*] Numbers in parentheses indicate kilometers.

[†] Excludes impingement catch and recaptures; excludes right and left pelvic fin clips and double pelvic fin clips.

[‡] From 2nd Annual Report, Texas Instruments Incorporated, 1974.

Table X-10

Population Estimates of Striped Bass Young-of-the-Year in Hudson River Estuary, Fall 1973

Population	River Miles[*]	Estimate	95% Confidence Internal	Type Estimate	Marking Period	Recapture Period
Young-of-the year	12-153 (19-245)	1,387,000	841,000 - 3,964,000	Petersen	Mid-Aug-Nov 1973	Jan-May 1974
Young-of-the year	12-62 (19-99)	1,680,000[‡]	1,290,000 - 2,405,000	Petersen	Mid-Aug-Nov 1973	Dec 1973
Young-of-the year	12-62 (19-99)	1,641,000[†]	1,110,000 - 3,144,000	Schumacher-Eschmeyer	Mid-Aug-Oct 1973	Mid-Aug-Oct 1973

[*] Numbers in parentheses indicate kilometers.

[†] From 2nd Annual Report, Texas Instruments, 1974.

[‡] Used for calculating impingement direct impact.

mixed during the fall than were the white perch or marked and unmarked bass were lost from the populations at unequal rates. A disproportionate emigration of marked and unmarked individuals from the study area may have occurred if most of the marks were applied to fish in the most upstream portion of the population, i. e., the portion least likely to emigrate from the study area by the spring recovery period. Because of these possible violations of assumptions in the spring estimate, the fall population estimate of 1, 680, 000 was used for computing impingement impact even though it may be an underestimate.

c. Impingement Impact

The impact of impingement on striped bass and white perch is presented graphically in Figures X-1 and X-2 for Indian Point Unit 2 and Bowline from July 1973 through June 1974. The impact of all plants combined and of plants that began operation after 1972 (Bowline and Indian Point Unit 2) appears in Figures X-3 for the same 12-month period. Estimates of percent impact are presented for a range of hypothetical values of nonimpingement mortality. The impact on striped bass was considered to be on the most recent year class, or those fish spawned during 1973. Juvenile and older white perch, because of their year-long residence in the estuary, were combined for estimates of impact.

Since actual values of nonimpingement mortality rates in the Hudson River are presently unknown, an alternative was to choose a range of realistic values. Plants that began operation after 1973 (Bowline Units 1 and 2 and Indian Point Unit 2) were responsible for a major portion of the impact on white perch (Figure X-3). Impact values for these plants, assuming a 40%-80% range of nonimpingement mortality, were as follows:

Percent Mortality	Percent Impact		
	40		80
Striped bass	1.8	-	2.8
White perch	3.2	-	5.0

The estimates of impact presented in this section assumed that all of the impinged fish were alive at the time of impingement and were subsequently killed by impingement. If impingement of dead fish or survival of impinged fish occurred, our method of impact estimation would tend to overestimate actual impingement impact.

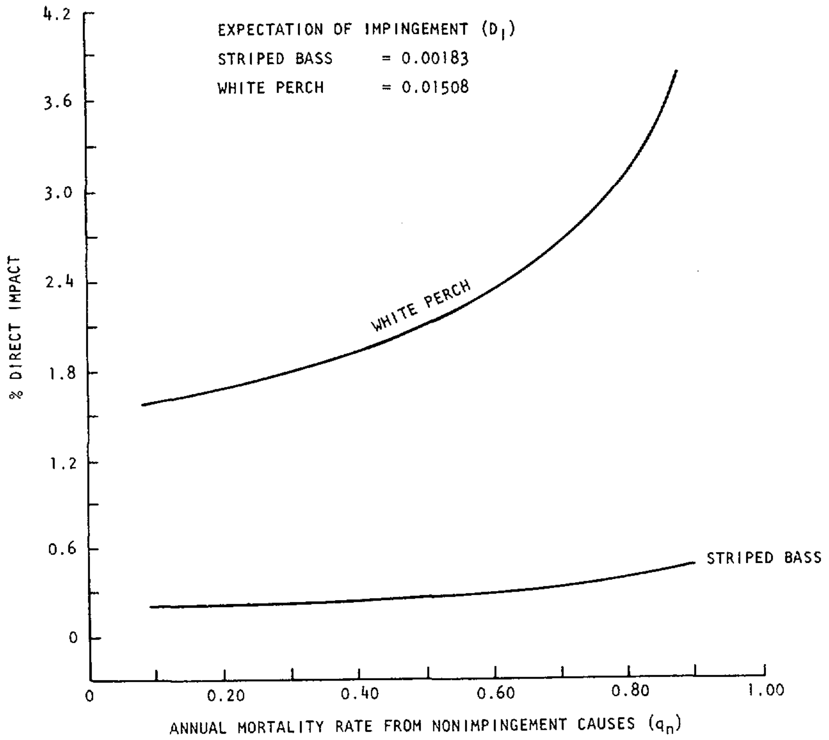


Figure X-1. Relationship between Annual Mortality Rates from Nonimpingement Causes and Percent Impact on Striped Bass and White Perch Based on Estimated Expectations of Death from Impingement at Indian Point Generating Station, Unit 2, July 1973-June 1974

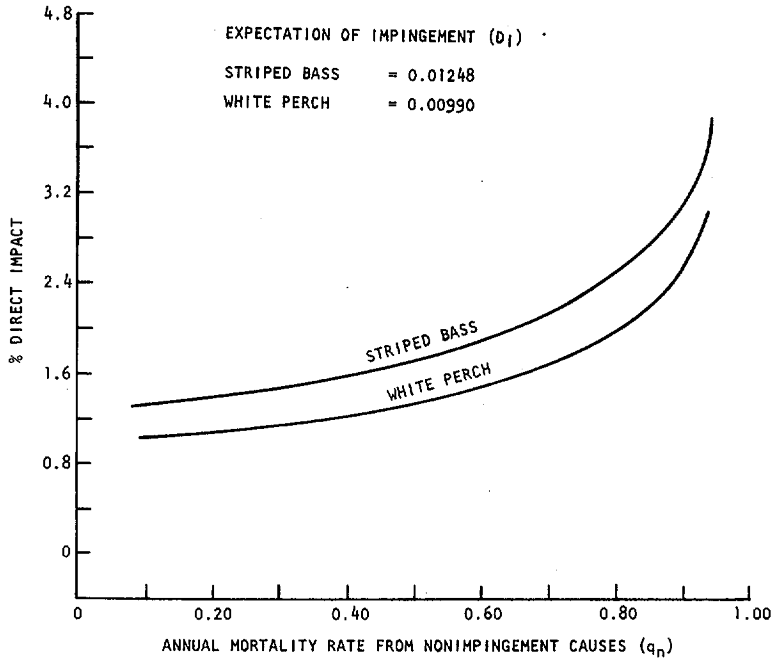


Figure X-2. Relationship between Annual Mortality Rates from Nonimpingement Causes and Percent Impact on Striped Bass and White Perch Based on Estimated Expectations of Death from Impingement at Bowline Generating Station, July 1973-June 1974

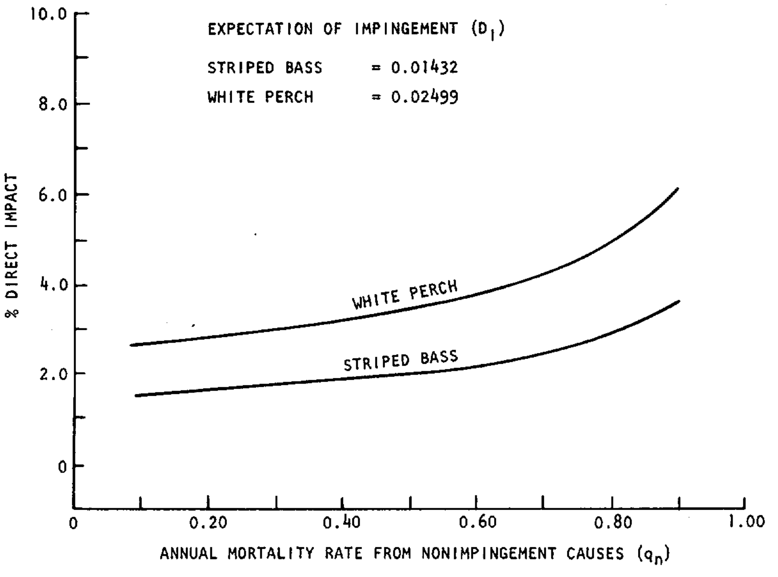


Figure X-3. Relationship between Annual Mortality Rates from Nonimpingement Causes and Percent Impact on Striped Bass and White Perch Based on Expectations of Impingement at Power Plants that Began Operation after 1973 (Bowline and Indian Point Unit 2) July 1973-June 1974

Two additional sources of error in the estimation of impingement impact possibly arise when computing the annual expectation of death from impingement. One must assume that impingement mortality and nonimpingement mortality are distributed proportionately within the year (Ricker, 1958); this assumption may not have been met, since nonimpingement mortality was probably greatest for young-of-the-year during their initial, summer months — and impingement mortality in many cases was greatest later in the year. Also, fall population levels rather than the initial (summer) population size were used to compute expectation of death from impingement; since the fall population had already experienced considerable mortality, the resulting values would be overestimates of expectation of death of impingement. The effect of underestimating the impingeable-size population can be offset somewhat by using justifiably lower mortality rates for these older fish.

D. DIRECT IMPACT ASSESSMENT

The direct impact of the power plants includes both entrainment impact and impingement impact. The precision of the combined impact assessment depends on the precision of these estimates and is subject to the qualifications associated with them. Both entrainment impact and impingement impact are expressed as probabilities so they can be readily combined. Since a fish cropped by entrainment is not available to be cropped by impingement, two sources of impact must be considered as competing sources of mortality; the total direct impact, therefore, is less than the sum of the entrainment and impingement direct impacts.

The only direct impact estimates presented here are for the 1973 year class of striped bass, since no estimates of entrainment in 1973 were available for other species (Table X-11). The combined direct impacts on the 1974 year classes of fish cannot be estimated until impingement data through June 1975 are available.

Table X-11

Estimates of Percent Combined Impact ($q_{e_c} \times 100$) of Entrainment and Impingement on 1973 Year Class of Striped Bass through July 1974 for Four Assumed Levels of Juvenile Mortality and Entrainment Parameters Considered Most Reasonable at This Time

	Juvenile Mortality			
Plant	$q_t = 0.40$	$q_t = 0.60$	$q_t = 0.80$	$q_t = 0.90$
Bowline (all units)	2.71	3.02	3.60	4.25
Indian Point (Unit 2)	1.32	1.37	1.46	1.55
Post-1972 Plants (all units)	4.01	4.35	5.02	5.76

The combined direct impact on the 1973 year class of striped bass by the post-1972 power plants through July 1974 was estimated to be 5.0%; for Indian Point Unit 2, 2.5%. These estimates were made under the assumption of an 80% juvenile probability of dying and our working estimates of the entrainment parameters. The estimates for Indian Point Unit 2 and Bowline and other juvenile probabilities of dying (Table X-11) are based on the combined probabilities of entrainment and impingement at Indian Point Unit 2 and Bowline.

SECTION XI

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APPENDIX A

EQUATIONS FOR CORRECTING DISSOLVED-OXYGEN READINGS AFFECTED BY INCREASES IN SALINITY

APPENDIX A

EQUATIONS FOR CORRECTING DISSOLVED-OXYGEN READINGS AFFECTED BY INCREASES IN SALINITY

An increase in sample salinity above the calibration salinity results in an apparent increase in dissolved-oxygen concentration. The change is nonlinear and temperature-dependent, as indicated by the following equation (Pijanowski, 1973):

$$D_c = D_m \left[0.9987\ e^{-\left(\frac{S}{1.255 + 145.5} \right)} \right] \qquad \text{(A-1)}$$

where

S = salinity ($^o/oo$)

T = temperature (°C)

D_c = dissolved-oxygen concentration corrected for increased salinity

D_m = observed dissolved-oxygen value at salinity S and temperature T

The original equation utilized salinity values rather than conductivity. By using the equation

$$S = -100\ \ell n \left(1 - \frac{C_T \left[-0.0770\ (\ell n T)^2 + 1.7975 \right]}{178500} \right) \qquad \text{(A-2)}$$

where

S = salinity ($^o/oo$)

C_T = conductivity (μmhos/cm) at temperature T and substituting this expression for S in Equation A-1, a dissolved-oxygen correction based on conductivity is derived. The fit of calculated values to experimentally determined values (Thomas et al, 1934) is within reasonable limits of accuracy (Figure A-1).

Equation A-2 cannot be applied below T = 1°C unless the conductivity at 25°C is entered into the equation after simplification for the form

$$S = -100 \ \ln \left(1 - \frac{C_{25}}{178500}\right) \quad \text{(A-3)}$$

where C_{25} = conductivity at 25°C, µmhos/cm. However, the addition of an arbitrarily chosen value to the observed temperature in Equation A-2 can eliminate natural logarithms below 0 while having no influence on the linearity of the relationship. The choice of 3.0 as an additive factor permits the use of Equation A-2 at observed temperatures of -2.0°C for seawater (~35 ^{o}/oo salin
The resulting linearized relationship is given by the equation

$$C_{25} = C_T \left[-0.0858 \left(\ln (T + 3)\right)^2 + 1.9488\right] \quad \text{(A-4)}$$

which replaces the numerator in Equation A-2.

Figure A-2 illustrates the approximate range of values used for correcting dissolved-oxygen readings (0.85-1.0); this range includes salinity values up to approximately 25%.

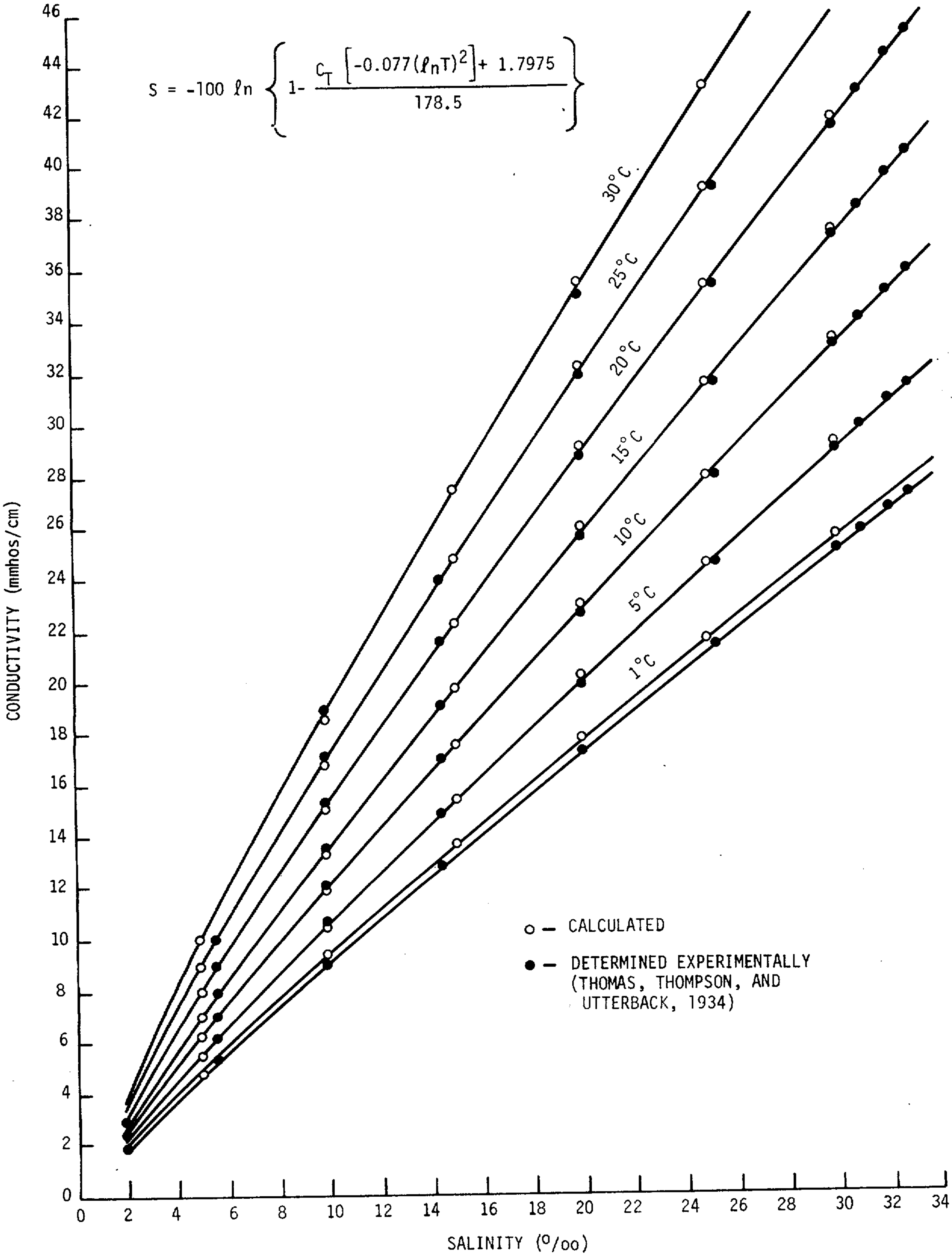


Figure A-1. Comparison of Calculated and Experimental Values for Conversion of Conductivity to Salinity

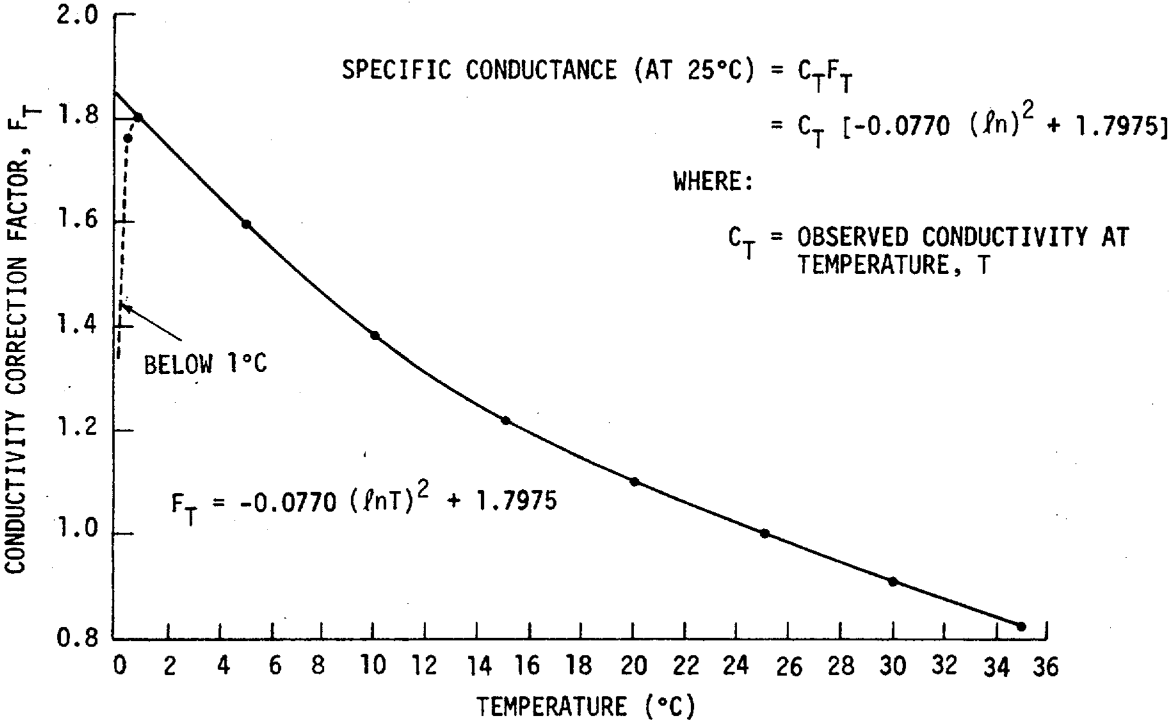


Figure A-2. Plot of Salinity Correction Factors for Dissolved-Oxygen Readings

APPENDIX B

BENTHIC STUDIES DATA

Table B-1

Mean Number of Individuals/m^2 at Indian Point Control Area during 1974

Taxon	Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Mean
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	
Limnodrilus sp	1712.2	366.0	3141.7	711.0	5305.6	1400.0	3305.6	694.0	6602.2	2005.0	2405.6	795.0	3539.4	845.0	3349.4	873.0	3052.8	789.0	3601.6
Scolecolepides ciridis	1901.1	391.0	3724.4	679.0	4449.4	1060.0	395.6	109.0	3383.3	584.0	1679.4	364.0	1432.8	236.0	909.4	146.0	905.6	164.0	2086.8
Amnicola sp	5.0	2.0	68.3	26.0	136.7	49.0	49.4	28.0	30.0	9.0	1.1	1.0	2154.4	390.0	3457.8	535.0	2879.4	467.0	975.8
Boccardia hamata	84.4	64.0	1.7	1.7	-	-	1.1	0.7	1028.9	532.0	4208.9	1453.0	275.6	136.0	1600.0	665.0	1398.9	655.0	955.0
Balanus improvisus	0.6	0.6	-	-	-	-	0.6	0.6	807.2	782.0	1704.4	804.0	4086.7	1706.0	16.7	6.0	816.1	562.0	825.8
Cyathura polita	131.1	34.0	160.0	26.0	134.4	29.0	216.1	44.0	653.9	120.0	1047.2	16.3	533.3	91.0	577.8	113.0	457.8	113.0	434.6
Corophium sp	0.6	0.6	1.7	1.0	0.6	0.6	-	-	360.0	144.0	875.6	341.0	125.6	55.0	21.7	7.0	42.2	14.0	158.7
Gammarus sp	96.1	59.0	116.1	55.0	779.4	590.0	19.4	6.0	25.0	9.0	40.0	11.0	193.3	61.0	35.0	12.0	85.6	27.0	154.4
Congeria leucophaeta	-	-	-	-	-	-	-	-	34.4	29.0	151.1	72.0	397.2	164.0	3.9	2.0	82.2	63.0	74.3
Chironomid larvae	27.2	9.0	32.2	11.0	46.7	10.0	31.7	7.0	50.6	10.0	13.9	3.0	64.4	15.0	91.7	19.0	110.0	22.0	52.0
Chaoborus sp	-	-	1.7	0.7	2.2	2.0	2.2	1.1	60.6	16.0	12.8	5.0	126.7	30.0	69.4	20.0	115.6	30.0	43.4
Edotea sp	-	-	-	-	-	-	-	-	10.6	3.0	206.1	47.0	65.6	11.0	6.7	2.0	-	-	32.1
Chiridotea almyra	37.8	15.0	13.3	6.0	40.6	6.0	142.8	45.0	25.0	10.0	1.1	1.0	1.1	1.1	0.6	0.6	8.3	2.0	30.1
Cyclopoida	-	-	-	-	2.2	1.1	3.3	2.0	4.4	2.0	-	-	64.4	16.0	86.7	20.0	9.4	4.0	18.9
Rhithropanopeus harrisi	0.6	0.6	0.6	0.6	0.6	0.6	-	-	7.8	3.0	44.4	13.0	32.8	12.0	5.6	3.0	18.3	11.0	12.3
Harpacticoida	-	-	1.1	0.7	1.1	1.1	74.4	45.0	-	-	1.7	1.0	2.2	1.0	6.7	5.0	5.6	5.6	10.3
Leptocheirus sp	0.6	0.6	1.1	0.1	0.6	0.6	1.7	1.1	16.7	5.0	3.9	2.0	18.3	11.0	6.1	5.0	2.8	2.0	5.8
Nudibranchia	6.7	3.0	2.2	1.0	5.0	3.0	0.6	0.6	10.6	0.6	0.6	0.6	0.6	0.6	1.1	0.7	14.4	4.0	4.6
Monoculodes sp	1.7	1.0	-	-	-	-	-	-	1.7	1.0	7.8	4.0	1.7	0.7	7.8	4.0	15.6	5.0	4.0
Nematoda	0.6	0.6	-	-	1.1	0.7	2.8	1.0	10.6	4.0	5.6	2.0	5.0	1.0	5.6	2.0	4.4	2.0	4.0
Peloscolex sp	24.4	15.0	3.3	2.0	0.6	0.6	1.1	1.1	0.6	0.6	-	-	-	-	-	-	2.2	2.0	3.6
Paleonemertea	-	-	-	-	1.1	0.7	-	-	1.1	1.1	12.2	3.0	5.6	2.0	2.8	1.0	2.2	1.0	2.8
Hypaniola grayi	2.2	1.0	0.6	0.6	1.1	0.7	0.6	0.6	0.6	0.6	2.2	1.0	2.2	2.0	5.0	3.0	3.3	2.0	2.0
Sphaerium sp	-	-	-	-	1.1	0.7	5.0	3.0	2.2	1.0	-	-	3.3	3.0	2.8	2.0	-	-	1.6
Daphnia sp	10.6	10.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2
Trichopteran-adult	-	-	-	-	-	-	-	-	0.6	0.6	2.8	1.0	1.7	1.0	2.8	2.0	1.1	1.1	1.0
Cassidina lunifrons	-	-	1.1	0.7	-	-	-	-	-	-	0.6	0.6	1.7	1.0	-	-	-	-	0.4
Chironomid pupae	-	-	-	-	0.6	0.6	1.7	1.1	1.7	1.0	-	-	-	-	-	-	-	-	0.4
Calanoida	1.7	1.7	-	-	-	-	-	-	-	-	-	-	1.1	1.1	-	-	-	-	0.3
Macrothricidae	-	-	-	-	0.6	0.6	1.7	1.0	-	-	-	-	-	-	-	-	-	-	0.3
Crangon septemspinosus	-	-	-	-	-	-	-	-	1.1	0.7	0.6	0.6	0.6	0.6	-	-	-	-	0.3
Hydracarina	-	-	-	-	-	-	-	-	0.6	0.6	-	-	0.6	0.6	1.1	1.1	-	-	0.3
Ceratopogonidae	-	-	-	-	0.6	0.6	-	-	-	-	-	-	0.6	0.6	0.6	0.6	-	-	0.2
Collembola	-	-	-	-	0.6	0.6	1.1	1.1	-	-	-	-	-	-	-	-	-	-	0.2
Nereis succinea	-	-	-	-	-	-	-	-	-	-	1.7	1.0	-	-	-	-	-	-	0.2
Planaridae	-	-	-	-	-	-	-	-	-	-	1.7	1.0	-	-	-	-	-	-	0.2
Ephemeroptera-adult	-	-	-	-	-	-	0.6	0.6	-	-	-	-	-	-	-	-	-	-	0.2
Piscicola sp	-	-	-	-	-	-	-	-	-	-	1.1	1.1	-	-	-	-	-	-	0.1
Ostracoda	-	-	-	-	-	-	-	-	-	-	0.6	0.6	-	-	-	-	-	-	0.1
Naididae	-	-	-	-	-	-	-	-	-	-	1.1	1.1	-	-	-	-	-	-	0.1
Leptodora sp	-	-	-	-	-	-	-	-	-	-	0.6	0.6	-	-	-	-	-	-	0.1
Ferrissia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	0.6	-	-	0.1
Odonata-juvenile	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	0.6	0.1
Total No. of Taxa		20		17		24		22		27		28		27		27		24	43
Total Mean No. of Specimens	4045.8		7271.1		10913.1		4259.1		13132.0		12434.7		13138.5		10275.4		10034.4		9500.7

Burkie

Table B-2

Mean Number of Individuals/m^2 at Indian Point Test Area during 1974

Taxon	Apr $\bar{x}$	Apr SE	May $\bar{x}$	May SE	Jun $\bar{x}$	Jun SE	Jul $\bar{x}$	Jul SE	Aug $\bar{x}$	Aug SE	Sep $\bar{x}$	Sep SE	Oct $\bar{x}$	Oct SE	Nov $\bar{x}$	Nov SE	Dec $\bar{x}$	Dec SE	Mean
Amnicola sp	20.6	7.0	463.3	317.0	972.8	313.0	211.1	95.0	105.0	74.0	18.9	10.0	10736.1	2380.0	12180.6	2201.0	11366.1	2200.0	4008.3
Scolecolepides viridis	5362.2	1636.0	5450.0	811.0	3443.9	572.0	1815.6	517.0	4018.3	483.0	2202.2	276.0	1207.8	186.0	1062.8	314.0	857.8	151.0	2824.5
Limnodrilus sp	1735.0	550.0	2006.1	480.0	3883.9	710.0	3047.8	475.0	3462.8	903.0	1743.9	349.0	1895.6	388.0	3086.1	641.0	2717.2	591.0	2730.9
Balanus improvisus	0.6	0.6	-	-	-	-	138.3	47.0	1112.8	547.0	1035.6	489.0	3425.0	1279.0	2658.3	962.0	781.7	306.0	1016.9
Cyathura polita	241.7	42.0	121.1	31.0	123.3	31.0	945.6	101.1	532.8	117.0	503.9	77.0	665.6	87.0	567.8	86.0	505.6	70.0	467.5
Congeria leucophaeta	34.4	11.0	17.8	12.0	3.3	2.0	3.9	1.0	87.8	47.0	207.8	119.0	1316.7	511.0	720.0	309.0	271.1	103.0	295.9
Gammarus sp	1042.8	245.0	157.8	34.0	191.1	42.0	251.7	70.0	35.0	11.0	24.4	8.0	302.8	68.0	70.6	31.0	510.0	159.0	287.4
Chironomid	376.7	32.0	262.2	30.0	200.6	28.0	146.1	28.0	82.8	20.0	60.6	16.0	197.2	27.0	306.7	35.0	408.9	64.0	226.9
Corophium sp	94.4	28.0	38.9	20.0	7.2	3.0	33.3	15.0	126.7	57.0	52.2	12.0	307.2	106.0	430.6	183.0	261.1	58.0	150.2
Boccardia hamata	40.6	18.0	0.6	0.6	5.6	5.0	7.8	5.0	71.1	40.0	31.7	16.0	322.2	108.0	430.0	172.0	297.8	121.0	133.6
Harpacticoida	-	-	-	-	2.2	1.0	261.1	257.1	143.9	133.3	6.7	5.0	39.4	25.0	15.0	7.0	4.4	2.0	52.5
Chaoborus sp	24.4	6.0	17.2	5.0	16.7	7.0	10.6	3.0	93.9	17.0	31.1	8.0	58.9	26.0	75.6	27.0	87.2	32.0	46.2
Cyclopoida	-	-	-	-	-	-	1.7	1.0	1.7	1.0	0.6	0.6	16.7	6.0	270.0	200.0	21.1	6.0	34.5
Chiridotea almyra	32.8	7.0	3.9	2.0	10.6	4.0	133.9	30.0	10.0	3.0	-	-	0.6	0.6	0.6	0.6	4.4	2.0	21.9
Nudibranchia	22.2	7.0	19.4	7.0	4.4	2.0	7.2	4.0	134.9	105.0	-	-	-	-	0.6	0.6	0.6	0.6	21.0
Leptocheirus sp	11.1	3.0	10.6	5.0	11.1	7.0	1.1	1.0	23.9	7.0	32.2	7.0	18.9	6.0	45.6	20.0	15.6	7.0	18.9
Rhithropanopeus harrisi	8.3	4.0	2.8	2.0	1.1	1.0	0.6	0.6	40.6	20.0	24.4	11.1	35.6	11.0	36.7	14.0	18.3	5.0	18.7
Edotea sp	-	-	-	-	-	-	-	-	7.2	3.0	23.9	9.0	66.1	10.0	18.3	7.0	-	-	12.8
Nematoda	3.9	2.0	1.1	1.0	9.4	3.0	18.9	4.0	16.7	8.0	11.1	4.0	23.9	3.0	13.3	3.0	13.9	3.0	12.5
Calanoida	0.6	0.6	-	-	-	-	-	-	-	-	-	-	0.6	0.6	-	-	98.9	98.9	11.1
Hypaniola grayi	25.0	8.0	6.7	3.0	11.1	6.0	6.1	2.0	11.1	5.0	7.8	3.0	8.9	3.0	12.8	5.0	6.7	2.0	10.7
Peloscolex sp	61.1	22.0	-	-	7.8	4.0	2.8	2.0	0.6	0.6	-	-	-	-	1.1	1.0	0.6	0.6	8.2
Monoculodes sp	2.8	1.0	-	-	-	-	2.8	1.0	2.8	1.0	2.8	1.0	1.7	1.1	11.1	4.0	25.0	7.0	5.4
Sphaerium sp	0.6	0.6	0.6	0.6	2.8	1.0	10.0	4.0	22.2	12.0	3.9	2.0	-	-	-	-	0.6	0.6	4.5
Paleonemertea	2.2	1.0	1.1	1.0	2.2	1.0	1.1	1.0	3.9	2.0	7.8	2.0	6.1	1.0	8.3	2.0	1.7	1.0	3.8
Chironomid pupae	-	-	6.7	4.0	3.9	2.0	8.3	3.0	8.3	6.0	-	-	1.1	0.7	-	-	-	-	3.1
Tricopteran-adult	-	-	1.7	1.0	-	-	0.6	0.6	0.6	0.6	1.1	1.0	1.1	1.1	-	-	1.1	1.1	0.7
Piscicola sp	3.9	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1	1.0	0.5
Planaridae	-	-	-	-	-	-	2.8	1.0	0.6	0.6	0.6	0.6	-	-	-	-	-	-	0.4
Hydracarina	-	-	-	-	0.6	0.6	-	-	-	-	-	-	0.6	0.6	-	-	1.7	1.0	0.3
Collembola	-	-	-	-	-	-	0.6	0.6	-	-	0.6	0.6	0.6	0.6	0.6	0.6	-	-	0.3
Cassidina lunifrons	0.6	0.6	-	-	-	-	0.6	0.6	-	-	-	-	-	-	0.6	0.6	-	-	0.2
Hydra americana	-	-	-	-	-	-	-	-	2.2	2.2	-	-	-	-	-	-	-	-	0.2
Elliptio sp	-	-	-	-	-	-	-	-	1.7	1.0	-	-	-	-	-	-	-	-	0.2
Neomysis americana	-	-	-	-	-	-	-	-	-	-	-	-	1.7	1.7	-	-	-	-	0.2
Ceratopogonidae	-	-	-	-	1.1	1.0	-	-	-	-	-	-	-	-	-	-	-	-	0.1
Ostracoda	-	-	-	-	-	-	1.1	1.0	-	-	-	-	-	-	-	-	-	-	0.1
Ferrissia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	0.6	0.1
Daphnia sp	-	-	-	-	-	-	0.6	0.6	-	-	-	-	-	-	-	-	-	-	0.1
Crangonyx sp	-	-	-	-	-	-	-	-	-	-	0.6	0.6	-	-	-	-	-	-	0.1
Total No. of Taxa		24		20		23		30		29		25		27		25		28	40
Total Mean No. of Specimens	9148.5		9589.6		8916.7		7073.7		10161.9		6036.4		20658.7		22023.7		18275.8		12409.2

Table B-3

Numbers of Individuals/1000 m^3 in Indian Point Test Area Plankton Samples during 1974

MCT '77

Taxon	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Daphnia sp	1815.1	12.3	-	98.0	-	-	-	-	24.5	216.7
Calanoida	1535.8	-	-	-	-	-	-	-	12.2	172.0
Amnicola sp	-	12.3	646.5	-	-	-	-	20.9	12.2	76.9
Balanus improvisus	-	-	-	-	452.8	202.8	-	-	-	72.8
Cyclopoida	-	36.8	541.4	4.7	-	-	-	-	6.1	65.4
Macrothricidae	-	-	355.6	-	-	-	-	-	-	39.5
Dipteran larvae	-	-	-	238.1	65.4	-	-	-	-	33.7
Leptodora kindti	-	-	-	140.0	4.7	-	4.8	-	-	16.6
Gammarus sp	-	-	-	-	14.0	-	-	-	67.3	9.0
Dipteran pupae	-	36.8	-	14.0	-	-	-	-	-	5.6
Zoeal larvae	-	-	-	-	14.0	32.5	-	-	-	5.2
Chaoborus sp	-	-	-	9.3	14.0	8.1	-	-	6.1	4.2
Neomysis americana	-	-	-	-	32.7	-	-	-	-	3.6
Cordylophora lacustris	-	-	-	-	28.0	-	-	-	-	3.1
Hydracarina	-	-	-	23.3	-	-	-	-	-	2.6
Amnicolidae	-	-	-	-	-	-	-	-	20.9	2.3
Sida sp	-	-	-	18.7	-	-	-	-	-	2.1
Cladoceran ephippia	-	-	16.2	-	-	-	-	-	-	1.8
Lophopodella carteri (Floatoblast)	-	-	16.2	-	-	-	-	-	-	1.8
Hydra americana	-	-	8.1	4.7	-	-	-	-	-	1.4
Naididae	-	-	-	4.7	4.7	-	-	-	-	1.0
Ostracoda	-	-	8.1	-	-	-	-	-	-	0.9
Piscicola sp	-	-	-	-	-	-	-	-	6.1	0.7
Ephemeroptera	-	-	-	-	-	-	-	-	6.1	0.7
Oligochaeta	-	-	-	4.7	-	-	-	-	-	0.5
Corophium sp	-	-	-	-	4.7	-	-	-	-	0.5
Trichopteran larvae	-	-	-	-	4.7	-	-	-	-	0.5
Total No. of Taxa	2	4	7	11	11	3	1	1	9	27
Total No. of Specimens	3850.9	98.2	1592.1	560.2	639.7	243.4	4.8	20.9	161.5	741.1

Table B-4

Numbers of Individuals/1000 m^3 in Indian Point Control Area Epibenthic Sled Samples during 1974

Taxon	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Daphnia sp	1851.1	No	14.9	-	-	-	-	-	42.1	238.5
Calanoida	979.3	Sample	82.1	-	-	-	-	-	16.8	134.8
Amnicolidae	-		-	-	-	-	887.4	29.1	-	114.6
Balanus improvisus	-		-	-	131.7	10.4	14.8	-	-	19.6
Leptodora kindti	-		7.5	58.5	87.8	-	-	-	-	19.2
Cyclopoida	107.6		-	-	-	-	-	-	-	13.5
Insecta - adult	21.5		37.3	14.6	14.6	-	-	-	-	11.0
Bosminidae	-		-	-	-	-	-	58.1	-	7.3
Hydracarina	-		-	29.3	14.6	-	-	-	-	5.5
Zoeal larvae	-		-	-	43.9	-	-	-	-	5.5
Gammarus sp	10.8		-	-	-	-	14.8	-	16.8	5.3
Cordylophora lacustris	-		-	-	-	-	29.6	-	-	3.7
Dipteran-larvae	-		-	-	-	10.4	14.8	-	-	3.2
Chaoborus sp	10.8		7.5	-	-	-	-	-	-	2.3
Neomysis americana	-		-	-	14.6	-	-	-	-	1.8
Trichopteran - adult	-		-	-	-	-	-	14.5	-	1.8
Unid. Insect larvae	10.8		-	-	-	-	-	-	-	1.4
Hyalinella sp (Floatblast)	10.8		-	-	-	-	-	-	-	1.4
Naididae	-		-	-	-	10.4	-	-	-	1.3
Amnicola sp	-		-	-	-	-	-	-	8.4	1.1
Piscicola sp	-		-	-	-	-	-	-	8.4	1.1
Monoculodes sp	-		-	-	-	-	-	-	8.4	1.1
Stylaria sp	-		7.5	-	-	-	-	-	-	0.9
Total No. of Taxa	8		6	3	6	3	5	3	6	23
Total No. of Specimens	3002.7		156.8	102.4	307.2	31.2		101.7	100.9	595.9

Table B-5

Numbers of Individuals/1000 m^3 in Indian Point Control Area Plankton Net Samples during 1974

Taxon	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Neomysis americana	-	No	9.0	-	33500.7	7716.5	55.8	3766.6	-	6435.5
Gammarus sp	4335.8	Sample	5293.4	74.8	692.0	2937.7	962.8	9346.6	4253.9	3487.1
Amnicola sp	-		-	-	-	-	22855.1	-	-	3265.0
Monoculodes sp	1368.1		35.8	27.4	1455.9	6061.5	3348.7	4975.6	360.6	2205.5
Calanoida	16216.4		376.2	121.6	14.4	-	-	81.4	-	2101.3
Daphnia sp	1639.7		35.8	16045.2	-	-	-	-	41.0	2220.2
Chaoborus sp	50.3		9.0	261.8	1686.6	310.3	195.3	511.5	8.2	379.1
Leptodora kindti	-		-	2169.3	360.4	-	-	-	-	316.2
Balanus improvisus	-		-	-	129.7	217.2	432.5	1104.4	8.2	270.3
Scolecolepides viridis	171.0		17.9	-	-	-	893.0	255.8	-	191.1
Crangonyx sp	-		-	-	-	568.9	-	534.8	-	157.7
Sida sp	-		-	187.0	994.6	-	14.0	-	-	149.5
Cyclopoida	171.0		62.7	-	187.4	-	-	58.1	-	68.5
Amnicolidae	140.8		-	274.0	14.4	-	-	-	-	66.2
Chiridotea almyra	100.6		53.7	-	28.8	-	-	11.6	-	27.8
Cordylophora lacustris	-		-	-	173.0	-	-	-	-	24.7
Lophopodella carteri (Floatoblast)	150.9		-	-	14.4	-	-	-	-	23.6
Edotea sp	-		17.9	-	-	113.8	27.9	-	-	22.8
Corophium sp	-		-	-	28.8	20.7	-	23.3	-	10.4
Hydracarina	-		-	-	-	-	69.8	-	-	10.0
Chironomid pupae	-		9.0	-	14.4	31.1	-	-	-	7.8
Zoeal larvae	-		-	-	43.2	-	-	-	-	6.2
Pisicola sp	10.1		-	-	-	-	-	-	8.2	2.6
Rhithropanopeus harrisi	-		17.9	-	-	-	-	-	-	2.6
Cyathura polita	-		-	-	-	-	27.9	-	-	4.0
Chironomid larvae	-		-	-	-	10.3	-	-	-	1.5
Leptocheirus sp	10.1		-	-	-	-	-	-	-	1.4
Total No. of Taxa	13		12	8	16	10	12	11	6	28
Total No. of Species	24474.9		5938.3	19271.1	39338.7	17987.9	28896.8	20669.7	4680.1	21460.6

Table B-6

Numbers of Individuals/1000 m^3 in Indian Point Test Area Epibenthic Sled Samples during 1974

Taxon	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Calanoida	136621.4	No	Sample	22.7	-	-	4.3	-	81.5	19532.8
Gammarus sp	4391.4			13.6	18.2	313.8	128.2	151.4	21227.5	3749.2
Neomysis americana	224.5			-	5398.5	12577.9	51.3	50.5	-	2614.7
Daphnia sp	322.0			9438.3	-	-	-	-	114.1	1784.2
Leptodora kindti	-			9847.3	36.4	-	64.1	-	-	1421.1
Monoculodes sp	3074.0			40.9	18.2	486.1	12.8	109.4	4271.6	1144.7
Chaborus sp	48.8			190.9	6870.8	-	-	8.4	97.8	1031.0
Sida sp	-			740.7	745.2	-	2.8	-	-	212.7
Balanus improvisus	-			-	290.8	898.4	183.7	50.5	59.8	211.9
Cyclopoida	48.8			36.3	199.9	-	4.3	-	65.2	50.6
Scolecolepides viridis	273.2			-	-	30.8	-	-	5.4	44.2
Amnicolidae	-			-	-	-	94.0	101.0	-	27.9
Cordylophora lacustris	-			-	109.1	61.5	-	-	-	24.4
Corophium sp	-			-	54.5	18.5	-	16.8	-	12.8
Crangonyx sp	-			-	-	-	-	75.7	5.4	11.6
Amnicola sp	9.8			-	-	-	-	-	70.6	11.5
Chironomid - pupae	78.1			-	-	-	-	-	-	11.2
Chironomid - larvae	78.1			-	54.5	12.3	4.3	-	-	10.2
Chiridotea almyra	39.0			-	-	-	-	-	5.4	6.3
Pectinatella magnifica (Floatoblast)	29.3			-	-	-	-	-	-	4.2
Zoeal larvae	-			-	-	24.6	-	-	-	3.5
Edotea sp	-			-	-	18.5	-	-	-	2.6
Collembola	-			4.5	-	-	-	-	10.9	2.2
Hydracarina	-			-	-	-	12.8	-	-	1.8
Pisicola sp	-			-	-	-	-	-	5.4	0.8
Total No. of Taxa	13			9	12	11	12	9	13	26
Total No. of Specimens	145170.1			20335.2	17595.0	15340.8	699.3	580.5	26015.2	32622.5

Table B-7

1972 Mean Wet-Weight Biomass/m^2

	Monthly Mean									
Station	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year Mean
1(M)	8.8	4.3	2.4	6.0	1.0	5.0	9.0	11.0	12.0	6.6
2	1.2	1.8	1.0	11.0	4.0	5.0	12.0	27.0	33.0	10.7
3	5.0	2.6	2.6	4.0	2.0	9.0	9.4	10.0	4.0	5.4
4(A)	28.8	12.8	4.6	4.0	5.0	21.0	62.0	54.0	59.0	27.9
5(C)	14.3	1.4	2.4	9.0	9.0	38.0	22.6	62.0	7.0	18.4
6	18.2	3.2	1.0	2.0	2.0	2.0	17.2	25.0	3.0	8.2
7	10.6	11.0	1.4	0.2	5.0	4.0	52.4	16.0	34.0	15.0
Mean	12.4	5.3	2.2	5.2	4.0	12.0	26.4	29.3	21.7	13.2
Test Mean	21.6	7.1	3.5	6.5	7.0	29.5	42.3	58.0	33.0	23.2
Control Mean	8.8	4.3	2.4	6.0	1.0	5.0	9.0	11.0	12.0	6.6

Table B-8

1973 Mean Wet-Weight Biomass/m^2

		Monthly Mean									
	Station	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year Mean
Test Area	A	9.3	14.7	17.0	22.5	31.5	31.3	34.7	13.7	11.3	20.7
	B	13.7	11.7	20.0	36.0	17.7	21.3	14.0	9.0	18.3	20.5
	C	24.3	13.3	26.7	41.0	21.3	25.3	20.3	6.0	12.3	21.2
	D	3.7	7.3	10.3	18.3	20.0	24.0	13.7	4.7	4.7	11.9
	E	34.3	24.0	17.7	38.0	26.8	22.3	7.0	7.0	14.0	21.2
	F	3.7	17.3	16.3	17.0	40.3	35.0	15.0	9.0	7.7	17.9
	Area Mean	14.8	14.7	18.0	28.8	26.3	26.5	17.5	8.2	11.4	18.5
Control Area	M	9.7*	24.7*	15.7	23.4	5.8	17.7	15.0	6.0	2.7	13.4
	N	7.7*	18.0*	9.7	11.0	12.3	13.3	6.7	3.3	3.7	9.5
	O	8.7*	22.7*	19.7	53.0	7.0	15.7	6.0	6.7	9.3	16.5
	P	13.0*	15.0*	18.3	11.2	5.5	20.7	8.7	13.0	18.0	13.7
	Q	7.7*	10.7*	20.7	24.7	20.7	29.3	20.7	27.0	21.7	20.4
	R	7.7*	16.0*	20.7	28.0	63.7	54.0	18.3	7.0	15.0	25.6
	Area Mean	9.1	17.9	17.5	25.2	19.2	25.1	12.6	10.5	11.7	16.5

*Stations G through L

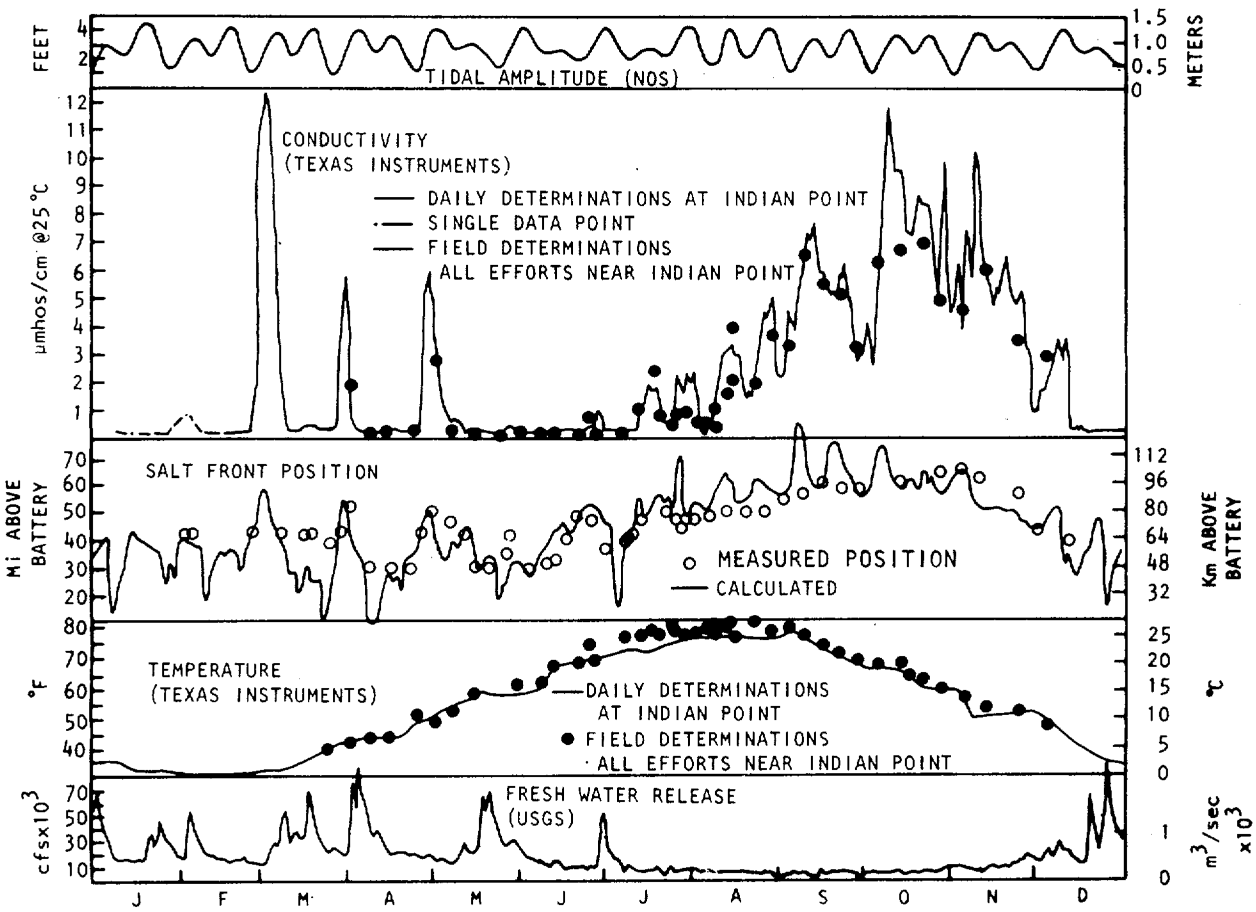
Table B-9

1974 Mean Wet-Weight Biomass/m^2

		Monthly Mean									
	Station	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Test Area	A	32.0	13.0	18.3	9.3	20.3	19.0	136.7	82.0	48.7	42.1
	B	18.7	36.3	11.7	5.7	30.7	70.3	91.0	11.7	12.0	32.0
	C	37.7	31.7	25.7	16.8	55.0	115.3	417.3	147.3	82.3	103.2
	D	39.7	41.0	43.7	9.0	35.0	42.0	15.0	113.7	18.7	39.8
	E	35.7	19.0	16.0	13.3	44.7	38.3	16.7	160.3	78.0	46.9
	F	114.0	52.0	45.3	39.3	47.3	16.0	28.0	55.7	17.0	46.1
	Area Mean	46.3	32.2	26.8	15.5	38.8	50.2	117.4	95.1	42.8	51.7
Control Area	M	10.7	8.7	7.3	2.3	21.0	13.0	43.3	27.7	5.7	15.5
	N	8.0	15.0	15.0	3.3	21.3	67.3	239.3	5.3	119.7	54.9
	O	7.3	8.3	16.7	3.3	10.3	42.7	86.0	8.7	13.0	21.8
	P	20.3	17.3	8.7	4.0	57.7	23.3	28.7	13.7	10.3	20.4
	Q	5.7	12.0	16.7	9.7	41.7	19.7	30.0	14.3	23.3	19.2
	R	7.3	40.3	79.0	7.0	49.3	89.0	10.0	7.0	5.0	32.7
	Area Mean	9.9	16.9	23.9	4.9	38.6	42.5	72.9	12.8	29.5	28.0

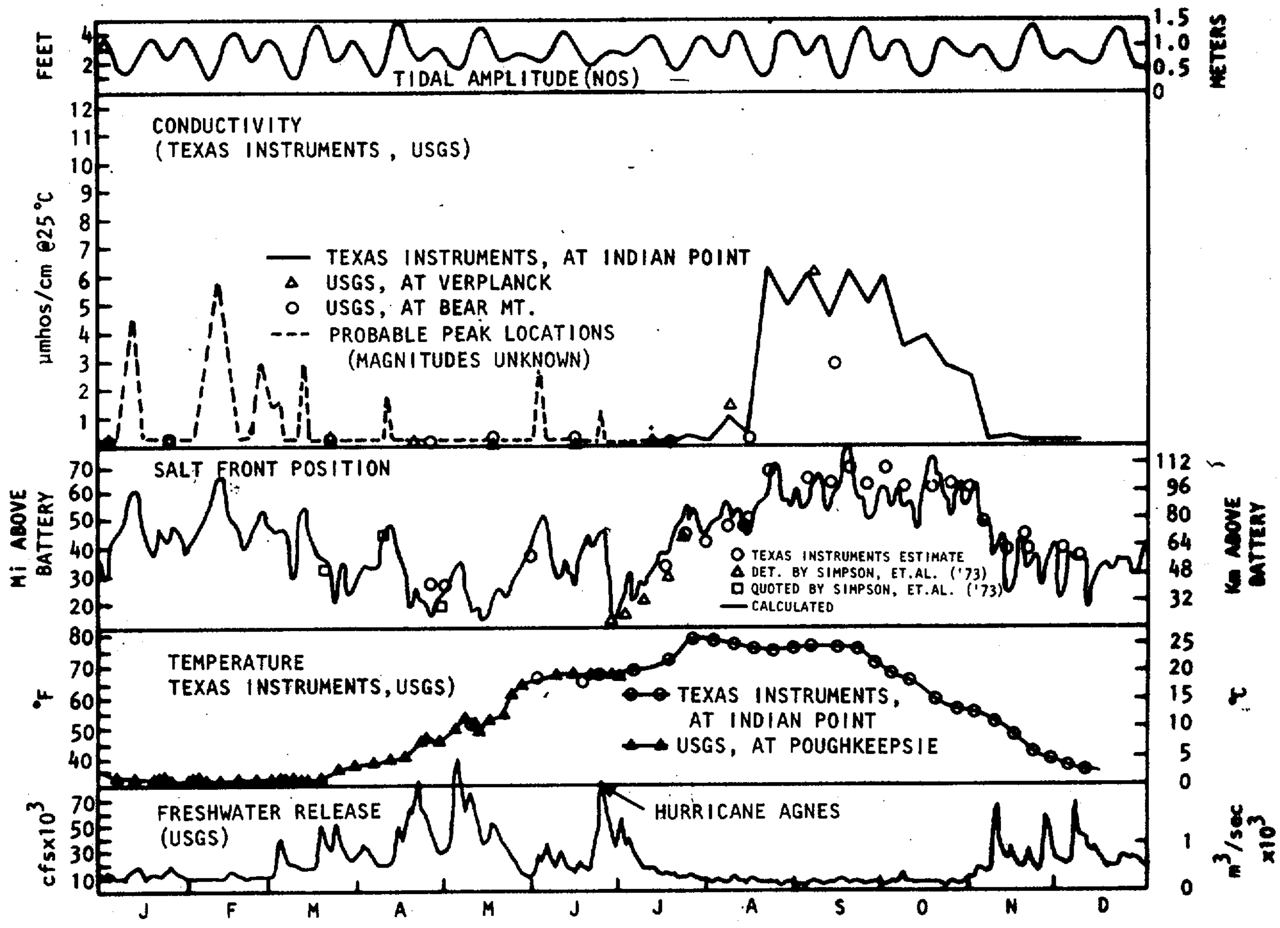
APPENDIX C

1965-1973 TEMPORAL DISTRIBUTION OF FRESHWATER RELEASE, WATER TEMPERATURE, SALT-FRONT POSITION, CONDUCTIVITY, AND TIDAL AMPLITUDE



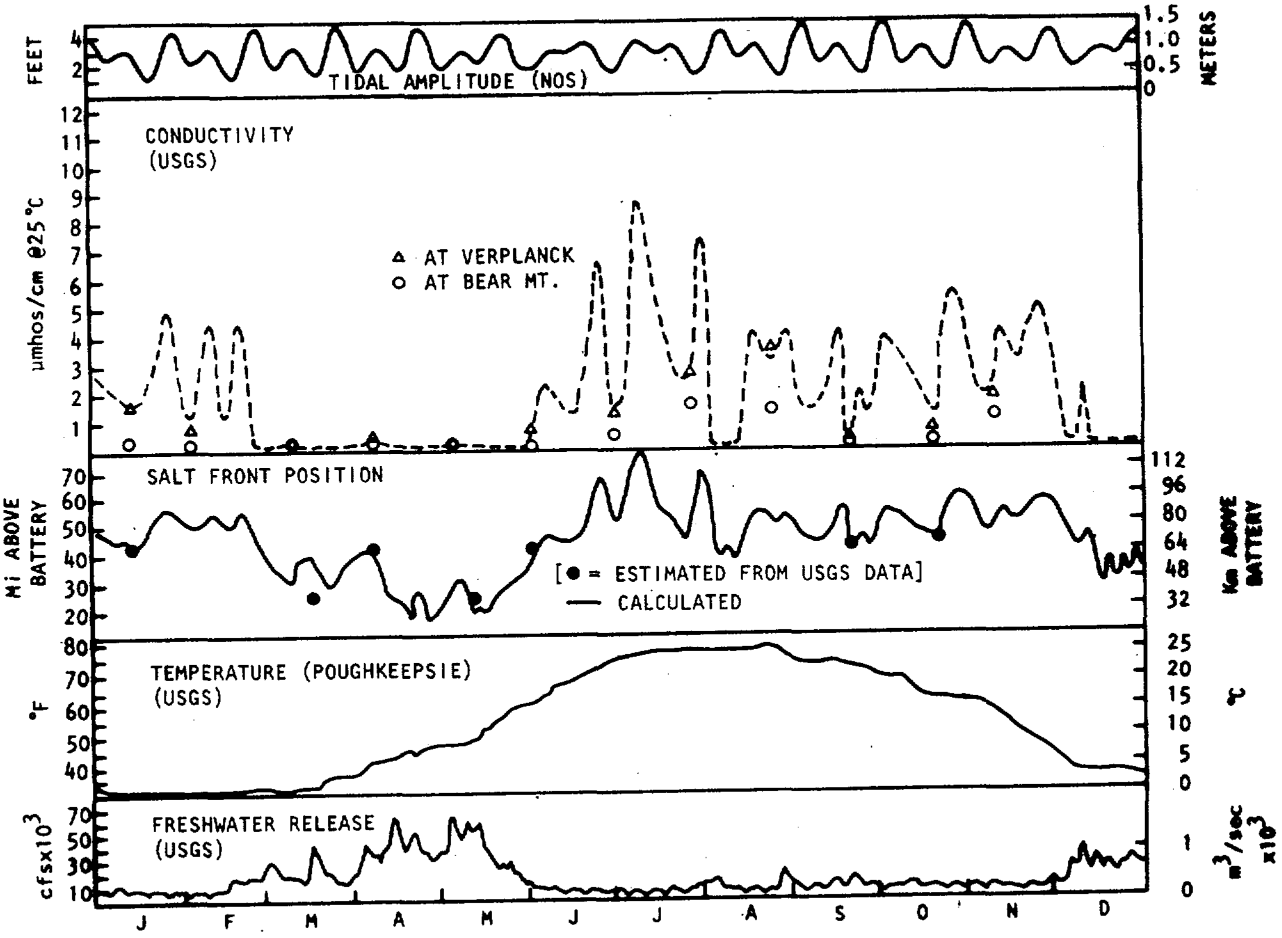
1973

Figure C-1. 1965-1973 Temporal Distribution of Freshwater Release, Water Temperature, Salt-Front Position, Conductivity, and Tidal Amplitude



1972

Figure C-1. Page 2 of 9



1971

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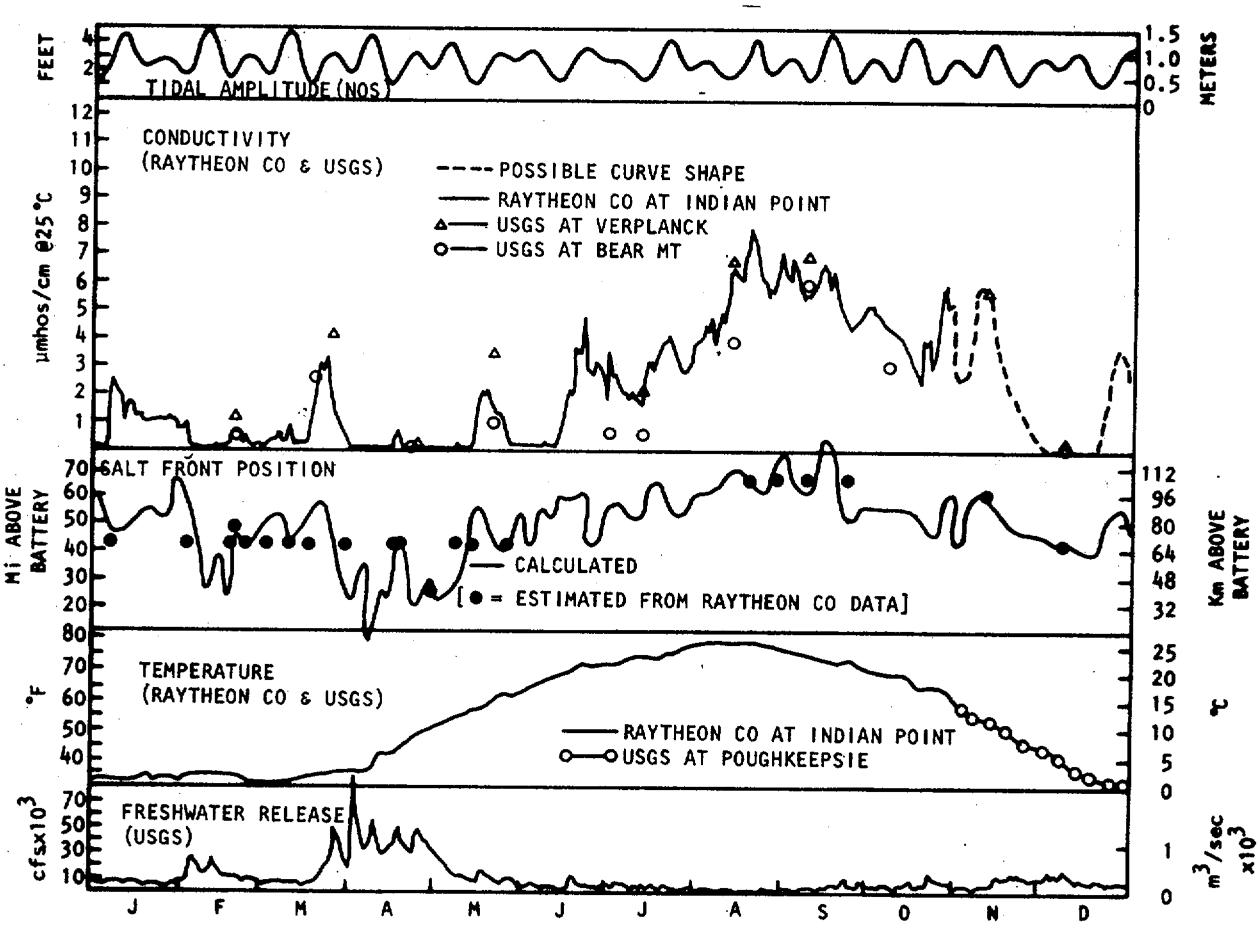

1970

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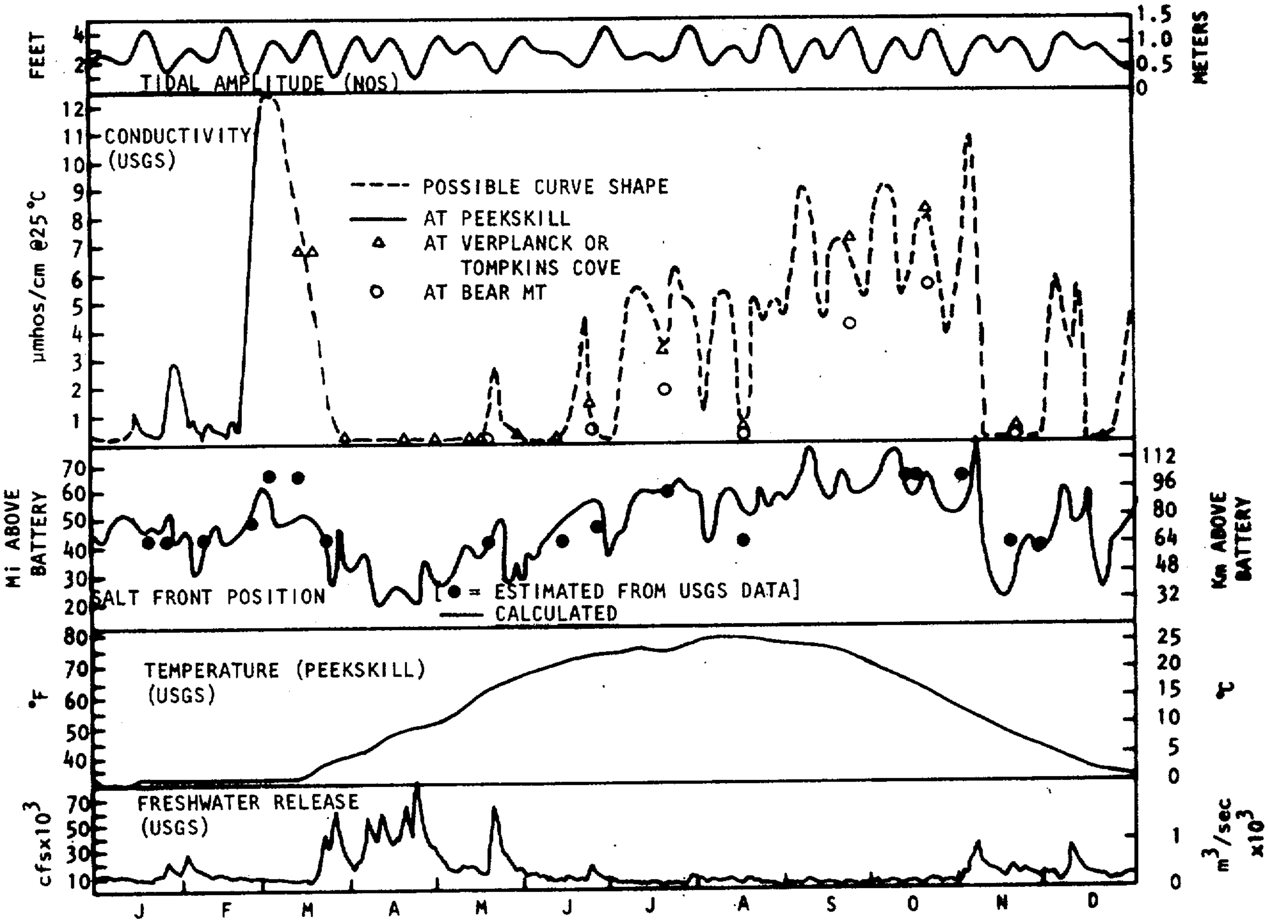
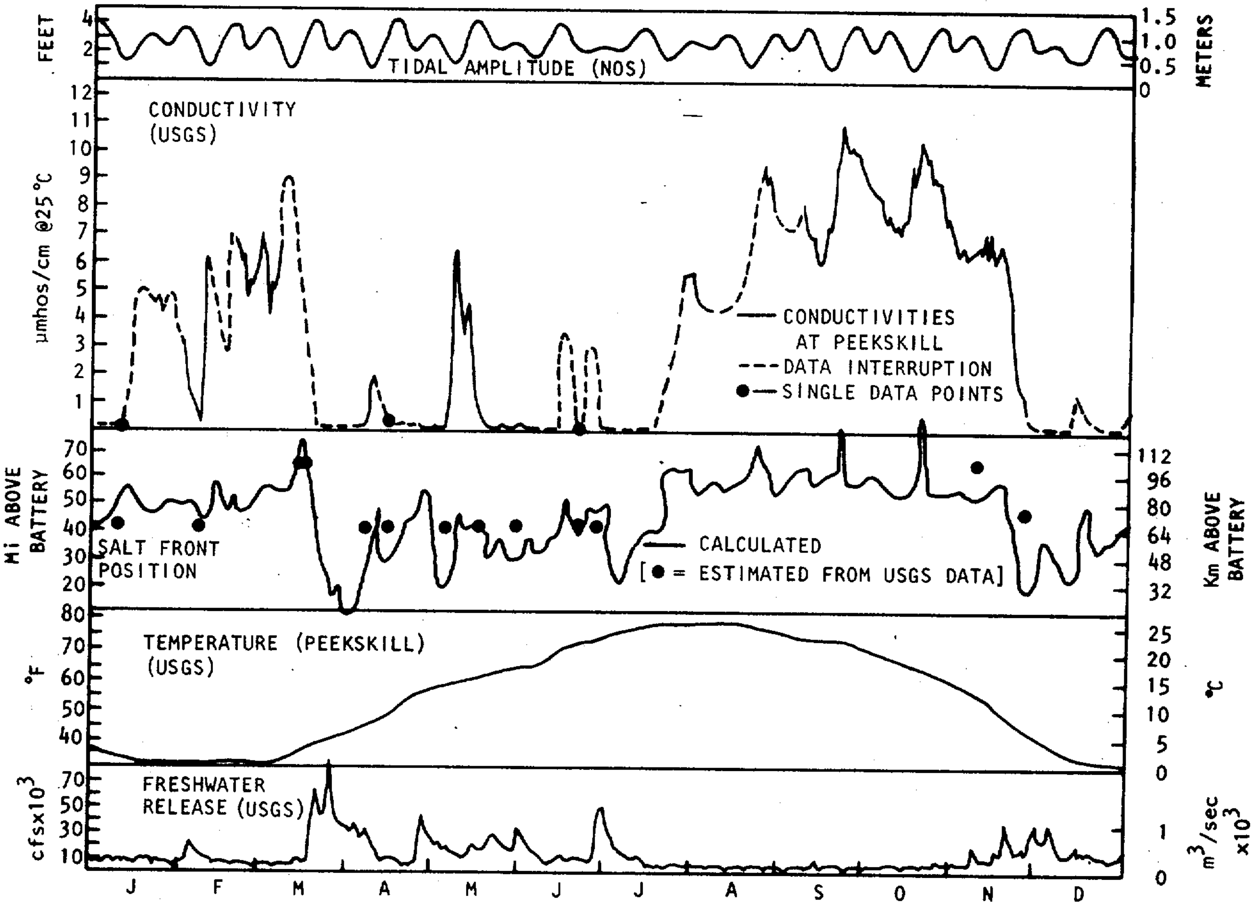


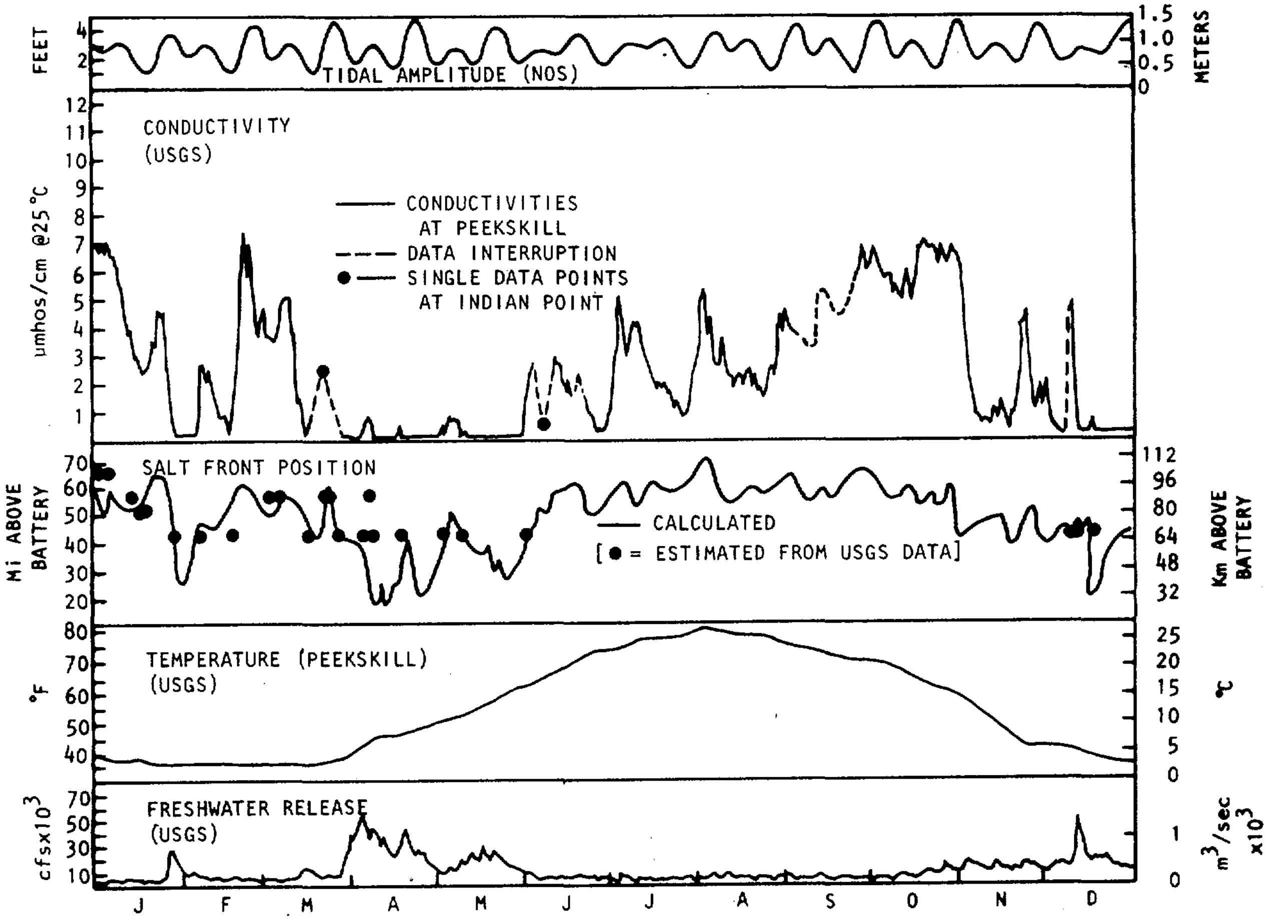
1969

Figure C-1. Page 5 of 9



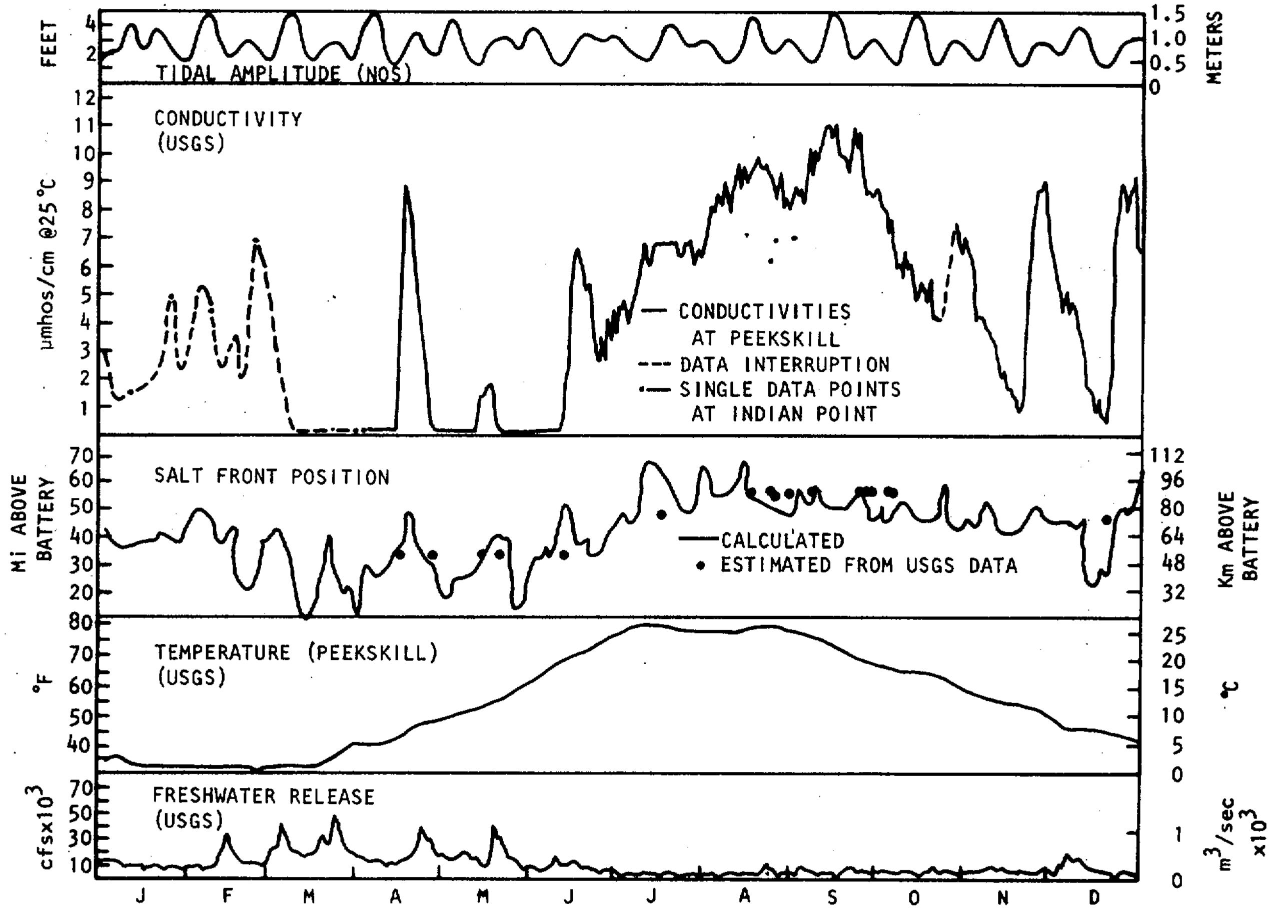
1968

Figure C-1. Page 6 of 9



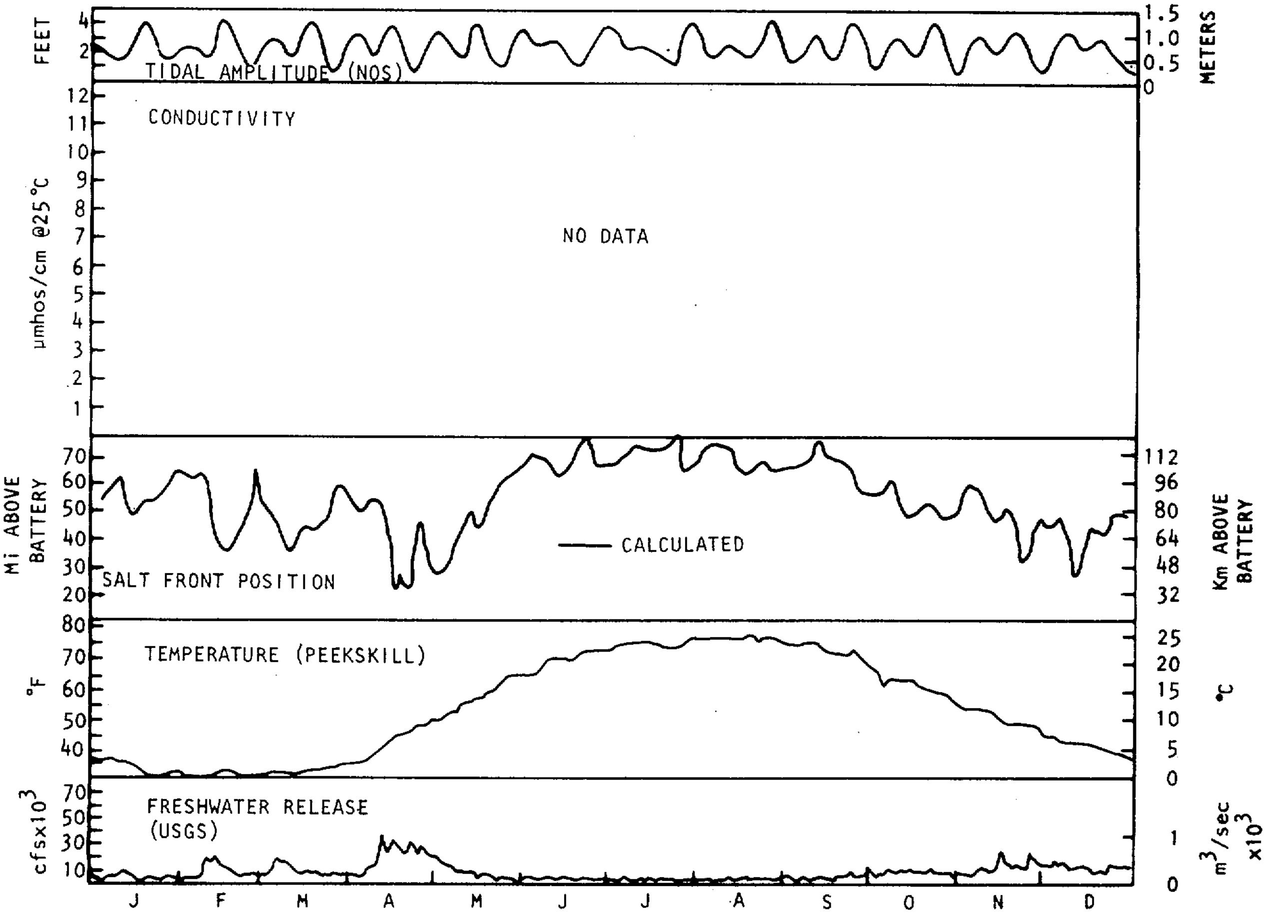
1967

Figure C-1. Page 7 of 9



1966

Figure C-1. Page 8 of 9



1965

Figure C-1. Page 9 of 9

(Updated for 1978)

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