HUDSON RIVER ECOLOGICAL STUDY

In the area of Indian Point

For the Period January 1 to June 30, 1973

SECOND SEMIANNUAL REPORT

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Prepared For

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC

4 Irving Place
New York, New York 10003

TEXAS INSTRUMENTS
INCORPORATED
services group

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FOREWORD

This semiannual report, which has been prepared for Consolidated Edison Company of New York, Inc., by the Ecological Services branch of Texas Instruments Incorporated (TI), contains the analysis and interpretation of data collected in the Hudson estuary from January through June 1973. The design, execution, collection, analysis, and interpretation of the collected data and the writing of the report were primarily the responsibility of the following personnel:

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONTD)

TABLE OF CONTENTS (CONTD)

APPENDIXES

ILLUSTRATIONS

ILLUSTRATIONS (CONTD)

ILLUSTRATIONS (CONTD)

TABLES

TABLES (CONTD)

SUMMARY OF RESULTS

PHYSICAL AND CHEMICAL STUDIES

Temperature

In the analysis of spatial variation of temperature with respect to tidal influences, it was found that shallow areas somewhat sheltered from tidal currents tended to accumulate thermal energy and areas subject to higher degrees of flushing (higher current rates) exhibited mean temperatures lower than the overall mean for the Indian Point region. Variations of this nature were attributable to the interaction effects of morphometry, insolation, and tidal flow.

An interesting water-temperature decrease of 1.2°C which occurred during May and early June was associated with corresponding decreases in air temperature and relatively high rainfall levels.

Currents

Tidal currents followed expected patterns, i.e., freshwater volumes tended to follow the "outside" of river bends and "saltwater" volumes tended to follow deeper areas of the channel by virtue of their greater density. These current patterns seemed to act in concert with the morphometry of the area north of the Indian Point plant to produce an increase in mixing during flood tides.

Conductivity

Conductivities varied between 95 and 8400 μmhos/cm. Distributions of values were associated with deeper channel areas until the saltwater front had extended upstream to such an extent that extensive mixing occurred.

Turbidity

Turbidity values (in terms of percent transmittance) also tended to follow a tidally influenced pattern in areas relatively free of other major turbidity sources. The general influence of turbid tidal flows originating in Haverstraw Bay was greatly overshadowed in shallower and high-turbulence areas.

Percent-transmittance values varied from a low of 6 percent (Haverstraw Bay) to a recorded high of 100 percent (taken in a very deep area south of Bear Mountain bridge).

Dissolved-Oxygen Concentrations

Dissolved-oxygen concentrations (mg/ℓ) decreased in response to increasing spring and summer temperatures, beginning with values averaging near 10.0 (8.0 to 14.1) in April and decreasing to values near 7.0 (2.0 to 9.6). Low values taken during a given sampling period correspond to shallow areas exhibiting detritus accumulations near the bottom.

pH

Relatively small variations in pH values were indicated. The low value recorded during the first months of 1973 was 6.64, with the highest being 8.3 at a beach-seine site in Haverstraw Bay. A decrease in the pH values during May corresponded to the high rainfalls during that period.

BENTHIC RESULTS

Benthic investigations during the first 6 months of 1973 indicated that community composition was virtually unchanged from that observed during the same period of 1972. *Limnodrilus* sp remains the dominant taxon, and the seven most common taxa maintain their dominance with only slight variation in numerical ranking.

Fewer species were recorded during the spring of 1973 as a result of both the use of larger mesh-size screens in the processing of samples and high mortalities of *Congeria leucophaeta* and *Amnicola* sp during the winter months. When total numbers of species are corrected for these factors, the results for the 2 years do not differ appreciably. Mean numbers of several dominant forms increased appreciably during 1973 but, in general, the variations observed seemed to be consistent with temperature and/or salinity responses observed during 1972.

FISH BEHAVIOR AND PHYSIOLOGY

Discharge-Canal Investigations

During the winter and spring of 1973, fish-trapping in the discharge canal continued yet resulted in small catches. No thermal discharge existed during the sampling periods, but the circulators were operating. Because a greater diversity (nine species) and much larger numbers of fish were caught during the fall when temperatures were elevated by thermal discharge, a positive attraction of fish to the heated effluent is confirmed.

Thermal-Plume Investigations

Surface trawls in the plume produced small catches during 1972; gear avoidance was a distinct possibility. Consequently, floating gill nets will be tested during 1973 to determine their effectiveness in catching fish in the plume and control areas.

Thermal-Preference Investigations

Thermal-preference investigations were initiated in the spring of 1973. Apparatus for establishing temperature gradients was constructed and, in initial experimentation, proved to be satisfactory for observing thermal preference. Preliminary results suggested that thermal selections by white perch were dependent on acclimation temperatures and independent of size. White perch that were acclimated to ambient temperatures of 17°C to 20°C selected temperatures of 27°C to 29°C.

Thermal-Avoidance Investigations

Thermal-avoidance experiments were performed with six species. Linear regression demonstrated that white perch, tomcod, and spottail shiners had a significant relationship between avoidance and acclimation temperatures ($\alpha = 0.01$). The relationship between acclimation temperature and avoidance temperature for striped bass during spring was unclear. Striped bass acclimated to temperatures of 14.0°C to 21.2°C avoided temperatures ranging from 21.3 to 29.0°C; white perch acclimated to 6.5 to 15.0°C avoided 15.0 to 26.0°C; tomcod acclimated to 0.5 to 2.1°C avoided 9.9 to 17.6°C; spottail shiners acclimated to 3.0 to 6.3°C avoided 8.0 to 17.2°C; smelt acclimated to 6.0°C avoided 16°C; and alewife acclimated to 10.6 to 12.5°C avoided 16.0 to 18.0°C.

Comparison of the upper avoidance temperatures of Hudson River fish and the theoretical maximum temperatures of the Indian Point plume (as determined by QLM) suggests that none of the investigated species will be behaviorally excluded from the thermal plume of Units 1, 2, and 3 during the spring of the year.

Thermal-Tolerance Investigations

Upper thermal-tolerance determinations for white perch (acclimation temperatures of 8.0°C to 20.0°C) indicated upper lethal temperature limits of 22.8°C to 30.2°C. Thermal-tolerance limits are related to acclimation temperatures, and seasonal effects are suggested. The upper thermal-tolerance zone of white perch was 392 $^\circ C^2$, which is similar to that of other estuarine species but lower than most freshwater/warmwater teleosts. Speculation on the effects of a thermal discharge is premature at this time.

FISHERIES SAMPLING PROGRAM

The 1973 fisheries sampling program has provided not only catch statistics for a number of species over a large area of the Hudson River* but fish for use in various laboratory studies related to environmental physiology and behavior and the biological characteristics of these fish species. Analysis-of-catch data provide information on spatial distribution and movements.

Beach-seine catch/effort for white perch and striped bass increased in an upriver direction in April-May. Also for both species, axial bottom trawl catch/effort increased in an upriver direction from late April to early May but declined precipitously over the entire 30-mi (48-km) region covered from early May to early June. White perch catch/effort in trap nets increased substantially in the month of June. The combination of information from these three gears suggests an upriver and inshore movement of both white perch and striped bass in the spring and early summer. The time of this movement coincides well with the white perch spawning season.

*From Troy, N.Y. in the north to the George Washington Bridge in the south.

The surface trawl was modified in 1973 and now provides an effective means of sampling pelagic fish. A pound net was used experimentally in the spring of 1973 but failed to catch any large striped bass. Gill nets provided the best means of obtaining large striped bass for study. Electrofishing, which was used in shallow areas inaccessible to other gear, provided a few large striped bass.

TAG/RECAPTURE PROGRAM

A feasibility study for tagging large striped bass to determine their migration patterns and, potentially, the contribution of the Hudson River stock to the mid-Atlantic fishery has been initiated. Striped bass captured primarily in Croton Bay and a few from farther upriver were tagged and released. Approximately 7 percent of the tags have been recovered, most from Western Long Island Sound. Initial results are encouraging.

Very few young stripers have been captured during 1973. No tag-survivorship experiments have been conducted on young striped bass in 1973 and only a few marked fish have been released. None of these marks nor any of the 1972 releases of young-of-the-year striped bass have been recovered. Most of the young stripers captured have been saved for the physiology and behavior experiments.

Survivorship experiments with white perch reaffirm the feasibility of the tagging program in the spring season. Continued research into a treatment method to reduce the secondary fungal infections, however, has not produced a satisfactory solution.

A substantial number of tagged and marked white perch have been recovered in 1973. The data indicate migration throughout the estuary in the winter and spring with impingement at Indian Point drawing from the entire estuarine population. Figures based on current data for the 1972 population size indicate initial underestimates in 1972, but the types of bias present in

1972 are thought to be absent from the currently calculated estimate of the >100-mm white-perch population. A preliminary estimate of the <100-mm group has been based on CPUE data and the size distributions in the fishing gears.

The Petersen estimate for all sizes of white perch in the fall of 1972 is 23.4 million, while the Spring, 1973 estimate for perch larger than 100-mm is 1.6 million. No recaptures of tagged or clipped white perch under 100 mm were made in Spring, 1973, but the CPUE size ratio (over 100 mm vs under 100 mm) yielded an estimate of one million yearling perch.

When the actual impingement from January to June 1973 is compared to the 1972 and 1973 population estimates, the 1973 impingement (January to June) ranged from 0.3 to 1.1 percent of the total population. The direct percentage of the 1972 tagged white perch population impinged during the first 6 months of 1973 was 0.21%. No attempt was made to extrapolate these impingement percentages to full operating conditions. The analysis is continuing.

BIOLOGICAL AND MORPHOLOGICAL CHARACTERISTICS OF WHITE PERCH AND STRIPED BASS

Age and Growth

This report does not include information pertaining to growth of white perch and striped bass inasmuch as 1973 annulus formation had not been completed in time for data analysis.

Food Habits

Although approximately one half of the white-perch stomachs examined in the winter months were empty, *Gammarus* continued to be the predominant food item for those specimens containing food. The occurrence of empty stomachs sharply diminished in April. Calanoid copepods, *Gammarus*, and chironomid larvae were most important in the diet of white perch collected in Region I. During the spring, recently spawned alewife eggs were predominant in Region-III stomachs.

In order of importance, calanoid copepods, *Gammarus*, *Neomysis*, and *Daphnia* were the primary diet of small striped bass collected in Region I during April and May.

The majority of stomachs from large striped bass were empty. White perch, alewives, and tomcod were the forage species most often observed in those stomachs containing food.

Reproduction

Gonads from white perch collected in our study area during the spring of 1973 have been preserved for later analysis.

Striped-bass spawning occurred from approximately the first week in May through the first week in June, with peak spawning occurring about May 15 when water temperatures approximated 15 to 16°C. No mature females less than 6 years old were found, but three males were mature at age 3. The percentage of contributing mature males ages 4 through 7 varied from 60 to 89 percent. Our findings indicate that many females in the 1973 spawning population were not mature at lengths previously associated with maturity.

Fecundity estimates for 41 striped bass ranged from 59,000 to 2,707,000 eggs per fish. The average number of eggs by age class was found to increase with an increase in age up to 12 years. The total number of eggs by body weight was 173,900/kg, which compared favorably with earlier reports.

The majority of spent ovaries were nearly void of mature eggs, with only one specimen showing retention of some 39,000 eggs, representing only 2.5 percent of the weighted mean individual fecundity estimate for that age group. No resting ovaries were observed, although the possibility of resting or senile testes was encountered.

Subpopulations

Through the use of morphometric and meristic characteristics, an attempt was made to identify resident or transient subpopulations of white perch and young striped bass. Multivariant discriminant analysis based on different combinations of meristic characteristics was unsuccessful in defining biologically realistic subpopulations. The results are confusing but can be interpreted as indicating one large mixing population of perch and young striped bass.

To help determine the contribution of Hudson River-born striped bass to the Atlantic fishery and expand present knowledge on racial investigations of Hudson River fish, 165 large striped bass were examined in the spring of 1973. Total length, standard length, fork length, lateral-line scale counts, and number of pectoral, anal, and soft dorsal rays were recorded and compared with previous studies. The results indicate that the present-day Hudson River striped bass have the same basic characteristics as their forefathers described by Raney and de Sylva in 1953 ($\alpha = 0.05$) and that the distribution of these characteristics is significantly different from that of described Chesapeake Bay striped bass. In contrast to the meristic studies on white perch and young striped bass, the subpopulation approach will provide very useful information on the older bass.

Miscellaneous

Length/weight relationships for a sample of impinged white perch in the fall of 1972 were compared with river-caught fish and found to be significantly lighter for comparable lengths (TI annual report, 1973a). A similar comparison using much larger sample sizes was conducted in the spring of 1973; once again, impinged white perch were significantly lighter ($\alpha = 0.05$) than fish collected in routine sampling throughout Region I.

Predicted weights for three sizes (lengths representing age-group modes) of impinged white perch were calculated from computed length/weight regressions for individual months through the winter season and into the spring as an index of relative stress through the winter. The resulting weights indicated winter stress to be much more severe for fish in their first year of life. This is the same age group that is relatively most vulnerable to impingement during the winter season.

CHAPTER I

INTRODUCTION

This semiannual report is part of a series describing the progress of a long-term study (through 1977) designed to determine the effects which Consolidated Edison's nuclear power plants at Indian Point have on the Hudson River ecosystem. The scope, timetable, and design are detailed in the 1972 annual report (Texas Instruments Incorporated, 1973a).

Briefly, there are two major objectives: to determine the biological significance of fish impingements suffered at the intake screens and to determine the biological significance of thermal and chemical discharges from the once-through cooling system. New York University is determining the significance of entrainment, and Texas Instruments (TI) will integrate the results into a complete impact analysis.

The TI studies not only concentrate on two fish species [white perch, *(Morone americana)* and striped bass *(M. saxatilis)*] and on one benthic species *(Cyathura polita,* Isopoda) at a high level of quantitative population and physiological ecology but include extensive quantitative community ecology measurements. Large-scale field experiments (upstream control/plant-site experimental, and before/after), as well as laboratory experiments, are incorporated into the design to measure plant effect empirically. These studies also are being used to update or completely revise long-term models of plant effect on the striped bass in the estuary.

This document focuses on the results of the study from January through June 1973, but the physiology/behavior work is reported on a more seasonal basis, i.e., covering the period through the spring season based on water temperature. Some results and analyses have been based on data collected in 1972 which, because of time restraints, could not be reported in the 1972 annaul report (Texas Instruments Incorporated, 1973a).

CHAPTER II

PHYSICAL AND CHEMICAL STUDIES

Introduction

Chemical and physical investigations associated with the Indian Point ecological survey of the Hudson estuary are being made to describe this portion of the ecosystem and determine power-plant effects on it with the intent, as ancillary functions, to estimate, isolate, or eliminate sources of variability in fisheries and benthic data. Much of the variability in the distribution and activity of populations within an estuary is associated with tidal effects, so, in addition to the regular analyses, the results in this report have been interpreted relative to tidal influences. By far, the most rapid changes occurring in an estuary are a result of tidal influences.

Reported are temperature, conductivity, turbidity, dissolved oxygen, current velocity, and several meteorological measurements taken from January through June 1973.

Equipment malfunctions have so plagued nutrient analyses that presentation of this information has been omitted at this time; it will be presented in a later report when sufficient data have been collected to permit adequate interpretation.

METHODS AND MATERIALS

Field measurements were made at 18 stations indicated in Figure II-1. Temperature, conductivity, pH, and dissolved-oxygen concentrations were determined at weekly intervals utilizing a Martek Mark-II water-quality monitoring system. Measurements were made at 3-m depth intervals. Turbidity measurements in terms of percent transmittance also were made in this manner using a transmissometer having a 10-cm light-path length.

Stream-current analysis was carried out with a current velocity-direction sensor combination incorporating a magnetic direction base over a 26-hr period at 2-week intervals — a schedule which allows (and will allow) measurement of predominant current regimes at each sampling station once during the present calendar year. At the time of this report, current regimes had been determined for stations 2, 3, 5, 7, 10, and 11. Supplementary flow information was provided in the form of estimated daily water-release rates at Green Island, New York. In addition, inflow information was provided by precipitation estimates incorporated in a regular meteorological monitoring program (relative humidity, air temperature, barometric pressure, and precipitation).

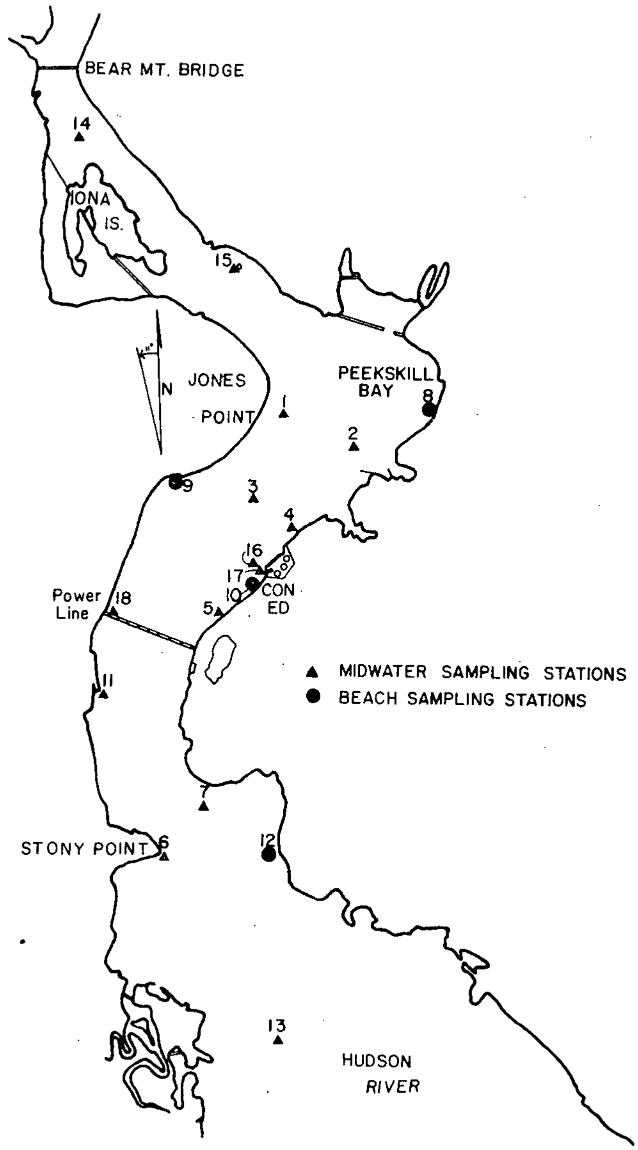


Figure II-1. Area Map Showing Sampling Stations

Wind speed and direction were determined by constant monitoring through use of a wind recording system. Air temperature, relative humidity, and barometric pressure were monitored with a meteorograph.

RESULTS AND DISCUSSION

Temperature/Current Relationships

Relative relationships between station means and overall means for each of five parameters (temperature, conductivity, turbidity, pH, and dissolved oxygen) were used as indices of horizontal variation; these differences are presented in Figures II-2, II-8, II-15, II-16, and II-17 as percentages of the overall mean for the given parameter. Negative values indicate station values below the overall mean.

In Figure II-2 are the water-temperature percentage differences. Of particular note are the high percentages indicated for stations 8, 9, 10, 11, and 12. These stations are in shallow beach areas and, as such, are subject to large insolation effects when compared to deeper areas. If only surface temperatures are considered in this manner, a slightly less biased interpretation is derived.

In Figure II-3 are surface percentage differences. The same pattern remains: shallower stations tend to exhibit relatively high deviations. However, the relative inequity with respect to deeper stations has been offset to some extent. Of interest is the preponderance of negative (lower than the overall mean) values in the immediate area of the Indian Point plant.

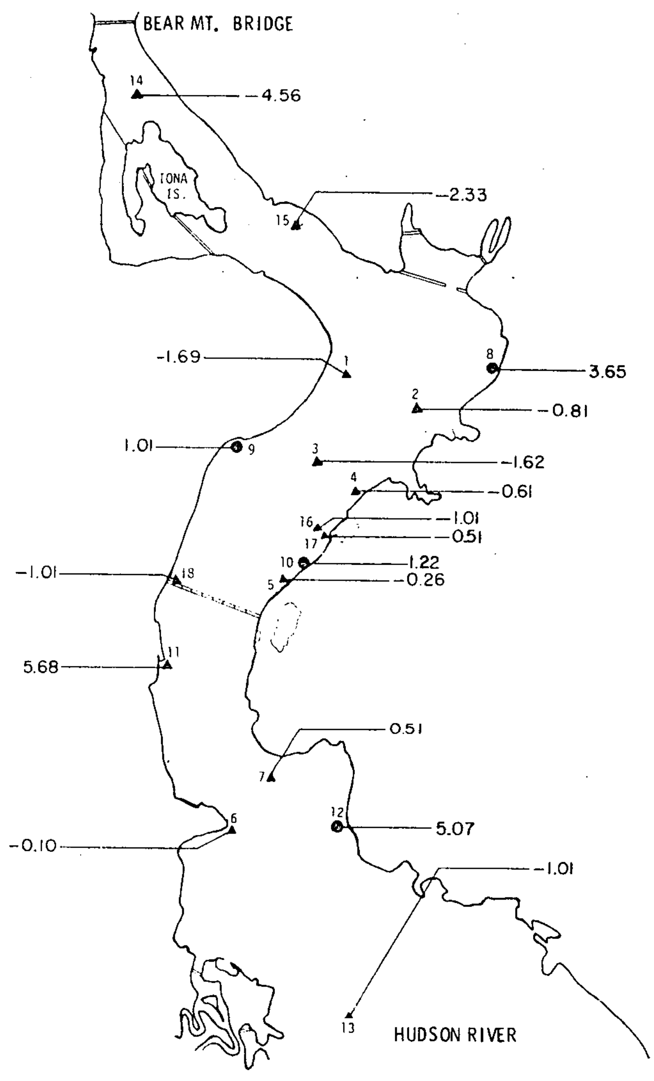


Figure II-2. Relative Deviations (Percent) from Overall Mean Temperature

It is interesting to note the similarity of percentage differences for temperature at stations 1, 2, 3, 4, 6, 13, 16, and 18; the values indicated at stations 6 and 13 suggest no longstanding thermal effects when compared to values at the remaining nonbeach stations upstream of the Indian Point plant effluent — and this comparison appears even more significant in view of the possible confluence of effluents from the Indian Point and Lovett plants. It should be noted, however, that the extent (or existence) of the Indian Point thermal plume could not be demonstrated in the area of Stony Point (stations 6 and 7) (Texas Instruments Incorporated, 1973a).

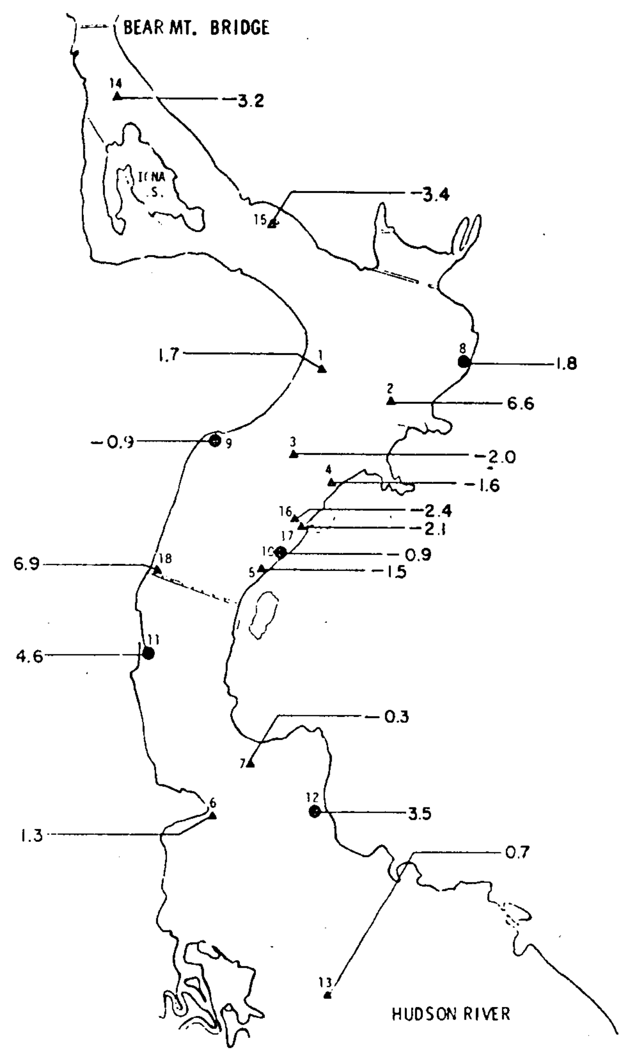


Figure II-3. Relative Deviations (Percent) from Mean Surface Temperature

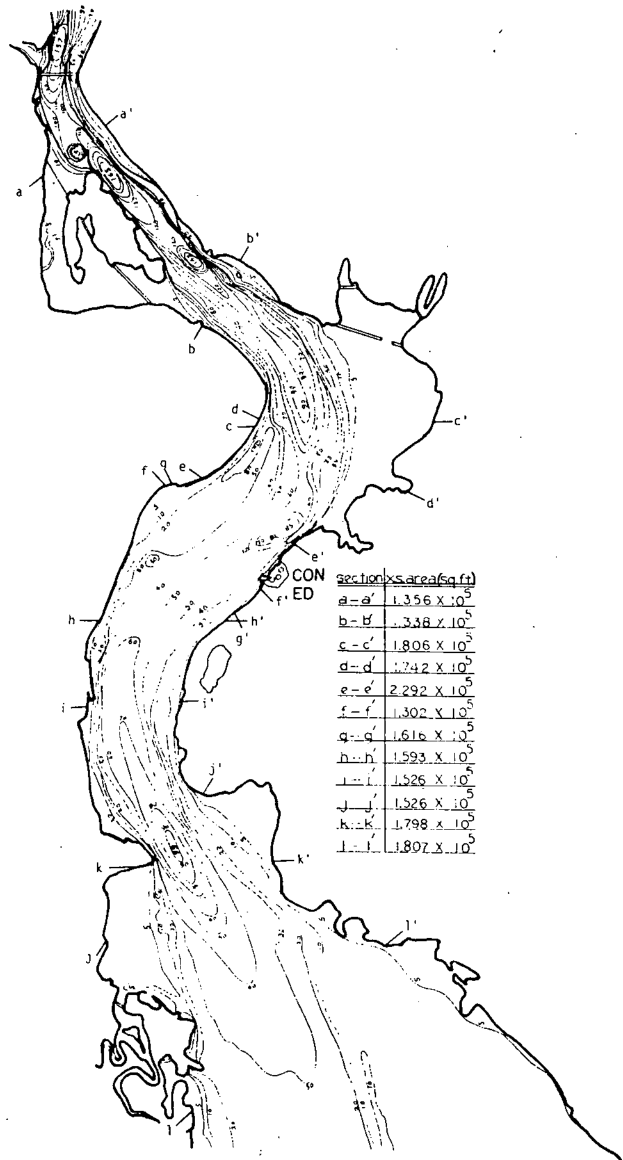
One further thermal characteristic is of particular interest. There is an area immediately downstream of the Indian Point effluent (station 10) where there was a relatively large thermal accumulation. When compared with the four adjacent stations, station 10 exhibited a somewhat higher mean surface temperature. This condition, previously documented (Texas Instruments, 1973) apparently results from the following:

(1) A general compression of the thermal plume against the east shoreline.

(2) A tendency for flood tides to follow the west shoreline between RM 42 and RM 43 (river kilometers 67 and 69), leaving the area of station 10 relatively undisturbed.

(3) A high insolation effect due to shallowness.

The significance of the influence of river morphometry on temperature distribution can be better appreciated if bottom contours, cross-sectional area, and current-velocity vectors are considered jointly. Figure II-4 is a bottom contour map of the Hudson River from RM 38 to RM 47 (km 61 to 75). Figure II-5 is an area map indicating predominant current directions; current measurements during 1972 are included to provide a more complete picture. Open triangles indicate current measurement stations which did not correspond to originally established sampling stations. The predominant current vectors were estimated from current plots appearing in Appendix A, Figures A-1 through A-6.



section	xs area (sq ft)
a-a'	1.356×10^5
b-b'	$.338 \times 10^5$
c-c'	1.806×10^5
d-d'	1.742×10^5
e-e'	2.292×10^5
f-f'	1.302×10^5
g-g'	1.616×10^5
h-h'	1.593×10^5
i-i'	1.526×10^5
j-j'	1.526×10^5
k-k'	1.798×10^5
l-l'	1.807×10^5

Figure II-4. Bottom Contours (ft) and Cross-Sectional Areas for Indian Point Region

At the present stage in the current analysis, a rule-of-thumb seems appropriate. Major current vectors tend to follow or parallel deeper channel areas, with major projections (points) acting to impose differences in flow lines between flood and ebb tides; this seems to be the case with respect to current measurements at stations 2, 3, 5, and 10, with both stations 5 and 10 appearing to exhibit higher and more predominant downstream vectors, while the greatest currents at station 2 are in the upstream direction. This change in predominance along the east shore, combined with approximately equal predominance of upstream and downstream velocities at station 3, indicates that major flood-tide currents are directed toward the Peekskill Bay flat by a moderately shallow bottom formation south of Jones Point and directly across the river from the Indian Point plant.

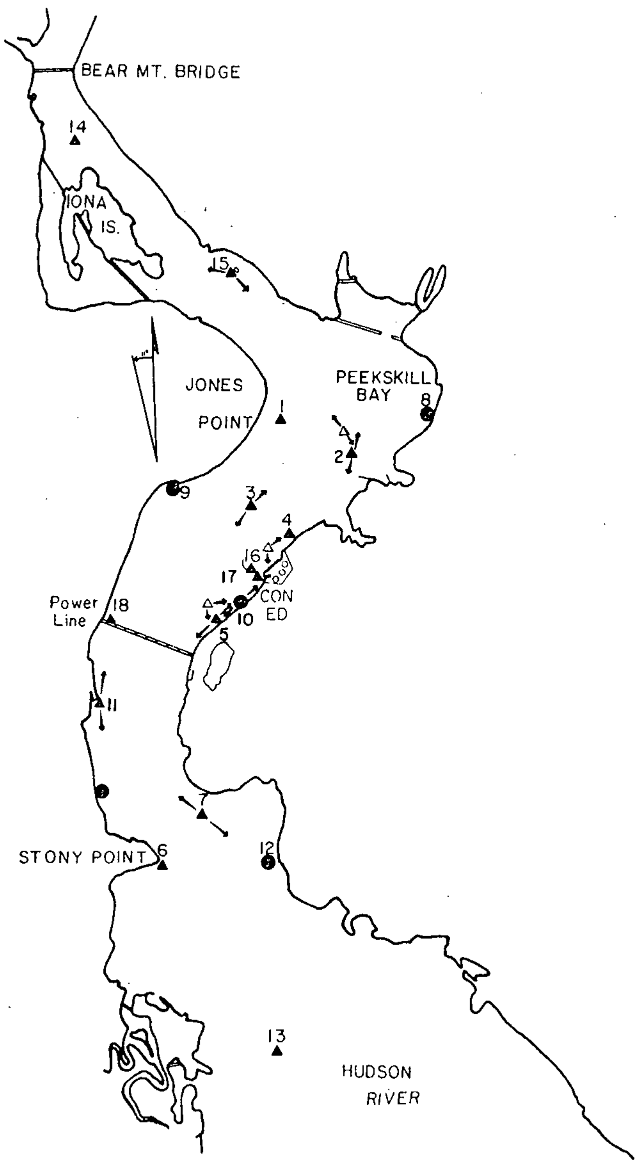


Figure II-5. Generalized Current Regimes at Selected Stations

Also included in Figure II-4 is a chart of cross-sectional areas for indicated transects. The transects correspond to the locations of the 18 sampling stations indicated in Figures II-1, II-2, II-3, and II-5. These cross-sections are presented here simply to indicate major river-wide flow-rate differences from one section to another. Of particular interest is a dramatic decrease in apparent cross-sectional area from transect e-e′ to transect f-f′ (probably imposing a greater river-wide flow rate at the latter section line). The significance of this change lies in the probability that the area immediately in front of the Indian Point plant acts as a venturi, thereby aiding in diluting plant effluent and preventing the plume from extending into the river to any large degree during ebb tides. This is not the case with flood tides, since the cross-sectional area rather suddenly decreases between the effluent and transects e-e′, d-d′, and c-c′ (Peekskill Bay). In Figure II-6, infrared thermal imagery collected on August 10, 1972, indicates a larger lateral plume extension in the Peekskill Bay area during flood tide than during ebb tide. It is conceivable that the plume may have been directed laterally across the river by the Peekskill Bay flat; however, the increase in extension appears to begin in the area of the e-e′ section line.

Table II-1 includes means, ranges, and standard errors for station water temperature between March and June. No range or standard error is indicated for March since only one sampling time was involved.

Figure II-7 shows the relation of weekly overall temperature means to the range of values established by the USGS over the 1959-1971 period in the area of Peekskill Bay. An interesting mean temperature decrease occurred in the last half of May. The only information which might have a bearing on this phenomenon is a relatively large decrease in air temperature from the last weeks of April into the first half of May — from 16.5°C in the first week to 13.6°C during the third week.

Conductivity

Bottom contours also influence distribution of conductivity values within the river.

Monthly means of conductance by station, along with associated standard (ranges) and standard errors, are given in Table II-2.

MAX EBB

SLACK AFTER EBB

MAX FLOOD

SLACK AFTER FLOOD

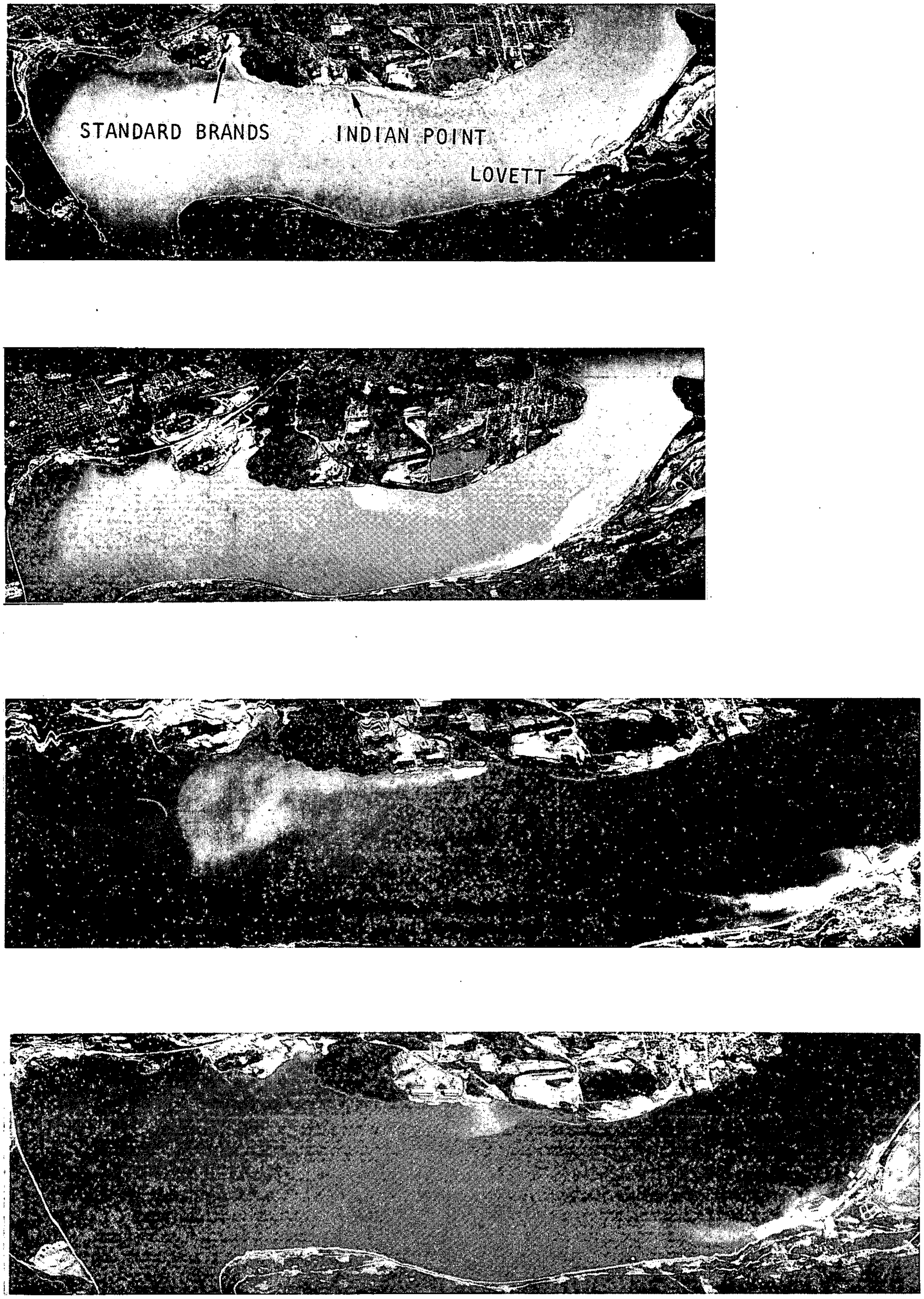


Figure II-6. August 10, 1972, Thermal Imagery (Texas Instruments Incorporated, 1972)

Table II-1

MONTHLY MEANS, RANGES, AND STANDARD ERRORS FOR TEMPERATURE (°C) BY STATION, 1973

		Month					
Station	Statistic	Jan	Feb	Mar	Apr	May	Jun
1	High			4.8	10.00	14.50	21.20
	Mean			4.7	7.70	13.40	18.60
	Low			4.6	5.80	11.40	14.90
	Standard error				0.72	0.68	1.37
2	High			5.0	9.80	15.80	21.20
	Mean			4.8	7.66	13.70	18.70
	Low			4.8	5.80	11.40	15.00
	Standard error				0.72	0.84	1.35
3	High			4.8	10.00	14.50	21.50
	Mean			4.6	7.70	13.48	18.80
	Low			4.6	5.90	11.40	14.90
	Standard error				0.72	0.65	1.41
4	High			5.0	9.80	15.00	21.20
	Mean			4.9	7.70	13.65	18.75
	Low			4.8	5.80	11.60	14.90
	Standard error				0.71	0.69	1.36
5	High			5.2	10.00	15.00	21.50
	Mean			5.1	7.23	13.60	18.73
	Low			5.0	5.80	11.80	15.00
	Standard error				0.61	0.67	1.37
6	High			5.0	9.80	15.50	22.10
	Mean			4.7	7.80	13.70	19.03
	Low			4.4	5.80	11.20	14.90
	Standard error				0.71	0.77	1.41
7	High			5.0	10.00	14.80	21.60
	Mean			4.9	7.92	13.65	19.10
	Low			4.8	5.80	11.40	15.20
	Standard error				0.75	0.64	1.35
8	High			5.8	11.60	15.40	21.20
	Mean			5.8	8.40	13.60	19.55
	Low			5.8	6.00	11.40	16.00
	Standard error				1.04	0.83	1.21
9	High			4.8	10.00	14.90	21.30
	Mean			4.8	8.06	13.63	19.15
	Low			4.8	5.90	11.80	15.10
	Standard error				0.91	0.67	1.38
10	High			5.2	10.00	15.00	21.90
	Mean			5.2	7.90	13.78	18.73
	Low			5.2	5.90	11.80	15.30
	Standard error				0.79	0.71	1.89
11	High			6.2	9.80	15.20	24.00
	Mean			6.2	8.16	14.30	20.55
	Low			6.2	5.90	12.20	15.50
	Standard error				0.71	0.71	1.84
12	High			5.2	10.00	15.80	22.00
	Mean			5.2	8.12	14.20	20.13
	Low			5.2	6.00	12.80	16.80
	Standard error				0.80	0.62	1.17
13	High			5.0	10.00	15.00	21.80
	Mean			4.8	7.78	13.48	19.08
	Low			4.4	5.80	11.20	15.00
	Standard error				0.72	0.75	1.39
14	High			5.0	9.80	14.50	21.30
	Mean			4.7	7.60	12.85	18.60
	Low			4.6	5.50	11.00	14.80
	Standard error				0.74	0.57	1.44
15	High			4.8	9.80	14.50	21.20
	Mean			4.7	7.68	13.30	18.60
	Low			4.6	5.80	11.00	14.90
	Standard error				0.73	0.69	1.40
16	High			5.0	10.00	15.00	21.50
	Mean			4.8	7.73	13.55	18.68
	Low			4.8	5.80	11.40	14.90
	Standard error				0.75	0.72	1.39
17	High			5.0	10.00	15.00	21.50
	Mean			4.8	7.72	13.55	18.68
	Low			4.8	5.80	11.80	15.00
	Standard error				0.75	0.72	1.39
18	High				10.00	15.00	21.80
	Mean			5.8	7.22	13.65	19.00
	Low				5.80	11.60	15.00
	Standard error				0.68	0.89	1.35

Table II-2

MONTHLY MEANS, RANGES, AND STANDARD ERRORS FOR CONDUCTIVITY (μmho/cm, 25°C) IN INDIAN POINT REGION (REGION I), 1973

		Month					
Station	Statistic	Jan	Feb	Mar	Apr	May	Jun
1	High			100	2700	300	203
	Mean			98	117	183	157
	Low			95	100	143	114
	Standard error				1.3	34.4	14.7
2	High			115	4700	430	274
	Mean			111	121	214	163
	Low			110	120	151	114
	Standard error				2.8	55.9	18.7
3	High			100	4300	320	510
	Mean			98	121	188	202
	Low			95	115	147	114
	Standard error				1.8	39.0	59.7
4	High			115	6000	330	290
	Mean			109	121	197	175
	Low			90	120	151	114
	Standard error				2.2	44.1	32.6
5	High			115	7800	390	390
	Mean			111	122	204	194
	Low			105	120	157	116
	Standard error				0.9	48.8	43.4
6	High			1900	8400	580	570
	Mean			491	122	204	257
	Low			135	105	165	152
	Standard error				2.3	45.6	71.1
7	High			135	4400	840	700
	Mean			131	123	304	310
	Low			125	120	170	157
	Standard error				1.5	144.7	120.4
8	High			120	1900	340	195
	Mean			120	118	203	179
	Low			120	118	155	125
	Standard error				3.8	45.9	11.8
9	High			105	3000	410	380
	Mean			105	123	216	207
	Low			105	120	150	118
	Standard error				2.9	64.6	58.9
10	High			120	2900	320	360
	Mean			120	123	197	216
	Low			120	120	160	118
	Standard error				1.5	41.2	72.8
11	High			140	4100	405	600
	Mean			140	127	219	285
	Low			140	125	165	160
	Standard error				1.5	61.3	105.4
12	High			200	4200	1200	780
	Mean			200	125	185	362
	Low			200	125	175	168
	Standard error				2.5	18.1	142.2
13	High			2400	8000	1200	1500
	Mean			1032	122	150	229
	Low			180	120	145	151
	Standard error				1.5	3.6	60.2
14	High			110	3600	230	174
	Mean			106	126	168	143
	Low			105	125	130	120
	Standard error				0.5	20.1	8.1
15	High			110	3200	350	167
	Mean			110	119	191	148
	Low			110	110	150	118
	Standard error				2.8	41.0	10.4
16	High			115	7200	310	520
	Mean			111	124	190	215
	Low			110	120	153	113
	Standard error				0.9	36.4	60.0
17	High			115	3000	320	375
	Mean			113	125	195	200
	Low			110	120	157	115
	Standard error				2.5	37.9	55.7
18	High				5100	390	475
	Mean				123	228	223
	Low				100	143	115
	Standard error				2.0	65.4	81.7

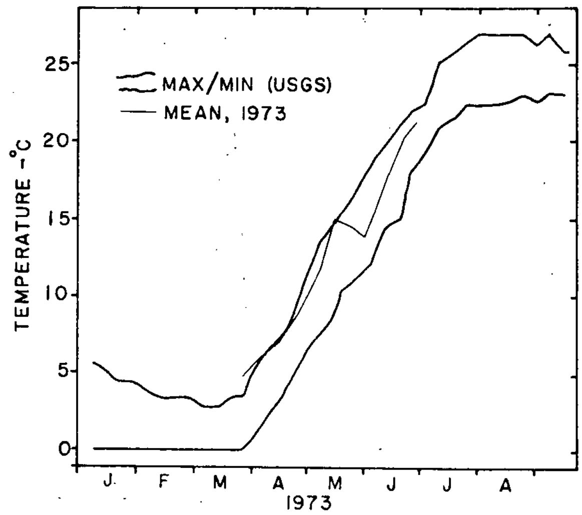


Figure II-7. Relationship of Measured Mean Temperatures to Absolute Temperature Ranges for 1959-1971 (USGS)

In Figure II-8 are the percentage deviations from the overall conductivity means. Saline water, often called a "salt wedge," tended to follow the deeper areas, proceeding along the west shore from Stony Point to the area of the Lovett plant and then back along the east shore into the deep area upstream of the Indian Point plant. This mass then entered the shallower areas such as the beach area south of the Indian Point effluent only after the saltwater incursion process had proceeded somewhat farther upstream.

Figure II-9 illustrates the saltwater incursion process: the upper graph gives weekly means for specific conductance; the lower graph presents salt-front extension in terms

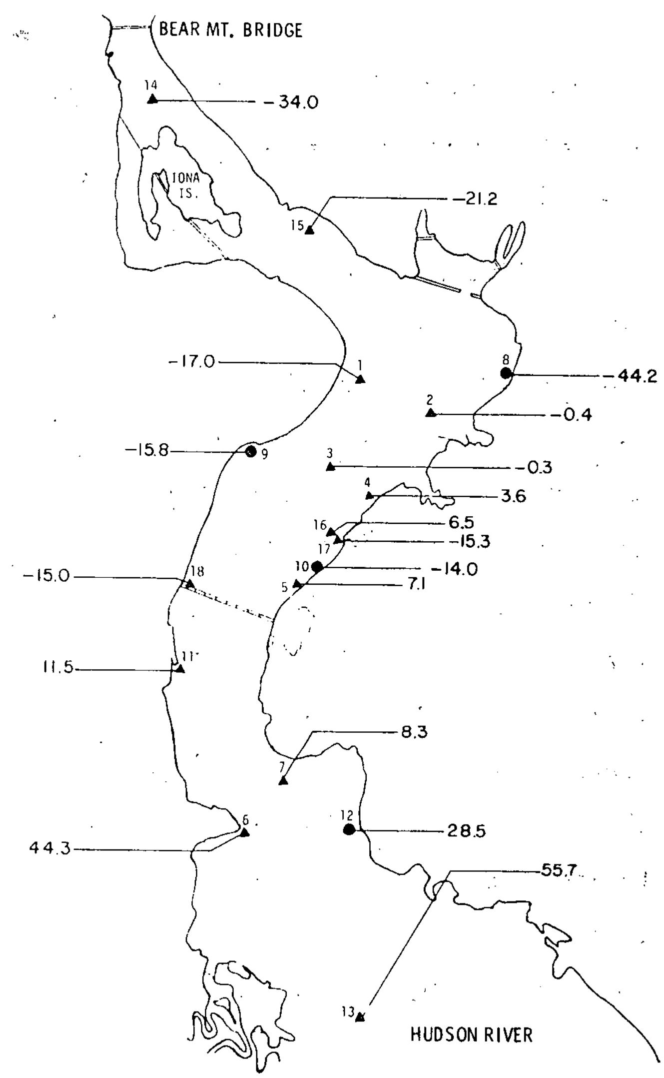


Figure II-8. Relative Conductivity Deviations (Percent) from Overall Mean of river miles (RM). For the purposes of illustration, a salt front is defined here as 0.15 $^{o}/oo$ salinity (375 μmhos/cm specific conductance at 25°C). Only occasional saltwater incursion above Stony Point was observed before the end of May 1973, with incursions becoming more frequent (although apparently less extensive) during June.

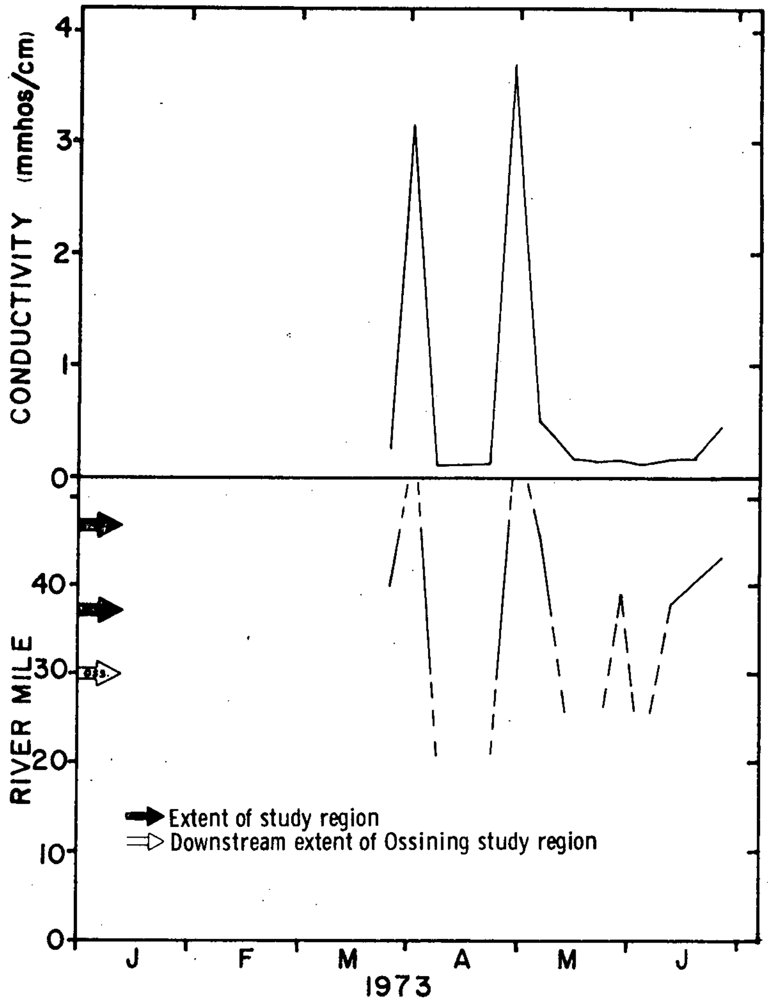


Figure II-9. Saltwater Influx Process

The process of saltwater intrusion and mixing has been adequately discussed by Pritchard (1952), Goldman (1970), Gross (1972), and especially Lauff (1967). Further elaboration has been made by Ketchum (1970) and Howells (1972), who have suggested a relatively large degree of mixing within the Hudson River estuary, especially in the section between Poughkeepsie and Haverstraw Bay which the latter author describes as oligohaline. TI efforts to date indicate that substantial mixing is the general case, although there is some slight indication of undetermined significance that a slight layering may occur at maximum ebbing.

Turbidity

Tidal influences were also seen in the variability of turbidity levels. This relationship was particularly noticeable on June 14 when a 26-hr current water-quality monitoring sequence was carried out at station 3 (Figure II-10). The apparent concurrent variation at this station may be quite deceptive in that high turbidities (low percent transmittances) originating in Haverstraw Bay would not be generated immediately by a salt wedge moving through the Stony Point channel; rather, a degree of lag would be expected, yielding a turbidity maximum 3 to 4 hr after initiation of flood-tide currents. The apparent lag between ebb-tide current initiation and minimum turbidity was somewhat more variable, ranging from 1 to 3 hr. The same lag situation seemed to be in effect also at station 7 where flow rates were rather high and rhythmic (Figure II-11); being somewhat sheltered from flood tides, however, as indicated in Figures II-12 through II-14, stations 2, 5, and 10 were not subject to high current velocities and, and as a consequence, turbidity variations were less severe and/or less periodic. This condition was maximized in the area of stations 5 and 10.

Table II-3 presents monthly mean ranges and standard errors for station turbidities in terms of percent transmittance, and Figure II-15 gives station mean deviations from the overall percent transmittance mean. Negative values represent mean transmittances below the overall mean such that negative values correspond to higher turbidities. High turbidities (low %T) at station 17 are apparently a function of turbulence in the area of the effluent ports.

Dissolved Oxygen

Figure II-16 represents the relative percentage deviation of station mean dissolved oxygen (DO) values from the overall mean for the Indian Point region. There are recognizable patterns with respect to depth, horizontal position, or proximity to the Indian Point plant. Low values were found at stations 1, 3, and 15, none of which has been demonstrated to be within the area of the plume (see Figure II-6); in fact, one higher mean value was calculated for station 5 which is within the plume during ebb tide. The high values at stations 8, 12, 16, and 18 evidence no pattern since 16 and 18 are moderately deep (approximately 15 m) and 8 and 12 are beach-seining stations.

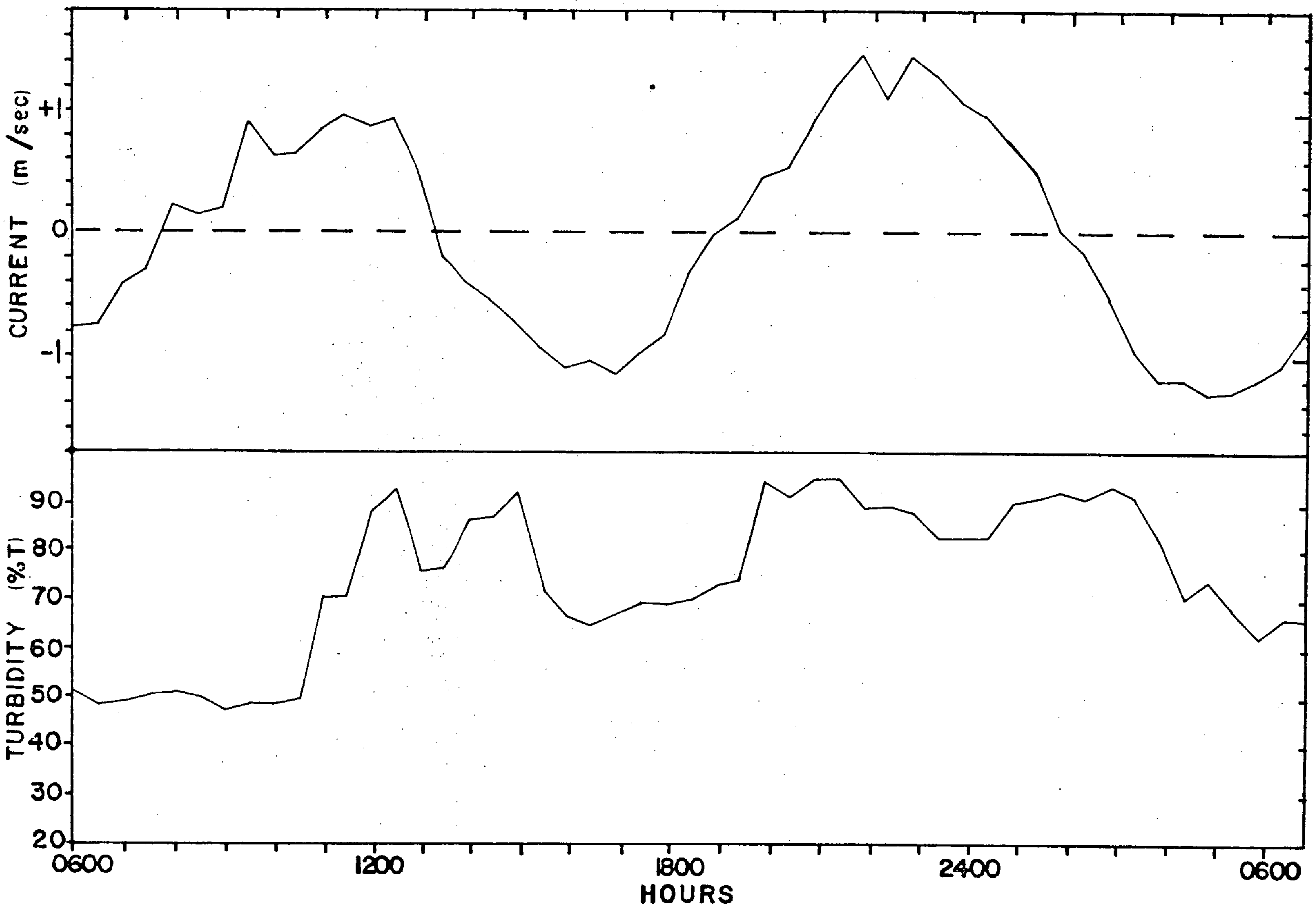


Figure II-10. Current/Turbidity (%T) Relationships at Station 3, June 14, 1973

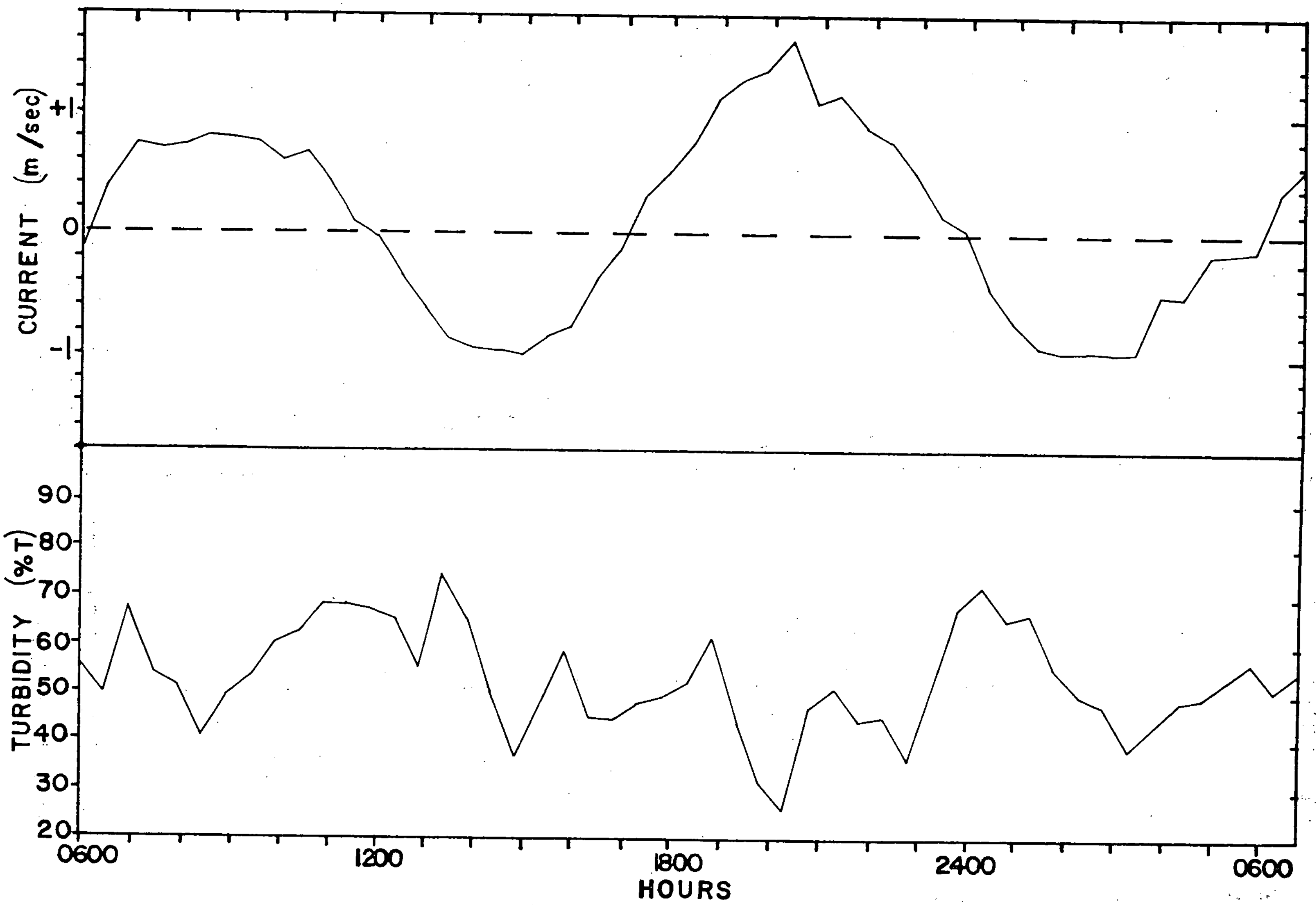


Figure II-11. Current/Turbidity (%T) Relationships at Station 7, June 28, 1973

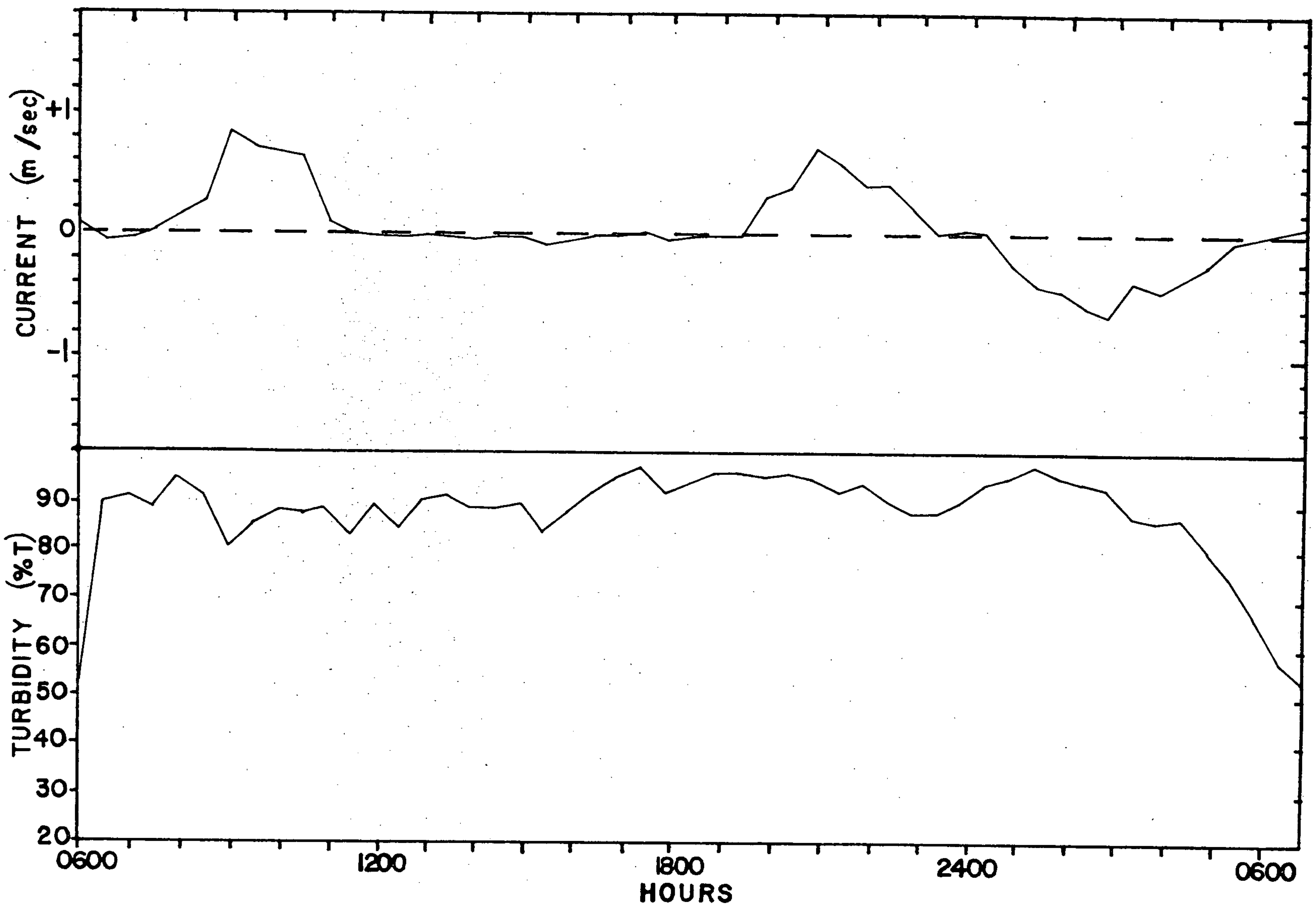


Figure II-12. Current/Turbidity (%T) Relationships at Station 2, May 31, 1973

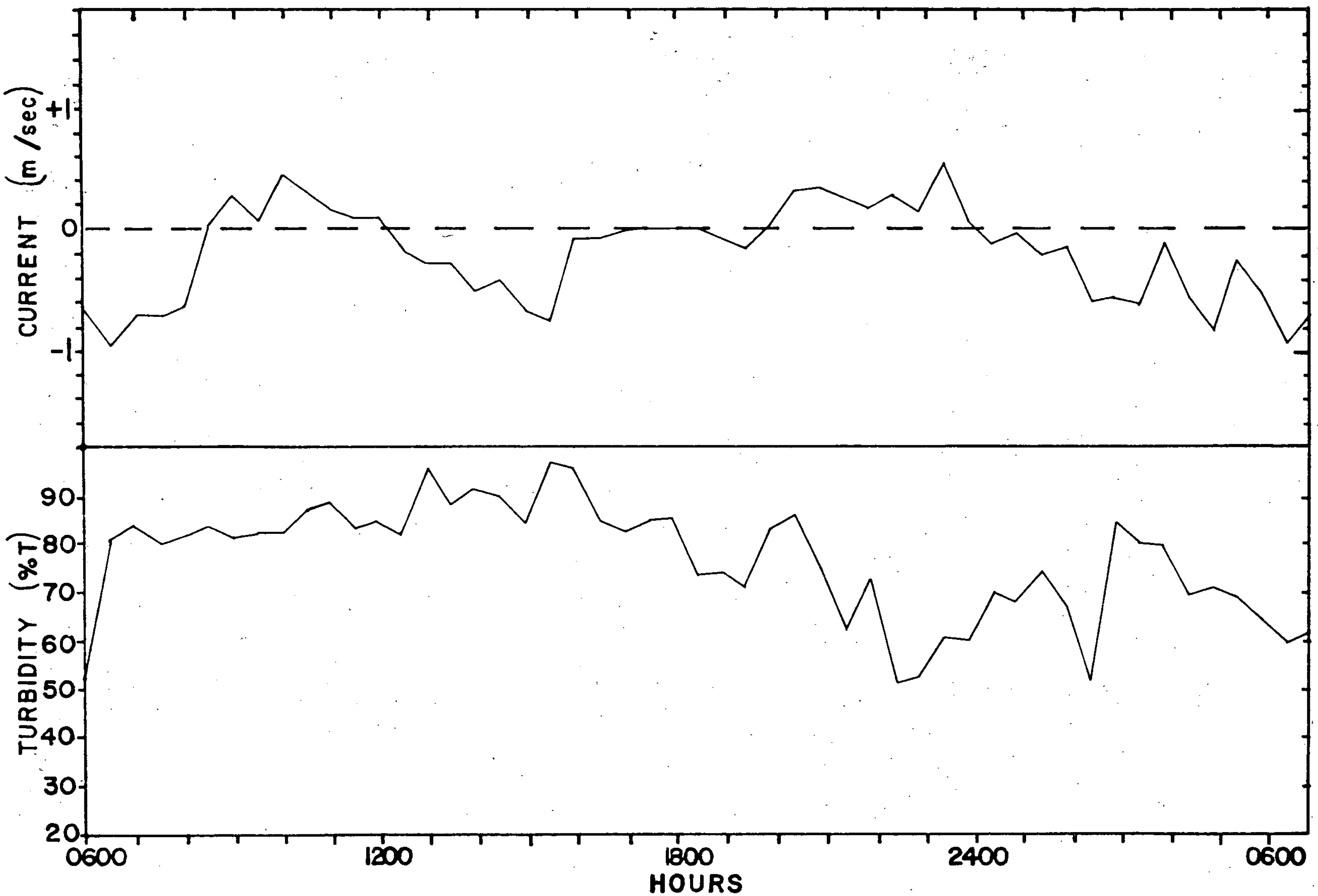


Figure II-13. Current/Turbidity (%T) Relationships at Station 5, May 17, 1973

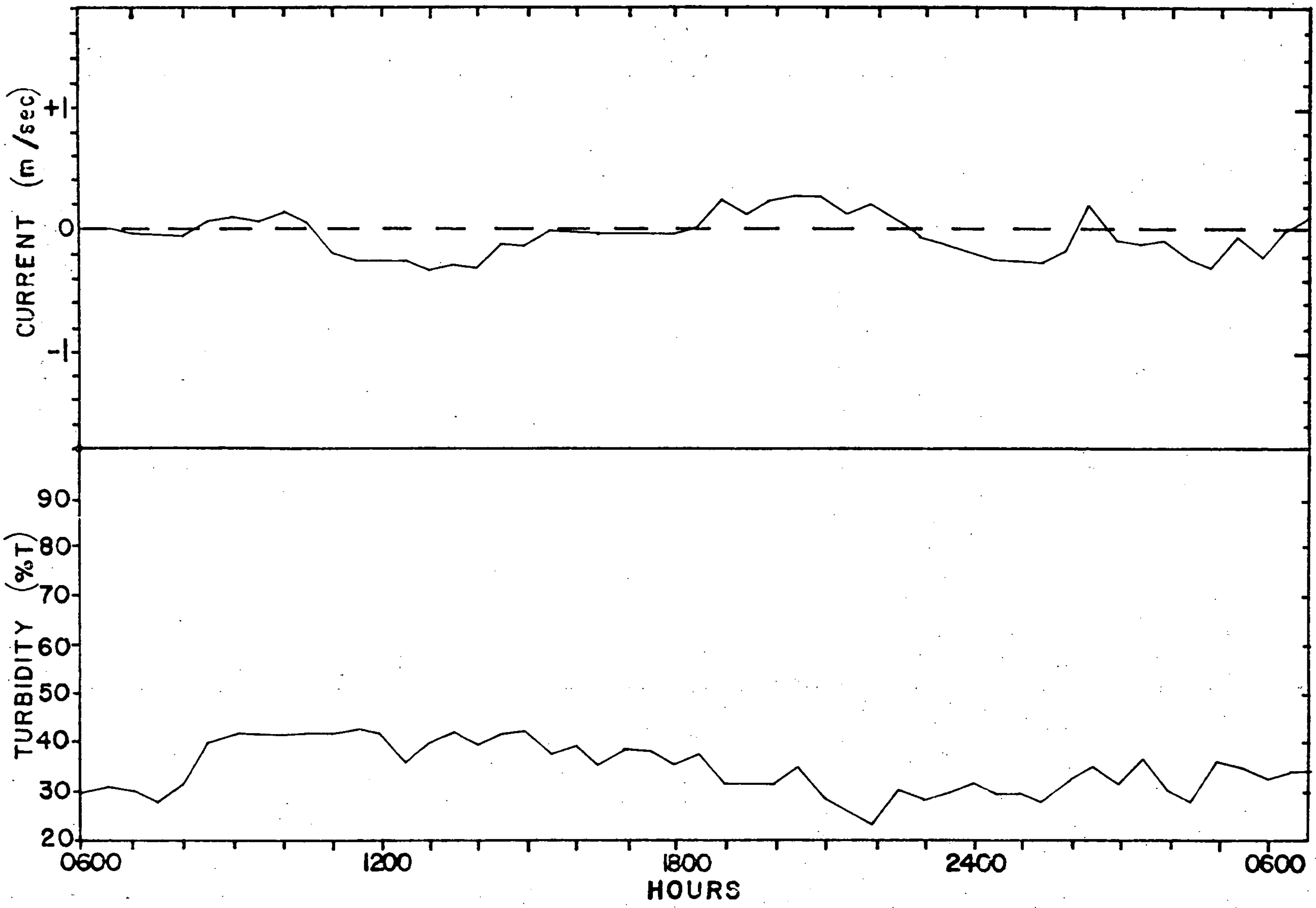


Figure II-14. Current/Turbidity (%T) Relationships at Station 10, April 18, 1973

Table II-3

MONTHLY MEANS, RANGES, AND STANDARD ERRORS FOR PERCENT TRANSMITTANCE (10-cm PATH) IN INDIAN POINT REGION, 1973

		Month					
Station	Statistic	Jan	Feb	Mar	Apr	May	Jun
1	High			74	72.0	88.0	78.0
	Mean			69	56.2	61.3	57.3
	Low			62	42.0	42.0	35.0
	Standard error				5.1	10.3	11.4
2	High			78	70.0	72.0	74.0
	Mean			74	58.6	50.0	59.3
	Low			70	46.0	10.0	14.0
	Standard error				4.2	14.9	11.9
3	High			73	76.0	85.0	73.0
	Mean			72	54.5	62.7	53.8
	Low			70	41.0	37.0	32.0
	Standard error				5.3	7.9	6.3
4	High			76	76.0	86.0	74.0
	Mean			75	56.8	65.3	54.3
	Low			70	45.0	28.0	36.0
	Standard error				4.1	8.8	17.3
5	High			76	86.0	85.0	76.0
	Mean			75	55.8	58.8	55.8
	Low			72	37.0	22.0	38.0
	Standard error				7.3	9.8	16.4
6	High			73	84.0	80.0	78.0
	Mean			72	54.5	56.8	59.0
	Low			70	41.0	8.0	30.0
	Standard error				3.5	13.8	14.5
7	High			76	72.0	71.0	75.0
	Mean			66	53.8	44.5	42.0
	Low			58	36.0	7.0	15.0
	Standard error				5.2	12.3	17.4
8	High			46	71.0	80.0	80.0
	Mean			46	61.8	65.8	63.0
	Low			46	42.0	47.0	44.0
	Standard error				3.5	7.1	15.0
9	High			68	74.0	80.0	74.0
	Mean			68	56.8	62.5	56.5
	Low			68	47.0	42.0	46.0
	Standard error				6.3	8.2	16.5
10	High			70	68.0	86.0	69.0
	Mean			70	55.0	62.0	52.0
	Low			70	42.0	40.0	34.0
	Standard error				5.3	9.5	13.8
11	High			68	74.0	88.0	70.0
	Mean			68	55.0	55.8	52.0
	Low			68	47.0	30.0	36.0
	Standard error				6.4	12.4	12.3
12	High			68	72.0	68.0	66.0
	Mean			68	58.8	45.5	42.8
	Low			68	38.0	6.0	10.0
	Standard error				7.5	14.5	25.6
13	High			81	78.0	78.0	80.0
	Mean			80	59.0	45.0	60.3
	Low			78	48.0	8.0	10.0
	Standard error				5.5	14.3	17.1
14	High			76	69.0	100.0	80.0
	Mean			73	52.3	73.8	63.3
	Low			70	37.0	46.0	48.0
	Standard error				6.0	4.4	7.0
15	High			76	77.0	90.0	78.0
	Mean			74	52.8	61.5	56.3
	Low			68	38.0	36.0	18.0
	Standard error				6.6	9.8	5.6
16	High			76	72.0	94.0	77.0
	Mean			75	53.0	72.3	56.3
	Low			72	42.0	40.0	20.0
	Standard error				4.7	11.6	16.3
17	High			76	72.0	85.0	68.0
	Mean			74	58.3	63.0	53.5
	Low			72	42.0	38.0	32.0
	Standard error				3.1	9.3	13.6
18	High				72.0	92.0	73.0
	Mean			58	52.7	60.0	57.8
	Low				49.0	28.0	18.0
	Standard error				0.9	10.5	13.7

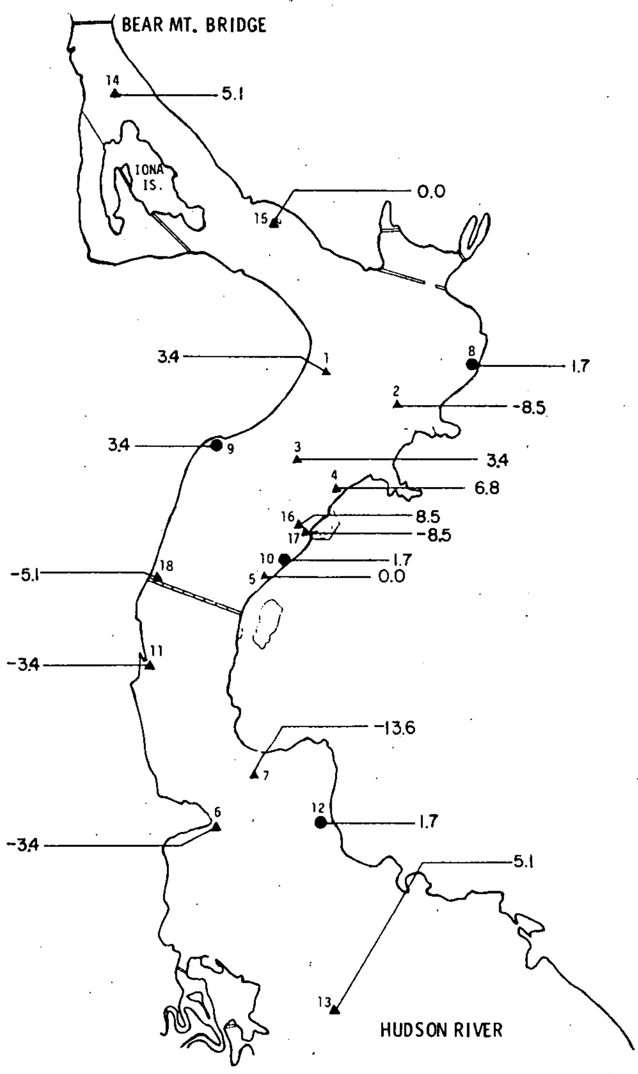


Figure II-15. Relative Turbidities (%T) as Percent Deviation from Overall Mean

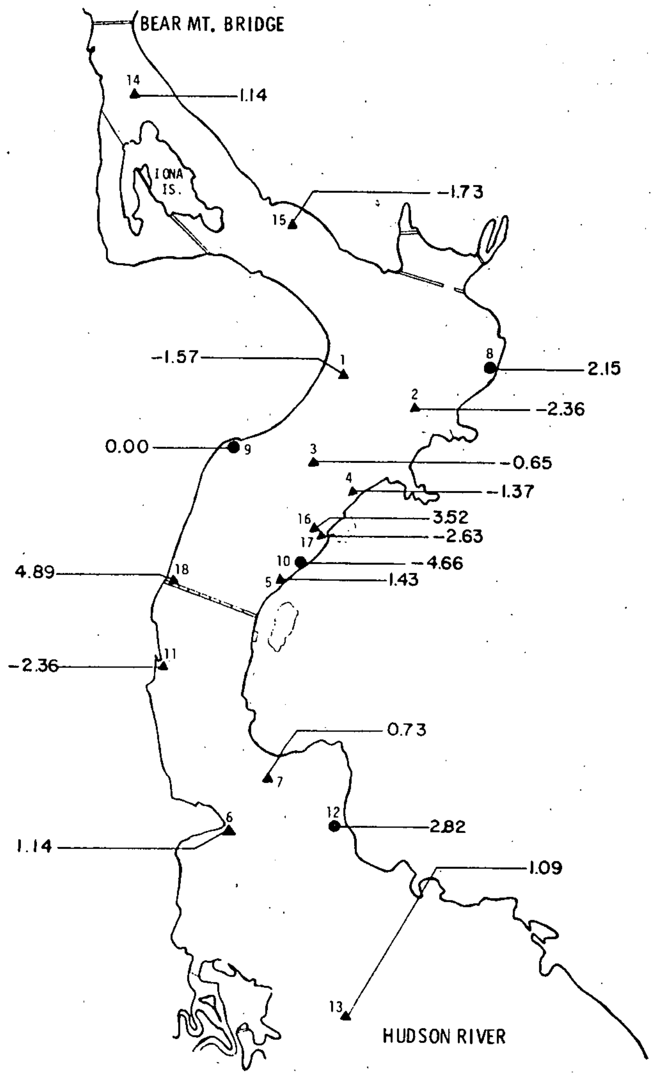


Figure II-16. Relative Dissolved-Oxygen Concentration Values as Percent Deviation from Overall Mean

Table II-4 summarizes monthly mean DO concentrations and includes ranges and standard errors. Since the solubility of oxygen in water is low and decreases with increasing temperature, percent saturation values are also presented in Table II-5. The lowest saturation percentage listed is 64 percent at 6.05 mg/ℓ at station 2 in June. On only one sampling sequence did the station mean values fall below 5.0 mg/ℓ; on that occasion (June 25), the following mean values were determined:

Station	DO (mg/ℓ)
4	5.67
5	4.62
10	5.90
13	4.84
16	4.60
17	5.23

Station 4 is under the influence of the thermal plume during flood tide. Stations 10 and 17 are more directly associated with the effluent than are stations 5 and 16. The low value at station 13 was possibly due to respiratory uptake in lower water levels; this also appears to be the case for stations 5 and 16. It is also interesting to refer to Figure II-15 where it may be seen that stations 5 and 16 exhibited higher mean year-to-date DO concentrations than areas which were apparently untouched by the thermal plume (stations 1, 3, 6, 7, 9, 13, 14, and 15).

Hydrogen-Ion Concentrations

In Figure II-17 are relative mean deviations from the overall mean for pH. Small differences are indicated, with the only apparent trend being a tendency for pH values to decrease upstream. This tendency is associated with an increased pH exhibited by saltwater incursions. Along a given lateral transect, higher pH means tend to be associated with stations

Table II-4

MONTHLY MEANS, RANGES, AND STANDARD ERRORS FOR DISSOLVED-OXYGEN CONCENTRATION (mg/ℓ) IN INDIAN POINT REGION, 1973

Station	Statistic	Month					
		Jan	Feb	Mar	Apr	May	Jun
1	High				12.70	10.00	9.60
	Mean				10.67	7.95	6.87
	Low				9.00	5.60	5.40
	Standard error				0.62	0.67	0.59
2	High				12.40	9.20	8.00
	Mean				10.59	7.70	6.05
	Low				8.60	6.20	4.90
	Standard error				0.61	0.48	0.43
3	High				12.70	9.50	7.60
	Mean				10.85	7.85	6.44
	Low				8.40	5.40	3.20
	Standard error				0.81	0.57	0.45
4	High				13.00	9.50	8.40
	Mean				10.79	7.78	6.17
	Low				8.60	5.00	4.00
	Standard error				0.71	0.38	0.46
5	High				13.80	9.30	8.30
	Mean				10.64	8.08	6.05
	Low				8.60	7.00	3.00
	Standard error				0.95	0.39	0.56
6	High				14.10	8.90	7.90
	Mean				10.96	8.08	6.63
	Low				8.40	6.50	4.80
	Standard error				1.01	0.33	0.47
7	High				13.40	8.80	8.80
	Mean				10.90	8.06	7.79
	Low				9.00	6.80	4.30
	Standard error				0.76	0.30	0.20
8	High				11.70	10.00	6.70
	Mean				10.86	8.55	6.49
	Low				9.40	7.10	5.40
	Standard error				0.48	0.61	0.35
9	High				11.70	9.20	8.70
	Mean				9.93	8.73	6.78
	Low				8.40	8.30	5.40
	Standard error				0.68	0.23	0.74
10	High				12.00	8.10	8.00
	Mean				10.48	7.07	7.20
	Low				8.60	5.20	5.80
	Standard error				0.77	0.81	0.65
11	High				12.20	9.00	8.00
	Mean				10.30	8.18	6.75
	Low				9.00	7.10	5.00
	Standard error				0.68	0.40	0.68
12	High				12.50	9.40	8.60
	Mean				10.75	8.60	7.65
	Low				9.60	7.10	5.60
	Standard error				0.69	0.51	0.71
13	High				14.00	8.80	9.20
	Mean				10.84	8.19	6.71
	Low				8.40	4.80	2.00
	Standard error				0.98	0.24	0.71
14	High				12.00	14.50	9.30
	Mean				10.56	8.50	7.12
	Low				9.10	5.80	4.30
	Standard error				0.66	0.74	0.79
15	High				12.80	9.50	9.10
	Mean				10.59	7.91	6.50
	Low				8.40	5.60	2.80
	Standard error				0.70	0.65	0.59
16	High				13.60	9.00	7.60
	Mean				10.95	7.92	6.27
	Low				8.00	6.90	3.50
	Standard error				0.98	0.34	0.57
17	High				12.40	9.60	7.90
	Mean				10.32	8.00	6.75
	Low				9.00	7.00	4.30
	Standard error				0.60	0.46	0.56
18	High				13.90	10.00	8.20
	Mean				11.36	8.38	6.39
	Low				8.80	7.00	4.60
	Standard error				0.82	0.28	0.57

Table II-5

DISSOLVED-OXYGEN CONCENTRATIONS AS PERCENT SATURATION

		Month					
Station	Datum	Jan	Feb	Mar	Apr	May	Jun
1	Mean DO % Saturation				10.67 89	7.79 76	6.87 73
2	Mean DO % Saturation				10.59 88	7.70 73	6.05 64
3	Mean DO % Saturation				10.85 90	7.85 75	6.44 69
4	Mean DO % Saturation				10.79 90	7.78 74	6.17 66
5	Mean DO % Saturation				10.64 88	8.08 77	6.05 64
6	Mean DO % Saturation				10.96 91	8.08 77	6.63 73
7	Mean DO % Saturation				10.90 91	8.06 77	7.79 83
8	Mean DO % Saturation				10.86 91	8.55 81	6.49 69
9	Mean DO % Saturation				9.93 83	8.73 83	6.78 72
10	Mean DO % Saturation				10.48 87	7.07 67	7.20 77
11	Mean DO % Saturation				10.30 87	8.18 79	6.75 74
12	Mean DO % Saturation				10.75 90	8.60 83	7.65 83
13	Mean DO % Saturation				10.84 91	8.19 78	6.17 71
14	Mean DO % Saturation				10.56 89	8.50 80	7.12 76
15	Mean DO % Saturation				10.59 89	7.91 75	6.50 69
16	Mean DO % Saturation				10.95 91	7.92 75	6.27 67
17	Mean DO % Saturation				10.32 86	8.00 76	6.27 67
18	Mean DO % Saturation				11.36 94	8.38 80	6.39 68

in the deeper regions of the channel, suggesting the same flow pattern observed for water with high electrical conductivity, i.e., following the deep river-floor areas upstream. Values for pH were consistently higher during saltwater intrusion, there being as much as 0.4 pH unit difference when compared with nonsaline flow.

In Table II-6 are the monthly means, ranges, and standard errors for pH determinations. No obvious changes were present during the 4-month sampling period.

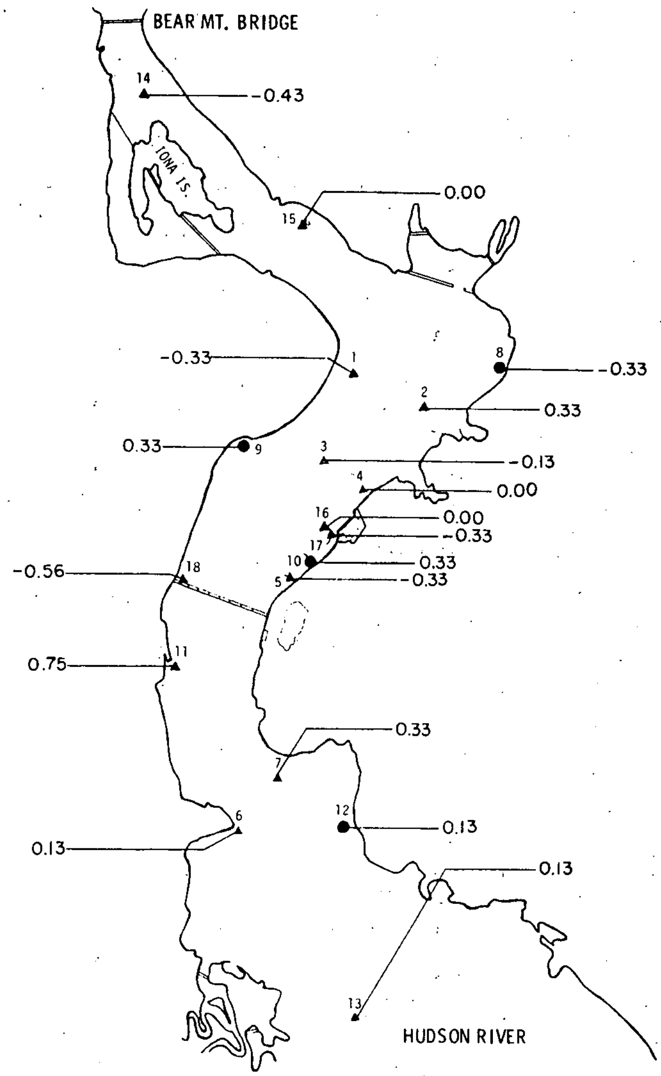


Figure II-17. Relative pH Values as Percent Deviation from Overall Mean

Water Inflow

Table II-7 gives estimated water-release rates at Green Island, New York, for the first 6 months of 1973; mean, high, and low values are entered in terms of the original data (cfs) supplied by the USGS office at Albany and in terms of acre-ft/day. Notice the low values for June. By way of illustration, suppose that the flow rate through a given section plane of the river channel is conservatively estimated to be a mean of 0.30 m/sec (0.30 knot) and that the cross-sectional area at that section is 1.5×10^5 sq ft; then, approximately 150,000 cfs of water would pass through that section plane. By comparison, the mean releases through the Green Island monitoring installation would have contributed, on a long-term basis, a range of 9 percent (June) to 27 percent (February) of the total flow.

Table II-6

MONTHLY MEANS, RANGES, AND STANDARD ERRORS FOR pH IN INDIAN POINT REGION, 1973

Station	Statistic	Jan	Feb	Mar	Apr	May	Jun
1	High			7.59	7.75	7.28	7.88
	Mean			7.56	7.48	6.97	7.58
	Low			7.54	7.26	6.66	7.15
	Standard error				0.08	0.22	0.11
2	High			7.58	7.71	7.22	7.74
	Mean			7.55	7.45	6.93	7.45
	Low			7.52	7.19	6.65	7.25
	Standard error				0.07	0.20	0.10
3	High			7.57	7.68	7.22	7.74
	Mean			7.55	7.46	6.94	7.49
	Low			7.53	7.31	6.66	7.22
	Standard error				0.06	0.20	0.80
4	High			7.56	7.75	7.38	7.75
	Mean			7.54	7.48	6.99	7.51
	Low			7.52	7.26	6.65	7.13
	Standard error				0.08	0.25	0.08
5	High			7.56	7.62	7.20	7.84
	Mean			7.54	7.47	6.93	7.57
	Low			7.52	7.31	6.65	7.22
	Standard error				0.04	0.20	0.08
6	High			7.60	7.84	7.30	7.73
	Mean			7.52	7.51	6.95	7.54
	Low			7.41	7.22	6.64	7.25
	Standard error				0.09	0.22	0.13
7	High			7.60	7.73	7.28	7.87
	Mean			7.55	7.51	6.95	7.61
	Low			7.51	7.35	6.66	7.23
	Standard error				0.07	0.22	0.12
8	High			7.46	7.56	7.36	7.75
	Mean			7.46	7.46	7.02	7.55
	Low			7.46	7.32	6.68	5.80
	Standard error				0.06	0.34	0.10
9	High			7.57	7.51	7.34	7.92
	Mean			7.57	7.48	7.01	7.59
	Low			7.57	7.44	6.68	7.39
	Standard error				0.02	0.33	0.12
10	High			7.42	7.66	7.32	7.73
	Mean			7.42	7.51	7.00	7.51
	Low			7.42	7.43	6.68	7.38
	Standard error				0.04	0.32	0.10
11	High			7.54	7.61	7.22	7.53
	Mean			7.54	7.53	6.95	7.41
	Low			7.54	7.44	6.67	7.29
	Standard error				0.04	0.28	0.06
12	High			7.55	7.58	7.24	8.35
	Mean			7.55	7.52	6.96	7.80
	Low			7.55	7.45	6.67	7.52
	Standard error				0.04	0.29	0.24
13	High			7.57	7.72	7.30	7.87
	Mean			7.49	7.52	6.96	7.63
	Low			7.45	7.34	6.65	7.14
	Standard error				0.05	0.22	0.13
14	High			7.62	7.73	7.40	8.13
	Mean			7.56	7.45	6.99	7.57
	Low			7.54	7.24	6.65	7.06
	Standard error				0.09	0.24	0.17
15	High			7.57	7.78	7.44	8.08
	Mean			7.54	7.47	7.05	7.58
	Low			7.52	7.23	6.66	7.22
	Standard error				0.08	0.28	0.11
16	High			7.56	7.80	7.22	7.74
	Mean			7.55	7.50	6.93	7.51
	Low			7.54	7.19	6.64	7.08
	Standard error				0.10	0.20	0.09
17	High			7.56	7.68	7.20	7.74
	Mean			7.55	7.49	6.93	7.54
	Low			7.53	7.31	6.66	7.32
	Standard error				0.06	0.20	0.07
18	High				7.80	7.28	7.78
	Mean			7.44	7.44	5.95	7.56
	Low				7.28	6.64	7.39
	Standard error				0.44	0.21	0.09

Table II-7

MEAN DAILY RELEASE FLOW RATES AT GREEN ISLAND, NEW YORK

Month		Release Flow Rate (acre-ft/day)	Release Flow Rate (cfs)
Jan	High	128,921.00	65,000
	Mean	51,686.15	26,725
	Low	28,560.96	14,400
Feb	High	100,558.38	50,700
	Mean	79,420.86	40,014
	Low	22,809.10	11,500
Mar	High	129,119.34	65,100
	Mean	57,276.86	28,878
	Low	23,205.78	11,700
Apr	High	162,837.14	82,100
	Mean	61,353.16	30,933
	Low	31,337.72	15,800
May	High	123,764.16	62,400
	Mean	54,626.65	27,542
	Low	22,610.76	11,400
Jun	High	44,824.84	22,600
	Mean	26,642.02	13,433
	Low	14,458.99	7,290

Admittedly, these values are only approximations; however, they do serve as a framework for recognizing the importance of watershed releases below Green Island and of the saltwater component of the total flow pattern.

Meteorological Monitoring

The meteorological information in Table II-8 indicates few unexpected values; however, the low precipitation value for June tended to follow the low release rate mean given in Table II-7 for the same month. Also, mean air temperatures (°C) for the months of May and June differed somewhat from those of 1972:

	1972	1973
May	19.1	15.9
Jun	19.2	24.4

Table II-8

MONTHLY MEAN METEOROLOGICAL PARAMETER VALUES IN AREA OF VERPLANCK, NEW YORK

Parameters		Month					
		Jan	Feb	Mar	Apr	May	Jun
Wind speed (mph)	Low	—	0	0	0	0	0
	Mean	—	11	10	11	8	5
	High	—	40	50	34	30	35
Relative humidity (%)	Low	48	46	36	32	43	30
	Mean	65	67	68	60	65	60
	High	92	96	89	88	89	88
Air temperature (°C)	Low	-11.2	-11.7	0	4.4	8.9	15.6
	Mean	-1.0	-1.4	7.3	12.1	15.9	24.4
	High	7.2	6.1	15.3	21.9	25.6	36.1
Barometric pressure (mm)	Low	751.33	747.02	738.76	746.51	750.83	757.17
	Mean	762.15	764.84	763.37	759.66	758.89	761.49
	High	772.18	778.77	775.72	772.92	769.62	767.08
Precipitation (mean cm./day)	Low	0	0	0	0	0	0
	Mean	0.15	0.23	0.13	0.33	0.15	0.09
	High	1.22	3.71	1.02	1.47	0.97	5.28

Wind-occurrence vectors for the first half of 1973 are shown in Appendix A, Figures A-7 through A-12; the arrows are directed toward the wind origin. Vector lengths were determined by taking the number of hourly occurrences in a given 22.5° quadrant as a percentage of the total number of occurrences for that month. An obvious change in predominant direction of origin accompanied a slight reduction in mean wind velocity (Table II-8).

The interaction of tidal influences, thermal conditions, stream morphometry, dissolved mineral content, and meteorological influences is complex at best, being especially so in an extensive estuary like the Hudson. As the tide comes into the estuary,

(1) The volume of water suitable for certain fish species may be effectively reduced in that the intrusion of saltwater will tend to follow the deeper areas of the river channel, driving fish upward in the water body, in effect increasing population standing stock.

(2) Turbidities may be increased due to the inflow of turbid water from Haverstraw Bay

(3) If any significant degree of layering occurs, the extent of dilution of effluent waters will be reduced since the overlying freshwater will be the diluting entity (this does not appear to be a problem at the Indian Point plant)

(4) Benthic organisms which are stenohaline (unable to withstand large salinity changes) and have invaded the estuarine situation between saltwater intrusions will be effectively eliminated from the community

High downstream flows of freshwater, uneven bottom topography, and high winds will have a mixing and flushing effect. High degrees of mixing may also increase nutrient contents in the waters of an estuary, but this is offset somewhat by the increased tendency for flushing of the system during high downstream flow.

CHAPTER III

BENTHIC ECOLOGY

INTRODUCTION

Sampling of Indian Point benthos during 1969, 1970, and 1972 yielded necessary information on community structure, species composition, relative abundance, diversity, and seasonality. Subsidiary studies provided indices of community response to variations in sediment particle-size composition and organic content and to salinity and temperature. Thus, these data serve as a generalized base for more detailed analyses of the effect of the Indian Point power-generating facility on the benthos.

Modifications of the program for 1973 were designed to provide a direct analysis of plant effects. This was accomplished by comparing community response of the benthos in a test region at the plant site and in a control region on the opposite side of the river beyond the direct effects of the thermal plume. In addition, comparative population dynamics studies of the estuarine isopod *Cyathura polita* were designed to provide a basis for estimating its secondary production and to study the thermal-discharge response of this important food species for white perch, striped bass, and sturgeon.

METHODS AND MATERIALS

Detailed descriptions of standard benthic procedures appear in Volume II of the first semiannual report, Hudson River Ecological Study in the Area of Indian Point (Texas Instruments Incorporated, 1972). The design of the experimental benthic studies is detailed in the first annual report covering the period April-December 1972 (Texas Instruments Incorporated, 1973a) and is abstracted in the following paragraphs.

Grab-Sampling Program

Three replicate 0.1-m^2 Petersen grab samples are taken monthly from each of 12 stations divided equally between test and control regions. Samples are washed through 500-μ screens and the residual fraction preserved in 4-percent formaldehyde to which Rose Bengal stain has been added. Organisms are picked from the debris with jewelers' forceps under dissecting microscopes, weighed (gm), their volume (cc) determined, and the data recorded. The specimens are then identified and enumerated. Periodically, a sample from each region (test and control) is washed through a 250-μ screen to monitor harpacticoid copepod, and ostracod populations.

Dredge Program

One biological dredge haul of approximately 300 m is taken diagonally across each region at the time of grab sampling and washed through a 4-mm screen. Subsequent treatment is identical to that employed for grab samples.

Cyathura polita Program

All specimens of *Cyathura polita* from monthly Petersen grab samples are measured and sexed and the data analyzed to determine size classes, sex ratios, size at maturation, growth rates, size-specific mortality rates, and differences between the test and control regions for these factors. In the event of significant variations between regions, respective stations are compared to determine localization of effects.

Sediment Analyses

Following determination of community differences between the test and control regions, carbon and nitrogen content of sediment samples from the control region was determined by Kjehldahl nitrogen analysis and hot-acid oxidation and infrared CO_2 analyses for total carbon (Americal Public Health Association, 1971) to assess the relative concentrations of these materials in the respective areas.

RESULTS

Petersen-Grab Studies

Summarized grab data for the spring of 1973 appear in Table III-1 as mean numbers of organisms per square meter of bottom, and their standard error for the test and control regions. Biomass and diversity for the period appear in Table III-2 and Figure III-1, respectively. Assessments of community structure in the control region during April and May indicate that the area was high in organic materials and not representative of the area as a whole. June data reflected relocation of the control region to 500 m north of the original control site, a region more consistent with area means.

Biodredge Studies

None of the larger epibenthic forms which the biological dredge was designed to sample were collected during the spring sampling period. Collections were limited to organisms which would normally pass through the 4-mm screens but were retained as a function of attachment to or entanglement in rock and debris.

Cyathura polita Studies

All *Cyathura polita* specimens from the 1973 sampling program were counted, measured (length), and sexed. Population-size distribution for April, May, and June is shown in Figure III-2. No significant difference could be determined between test-area and control-area samples during April, but control-region samples collected in May and June were significantly lower ($\alpha = 0.01$) in total numbers. Additional analysis showed that this variation was attributable to a lower density of immature specimens in the 3- to 10-mm size range ($\alpha = 0.01$).

Table III-1

MEAN NUMBERS OF SPECIMENS PER METER SQUARE AND STANDARD ERRORS FOR TEST AND CONTROL REGIONS DURING APRIL, MAY, JUNE 1973

Taxon	Apr				May				Jun			
	Test		Control		Test		Control		Test		Control	
	Mean	S. E.	Mean	S. E.	Mean	S. E.	Mean	S. E.	Mean	S. E.	Mean	S. E.
Gammarus tigrinus (?)	1033.3	32.36	437.2	15.26	477.8	30.10	52.2	4.50	355.6	10.70	116.7	15.50
Limnodrilus sp	474.4	7.28	1513.9	32.51	193.3	13.60	5151.7	179.70	1111.1	65.20	4497.8	156.20
Chironomid larvae	202.8	1.15	82.8	1.54	137.8	4.80	19.4	0.80	132.2	4.80	29.4	4.90
Cyathura polita	162.2	2.36	223.9	4.11	220.0	9.00	68.3	3.00	166.7	4.60	151.1	15.60
Scolecolepides viridis	92.2	1.75	91.1	1.60	180.6	4.30	372.2	11.1	382.8	13.40	243.9	19.00
Chaoborus sp	28.9	0.64	0.6	0.05	15.0	1.00	2.2	0.20	4.4	0.40	1.1	0.33
Phithropanopeus harrisi	16.7	0.53	2.8	0.07	15.6	1.30	0.6	0.10	10.6	0.80	4.4	1.20
Corophium sp	14.4	0.40	5.0	0.31	2.8	0.20			12.8	1.50	0.6	0.20
Monoculodes sp	11.7	0.61	7.2	0.36								
Peloscolex sp	7.2	0.57	0.6	0.05			3.3	0.20	77.8	9.60	23.9	5.50
Congeria leucophaeta	6.7	0.39	1.1	0.07								
Hypaniola sp	5.6	0.20	0.6	0.10	3.3	0.30	18.3	1.80				
Pectinatella magnifica	5.0	0.21	39.4	1.05	2.2	0.20	22.8	1.90	1.7	0.20	4.4	0.70
Cyclopoida	3.3	0.25										
Chiridotea almyra	2.8	0.13	5.0	0.16	6.1	0.30	0.6	0.10	5.6	0.60	5.0	1.50
Lophopodella carteri	2.8	0.10	81.7	2.40			31.7	1.50	1.7	0.20	12.2	1.20
Leptocheirus plumulosus	2.2	0.14	0.6	0.50	0.6	0.10	0.6	0.10	1.7	0.20		
Pisicola	1.7	0.17	1.1	0.07								
Calanoida	1.7	0.07										
Nematoda	1.7	0.13	1.1	0.12	0.6	0.10	0.6	0.10			1.1	0.30
Boccardia hamata	1.7	0.13	0.6	0.05	7.2	0.70	0.6	0.10	0.6	0.10		
Cristatella mucedo	1.1	0.07	5.0	0.30			1.1	0.10	1.1	0.30	2.2	0.50
Amnicola sp	1.1	0.07										
Palaeonemertea	0.6	0.05										
Agraylea	0.6	0.05										
Tricoptera			0.6	0.05	0.6	0.10						
Hydracarina			0.6	0.05								
Cladoceran ephippia			0.6	0.05								
Glossiphoniidae			0.6	0.05								
Harpacticoida					0.6	0.10						
Acanthocephala					0.6	0.10						
Odonata larvae					0.6	0.10						
Nudibranchia (?)									2.8	0.40	0.6	0.60
Edotea sp									0.6	0.10	1.7	0.40
Cordylophora lacustris									0.6	0.10		
No. of species	25		24		18		16		18		16	

Table III-2

WET WEIGHT (WW) AND WET VOLUME (WV) BIOMASS
IN TEST AND CONTROL AREAS
DURING APRIL, MAY, AND JUNE 1973

		Test							Control I							Control II						
		A	B	C	D	E	F	MEAN	G	H	I	J	K	L	MEAN	M	N	O	P	Q	R	MEAN
APRIL	WW	9.3	13.7	24.3	3.7	34.3	3.7	14.8	9.7	7.7	8.7	13.0	7.7	7.7	9.1	-	-	-	-	-	-	-
	WV	8.3	14.3	22.3	3.7	36.7	3.7	14.8	10.3	7.0	9.0	14.3	8.3	7.0	9.3	-	-	-	-	-	-	-
MAY	WW	14.7	11.7	13.3	7.3	24.0	17.3	14.7	24.7	18.0	22.7	15.0	10.7	16.0	17.9	-	-	-	-	-	-	-
	WV	6.7	7.3	13.3	10.0	10.0	15.3	10.4	20.7	12.7	12.7	9.0	10.0	14.7	13.3	-	-	-	-	-	-	-
JUNE	WW	17.0	20.0	26.7	10.3	17.7	16.3	18.0	-	-	-	-	-	-	-	15.7	9.7	19.7	18.3	20.7	20.7	17.5
	WV	12.3	15.3	22.0	8.7	12.7	12.0	13.8	-	-	-	-	-	-	-	13.3	4.7	11.3	10.7	12.7	13.3	11.0
MEAN	WW	13.7	15.1	21.4	7.1	25.3	12.4	15.8	17.2	12.9	15.7	14.0	9.2	11.9	13.5	15.7	9.7	19.7	18.3	20.7	20.7	17.5
	WV	9.1	12.3	19.2	7.5	19.8	10.3	13.0	15.5	9.9	10.9	11.7	9.2	10.9	11.4	13.3	4.7	11.3	10.7	12.7	13.3	11.0

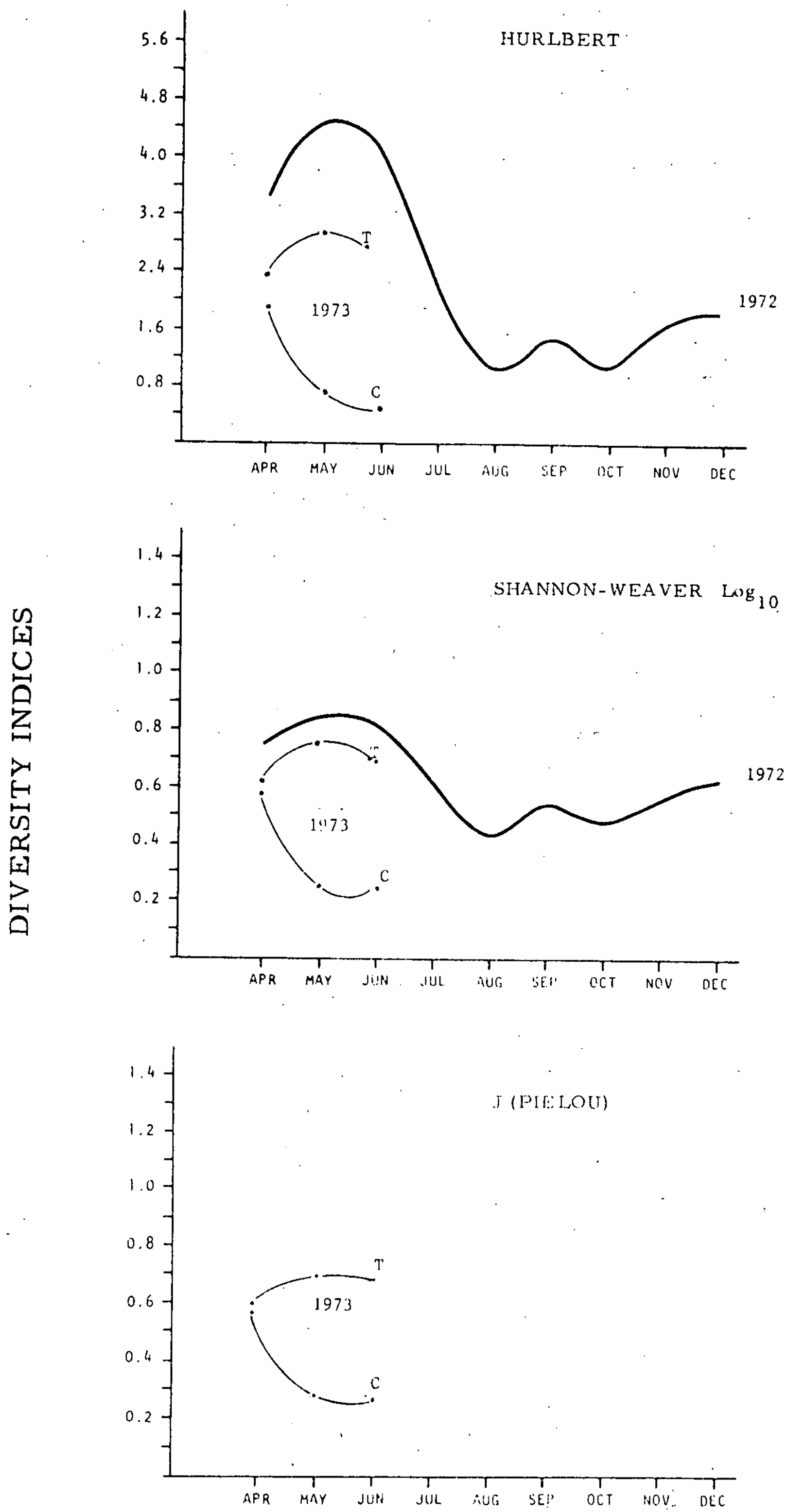


Figure III-1. Hurlbert, Shannon-Weaver Log_{10}, and J (Pielou) Diversity Indices for Test and Control Regions during Spring of 1973 Plotted against Area Mean Values for 1972 where Available

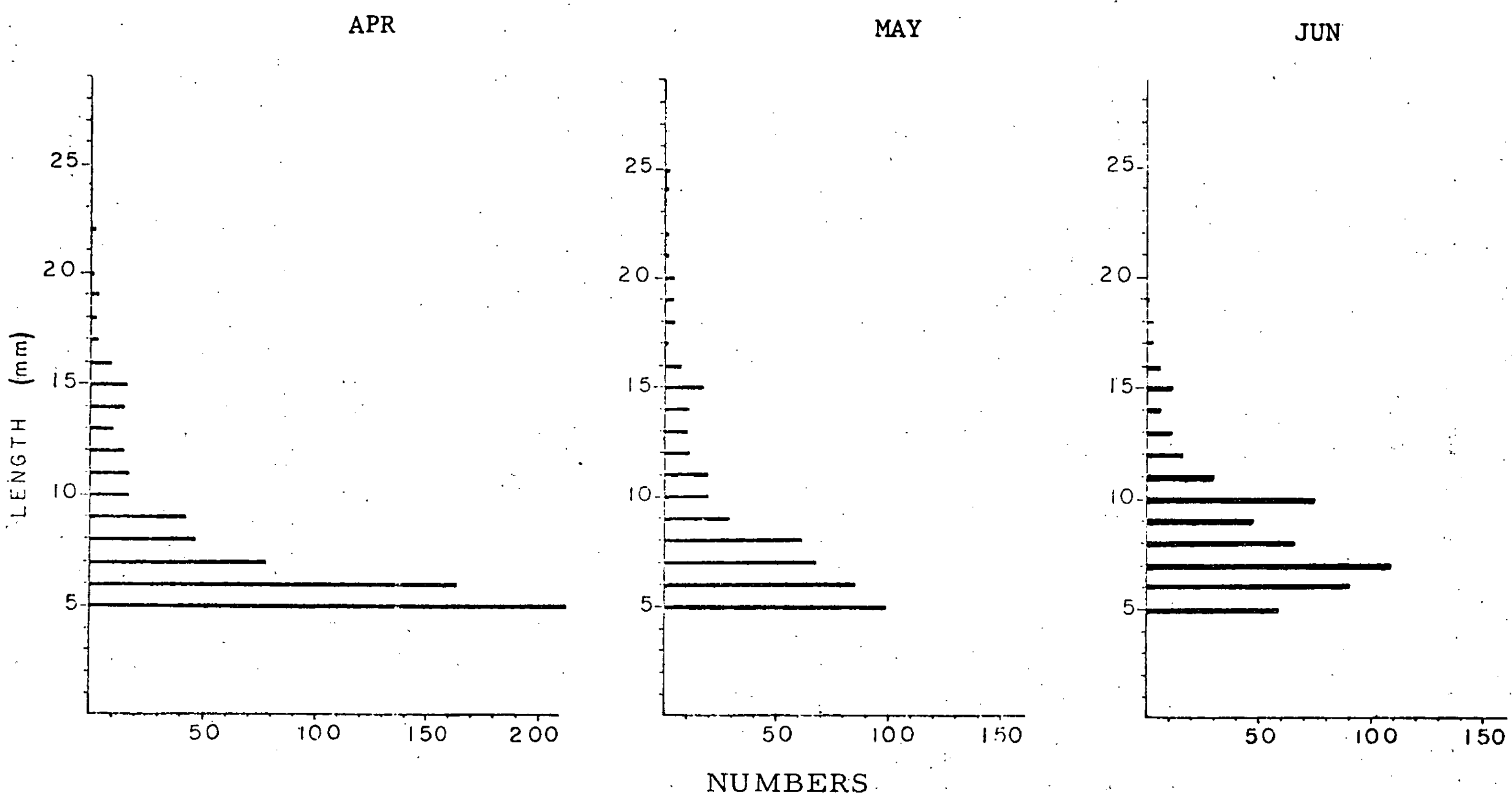


Figure III-2. *Cyathura polita* Size Frequency Distribution during April, May, and June 1973

Sediment Analysis

Faunal indications of elevated organic levels in the control region prompted the collection of additional samples in this area. These were analyzed to determine the carbon and nitrogen content of the sediments at the northern extreme of the control region (station G) and auxiliary stations taken at 100-m intervals for a distance of 600 m north of the control.

Results showed the sediments at station G and an area extending approximately 200 m north to have an average of 47.6 percent carbonaceous material and the area from 300 m to 500 m north of station G to have an average value of 28.3 percent carbon; carbon during this period at standard stations in the Indian Point region ranged between 28 and 33 percent. Total nitrogen content of the sediments did not differ appreciably from site to site in these tests and all recorded values fell within the range determined for Indian Point standard stations.

1972/1973 COMPARISONS

Accumulated numerical data for the spring collection periods of 1972 and 1973 are compared in Table III-3 as mean numbers of specimens per square meter for the respective quarters. Figure III-3 presents seasonal cycles of major species during 1972 and population levels of these species during the spring of 1973.

Discussion

Spring collections in 1973 indicate that benthic community composition in the Indian Point region is little changed from that of the same period of 1972. The tubificid worm *Limnodrilus* is again the most numerous benthic organism and, while there are minor variations in ranking, the seven most numerous species of 1972 still occupy this position of dominance. *Amnicola* sp. and *Balanus improvisus*, which ranked eighth and tenth in total numbers

Table III-3

COMPARISON OF NUMBERS OF MAJOR SPECIES AT COINCIDENT STATIONS DURING 1972/1973 SPRING MONTHS (MEAN NUMBERS PER SQUARE METER)

TAXA	Station 4 (A)		Station 5 (C)		Station 1 (M*)		Station 1(M) + 4(A) + 5(C)		Δ
	1972	1973	1972	1973	1972	1973	1972	1973	
Limnodrilus sp	89.7	388.9	44.0	330.0	658.0	1806.7	263.9	841.9	+
Cyathura polita	155.3	177.8	199.0	294.4	232.7	183.3	195.7	218.5	+
Chironomid larvae	312.0	146.7	208.3	187.8	65.3	23.3	195.2	119.3	-
Gammarus sp	220.7	264.4	109.7	926.7	6.7	96.7	112.4	429.3	+
Peloscolex sp	134.7	93.3	206.3	20.0	104.7	23.3	148.6	45.5	-
Scolecolepides viridis	68.0	127.8	120.7	300.0	112.7	423.3	100.5	283.7	+
Nematoda	2.0	1.1	29.3	3.3	44.7	0	26.2	1.5	-
Amnicola sp	10.0	0	47.0	0	20.7	0	25.9	0	-
Boccardia hamata	9.7	1.1	21.7	2.2	12.7	0	14.7	1.1	-
Balanus improvisus	23.7	0	6.0	0	0	0	9.9	0	-
Corophium sp	32.0	1.1	17.7	20.0	3.3	0	17.7	7.0	-
Hypaniola sp	5.7	1.1	5.7	4.4	8.0	0	6.5	1.8	-
Rhithropanopeus harrisi	19.3	17.8	3.7	28.9	1.3	20.0	8.1	22.2	+
Chaoborus sp	5.3	13.3	11.0	6.7	3.3	0	6.5	6.7	0
Congeria leucophaeta	5.3	0	3.3	5.6	0.7	0	3.1	1.9	-
Chiridotea almyra	0	0	1.7	1.1	2.0	6.7	1.2	2.6	+
Monoculodes sp	1.7	0	0	0	0	0	0.6	0	-
Leptocheirus plumulosus	0	3.3	0	2.2	0	0	0	1.8	+

*Sampled during June only.

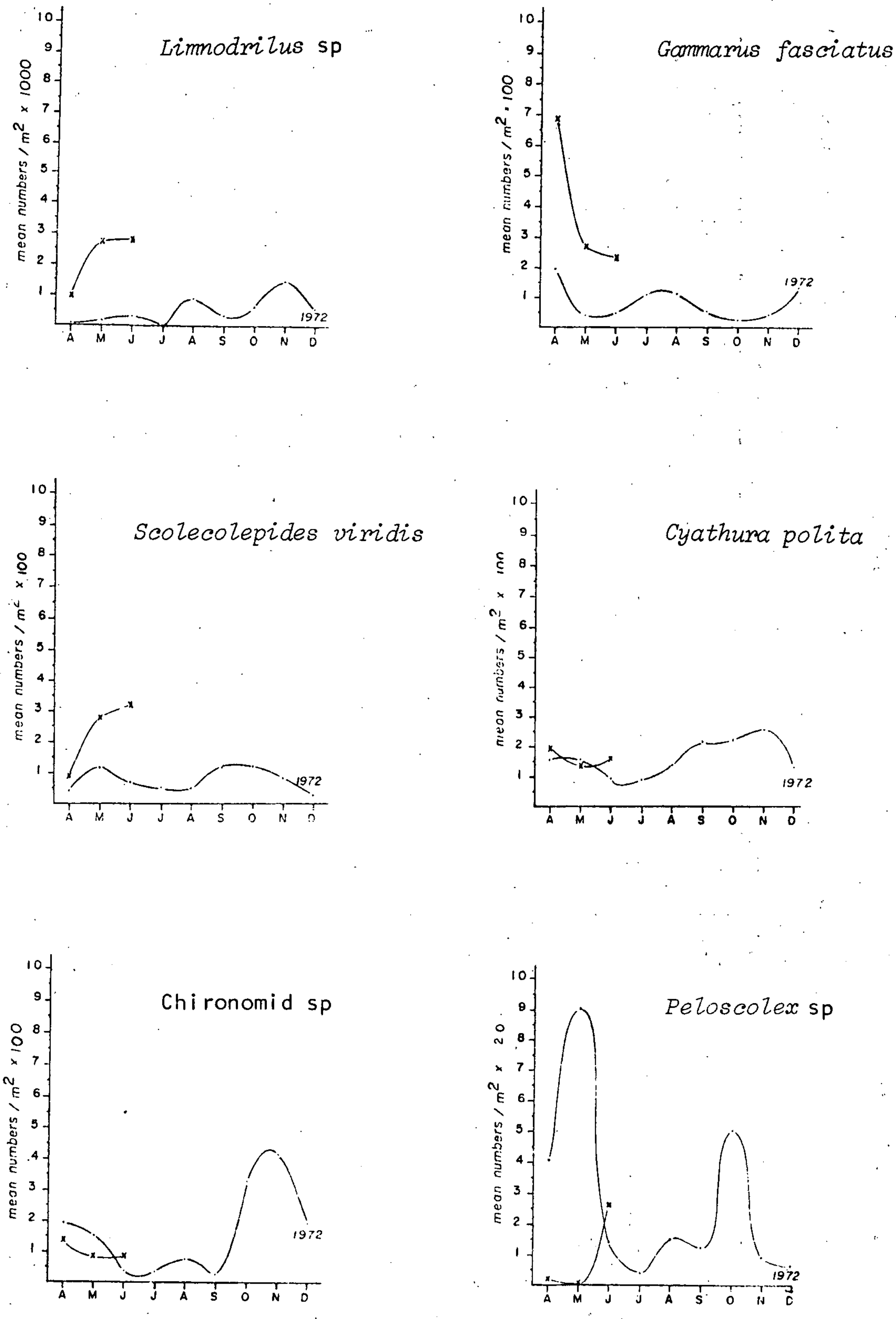


Figure III-3. 1972 Seasonal Variations in Numbers of Selected Indian Point Species with Numbers Observed during Spring of 1973 during the corresponding period of 1972, are greatly reduced or lacking in the 1973 collections; this reflects high mortalities throughout the area during the late winter months which were previously reported in the Ossining final report (Texas Instruments Incorporated, 1973a). Similar decreases in numbers of *Congeria leucophaeta* were observed.

Numbers of taxa collected were lower during the spring of 1973 than in the same period of 1972. This decrease is attributable both to the use of larger screen mesh in the preparation of samples (500 μ vs 250 μ) and to the high mortality of several species during the winter month.

The use of 500-μ screening reduces the likelihood of collecting copepods, ostracods, and *Hyalinella* sp floatoblasts (TI, 1973a). This generally accounts for a decrease of three taxa. When numbers of species collected during April, May, and June 1972 are corrected for the fraction which was lost due to larger sieve size and compared to numbers of species collected during 1973, the variation observed is relatively small (Table III-4) and generally attributable to the absence of *Balanus*, *Congeria* and *Amnicola*.

Table III-4

MEAN NUMBERS* OF SPECIES IN INDIAN POINT BENTHIC COLLECTIONS DURING 1972 AND 1973

	1972	1973
Apr	15.0	13.0
May	16.6	9.8
Jun	12.6	10

*Corrected for difference in sieve mesh size, as in the text.

Extremely high mortalities of *Congeria leucophaeta*, *Amnicola* sp, and *Balanus improvisus* were observed at Ossining, New York, following the clearing of ice from the river in 1973 (Texas Instruments Incorporated, 1973b). The presence of an extremely high number of freshly deposited *Congeria* shells at both Ossining and Indian Point during the spring of 1972 indicates that this phenomenon also occurred during the winter of 1971-72 and is probably a normal population response to the temperature/salinity regime of the estuary. Reduced numbers of these species from 1973 collections may then be attributable to prolonged exposure to low temperatures since mean monthly bottom-water temperatures were lower by 3.4°C and 2.5°C during April and May 1973 than those in 1972.

Comparisons of population densities of major species during the spring seasons of 1973 indicate that mean numbers of several species have increased appreciably. Additionally, the response of dominant species to annual variations in temperature and/or salinity seems to be reasonably consistent with trends observed in the past year (Texas Instruments Incorporated, 1972), resulting in population variations at slightly different times (Texas Instruments Incorporated, 1972; 1973a).

The deposition of large quantities of organic detritus in the control region following periods of heavy runoff in late April and early May produced a shift toward organic-tolerant forms during May, which detracted greatly from the validity of these stations as a control. Supplementary sampling and analyses have determined that an area 500 m north of the original control and outside the eddy-deposition area provides biological and chemical conditions considerably more compatible with average values for the Indian Point region. Thus, the control has been moved to this area to assure the highest possible validity of comparison.

CHAPTER IV

FISH BEHAVIOR AND PHYSIOLOGY

GENERAL INTRODUCTION

The behavior and physiology program will integrate field and laboratory investigations to define the effects of elevated temperatures on Hudson River organisms and to evaluate the biological effects of the Indian Point thermal discharge. A close relationship between laboratory and field findings strengthens the predictive value of the research results and allows generalizations about an organism's response to warm water that could reduce future expenses for complete biological investigations at each specific heat source in this or similar estuaries (or other water bodies).

Laboratory experiments are conducted under conditions as similar as possible to those of the river environment. Seasons for experiments are defined by the river's ambient water temperatures and lag behind the calendar seasons because of the high specific heat of the river water mass. This report covers results obtained through the spring period which ended June 25 at 22°C.

During winter and spring periods, young white perch and especially striped bass were relatively unavailable despite extensive collection efforts, suggesting a very poor 1972 year class in the Hudson River or a migration to the very southern portion of the estuary that was not sampled. The scarcity of striped bass limited thermal-tolerance experiments to only using white perch.

DISCHARGE-CANAL INVESTIGATIONS

Introduction

During the winter and spring of 1973, fish-trapping continued in the discharge canal to determine species composition, indicate relative abundance, and show length distributions of fish caught there. Information from this study also indicates some of the effects that plant discharge has on local fish entering the canal (part of the second major objective).

Materials and Methods

Winter and spring sampling was conducted for 1 day with a box trap net and then exclusively with a fyke net fished on the bottom near the east wall of the canal at station D2. Methods of fish-handling and environmental measurements were identical to those reported in the 1972 annual report (Texas Instruments Incorporated, 1973a).

Results

Winter. Sampling was conducted for the first 19 days of March 1973 when the plant was not discharging warm waters but the circulators were operating. Although the trap was fished 9 nights and 3 weekends (3 nights plus 2 days), only one tomcod (140 mm) and three white catfish were caught. The catfish, ranging in length from 72 to 95 mm, were collected during the last 4 days of fishing after water temperatures rose above 3°C. The calculated C/f for the entire winter sampling was only 0.01. Water temperatures in the canal during the sampling period ranged from 1.0°C to 4.5°C. Surface flow was generally about 0.17 m/sec, although the flow ranged from 0 to 0.25 m/sec. Salinity measurements at a nearby river station indicated that the river water was fresh during the sampling period.

Spring. There was no thermal discharge during this sampling period (May 7 to 29, 1973), which included 12 night sets and 3 weekend sets. The percent composition of the total catch (n = 160) for each species during spring was as follows: white catfish, 46.3 percent; white perch, 34.4 percent; American eels, 8.8 percent; tomcod, 5.0 percent; spottail shiners, 5.0 percent; and carp, 0.6 percent. The C/f for spring was 0.4. White catfish ranged in total length from 64 to 287 mm, with fish of the 50- to 100-mm size class being most abundant (Figure IV-1). White catfish had a length-frequency distribution similar to those caught in the fall of 1972, but the numbers of fish were greatly reduced. White-perch lengths ranged from 150 to 230 mm, American eels from 400 to 580 mm, tomcod from 147 to 171 mm, and spottail shiners from 92 to 112 mm. Length of the one carp was 381 mm.

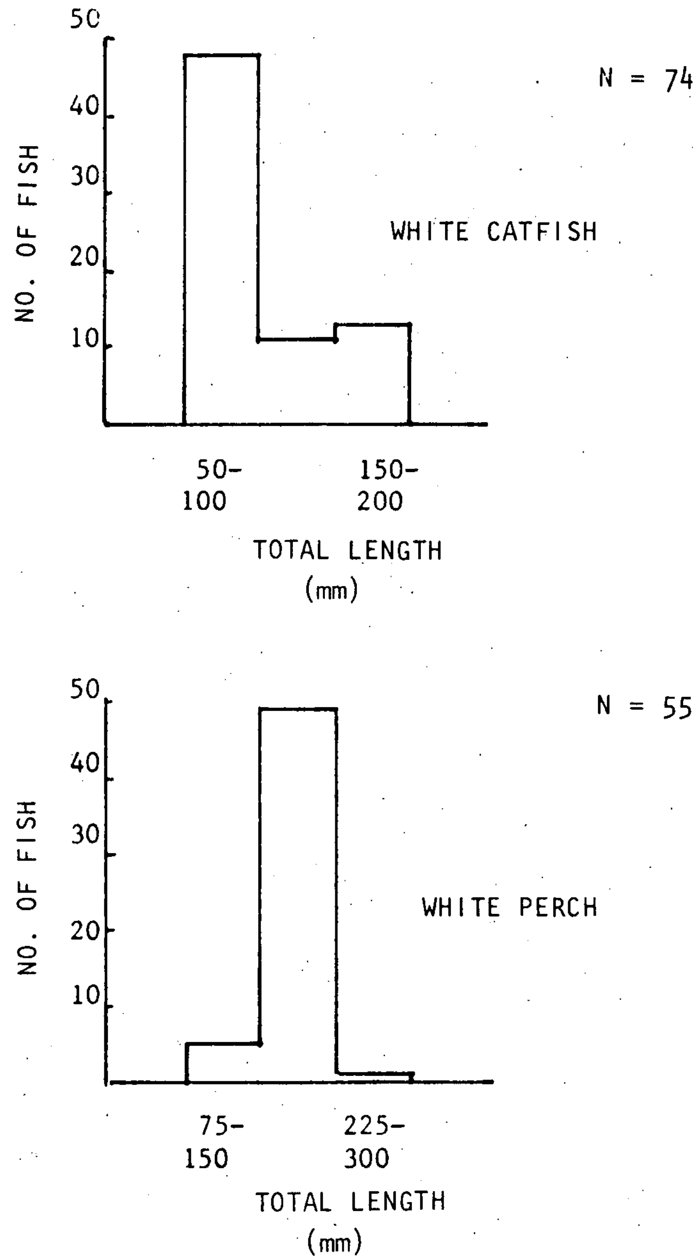


Figure IV-1. Length-Frequency Distributions of Fish from Discharge Canal, May 7-29, 1973

Five white catfish marked with fin clips and returned to the discharge canal in the fall (before the plant shutdown, see Chapter IV, Texas Instruments Incorporated, 1973a) were recaptured during the spring sampling (Table IV-1). Recaptured fish with anal clips had been released at least 165 to 180 days earlier, and those marked with a left-pelvic clip had been in the canal no less than 144 to 154 days. The only recovered white catfish tagged in 1973 may have been recaptured less than 8 hr after its release; the fish was released on a Friday morning and caught during the weekend collection which was set Friday afternoon. No additional tagged or marked fish were recovered in the canal during the spring.

The estimated population of white catfish < 140 mm in length in the discharge canal during the spring was 311, with 95-percent confidence limits of 143 to 4304. An estimate of the population size of white catfish > 140 mm in length was impossible because the only recapture occurred directly after its release. Two of the catfish caught in the canal had eye abnormalities.

Table IV-1

FISH CAUGHT IN DISCHARGE CANAL, MAY 7 TO 29, 1973

Species	No. Caught	No. Tagged	No. of Tag Returns	No. Clipped	No. of Clip Returns	No. of Fall Clip Returns
White catfish	74	17	1	44	2	5
White perch	55	34	0	7	0	0
American eel	14	14	0	0	0	0
Tomcod	8	0	0	5	0	0
Spottail shiner	8	0	0	0	0	0
Carp	1	1	0	0	0	0

Water temperatures in the canal ranged from 12.5°C to 15.2°C; surface flow ranged from 0.09 to 0.36 m/sec. The river's salinity ranged from 0.07 to 0.22 °/oo.

Fish from the last catch on May 29 were held in the laboratory for 2 weeks in an attempt to estimate tagging mortalities during spring sampling in the canal. Three of eight tagged white perch and three of seven untagged (control) fish died within 14 days. The one tagged and one control white catfish (> 140 mm) also died. Surviving were three white catfish (< 140 mm) with lower caudal fin clips. The high mortalities in both tagged and control fish indicated that handling rather than tagging was responsible for the deaths. Fish in this study were subjected to the additional stress of confinement in a small container for the return trip to the laboratory. Stressed white perch had been observed in crowded holding conditions on several occasions during previous canal studies. The small white catfish appeared least affected by the fin clips and any additional stress. In the normal tagging procedure, fish were minimally stressed by brief holding prior to return to the canal.

Discussion

The smallest catches from the canal occurred in winter. The low catch may have reflected the combined effects of the population drop after plant shutdown in fall and the unavailability of fish at low ambient temperatures (< 3°C). As shown in Table IV-2, the recaptures in the spring of white catfish marked during the fall indicate that fish may have been present in the canal during winter but not vulnerable to the fyke net; a similar species, the brown bullhead, burrows into bottom sediments during winter months (Loeb, 1964). Although the small spring catch may have been the effect of population decrease in the fall, the recaptures indicate that these fish and others survived the plant shutdown on December 12. These results tend to collaborate our findings that white catfish in the canal, although stressed by the shutdown, later recovered.

Table IV-2

CHRONOLOGICAL LIST OF TAG RECOVERIES FROM DISCHARGE-CANAL STUDY, JULY 17, 1972 - MAY 29, 1973

Species	Tag No.	Date Tagged	Date Recovered	Lag Time (days)	Location Recovered
White catfish	1351	8/2/72	8/15/72	13	Canal
White catfish	1449	8/15/72	8/28/72	13	Canal
White catfish	1472	8/28/72	4/15/73	230	Peekskill Bay by fishermen
White catfish	1257	11/13/72	11/24/72	11	Canal
White catfish	1135	11/13/72	12/5/72	22	Canal
White catfish	2674	11/15/72	11/24/72	9	Canal
White catfish	2873	11/15/72	3/14/73	119	Unit No. 2 screen
White catfish	1533	11/20/72	12/13/72	23	Canal
Eel	1676	11/22/72	12/1/72	9	Canal
Eel	1676	11/22/72	12/7/72	15	Canal
Eel	1676	11/22/72	12/12/72	20	Canal
White catfish	1560	11/24/72	11/28/72	4	Croton Bay by gill net
White catfish	1753	11/24/72	12/4/72	10	Canal
White catfish	1643	11/24/72	12/4/72	10	Canal
White catfish	1632	11/24/72	12/5/72	11	Canal
White catfish	1663	11/24/72	12/7/72	13	Lovett screens
White catfish	1553	11/24/72	12/13/72	19	Canal
Eel	1796	11/27/72	12/4/72	7	Canal
White catfish	1788	11/27/72	12/12/72	15	Canal
White catfish	1813	11/29/72	12/15/72	16	Canal
White catfish	5223	5/11/73	5/14/73	3	Canal

Spring catches in the canal increased greatly over those of winter but were far below those made during the fall of 1972. The numbers of white perch were similar to the numbers caught in the summer of 1972. No white perch were caught during fall or winter. Spring collections indicated that white catfish, white perch, and American eel were in the canal regardless of whether a thermal discharge was present. This conclusion concurs with findings of an earlier study (Raytheon, 1971).

The greatest diversity (nine species) and the largest catches (catfish) were made during the fall of 1972 when water temperatures in the canal were above ambient; in the earlier study (Raytheon, 1971), the greatest numbers of species (11) were collected in August and the largest catches (striped bass and tomcod) in September when canal temperatures were equal to ambient. Plant operation, natural variability, and major changes in the discharge structure probably influenced the differences in results between the present and previous studies. During the 1972-73 study, the effluent waters were discharged through submerged ports, which may have greatly reduced the movement of the fish into the canal.

The white catfish was the most abundant species in the canal at Indian Point during 1972-73, as well as the most consistently captured species in this study and the previous Raytheon study. The recapture of tagged fish indicated that small (< 100 mm) white catfish were resident for the longest periods and that other species and larger white catfish were in the canal more temporarily.

The effects of elevated temperatures in the canal are confused by the lack of comparable data from winter and spring when the plant was not operating. High summer temperatures did not appear to be detrimental to the survival of a large population of white catfish and the occurrence of eight other fish species. Data from this and previous studies suggest that white catfish were positively attracted to the warm water of the canal, especially during fall. Although sampling methods were not comparable, catfish were much less abundant when the water in the canal was equal to ambient temperatures (Raytheon, 1971). During the fall of 1972 when the plant was discharging warm waters, the number of catfish in the canal was two times greater than in the summer of 1972.

White catfish were stressed by the sudden drop in water temperature caused by plant shutdown in December 1972. In the future, the common discharge of thermal effluent from three independent units should reduce the possibility of sudden discontinuations of the warm water in the canal (and in the plume). The high rate of water flow (3m/sec) produced by the circulators of Units 1, 2, and 3 may exclude all species from entering and living in the canal.

The sampling conducted seasonally during 1972-73 in the discharge canal determined species composition and relative abundance under the present plant operating conditions. It is recommended that sampling be discontinued until Unit 1 plus Unit 2 and/or 3 are operating under normal conditions of flow and water temperature.

THERMAL-PLUME INVESTIGATIONS

Surface trawling was discontinued after December 1972 because there was no thermal discharge. Preparations were made to continue sampling at the earliest opportunity, but plant operations were delayed. Now, sampling in the thermal discharge of the Lovett power station (approximately 2 km downstream) is being considered, but it is unknown if differences in localized water velocity, rate of temperature change, topography, and fish populations may affect comparison of information from sampling in the Lovett and Indian

Point plumes. Our experience at Indian Point indicates that localized phenomena do affect species composition in the near vicinity of the Indian Point plant; i.e., Unit 3 appears to impinge less fish relative to Unit 2, and the species composition is different.

In 1972, surface trawls in the plume produced relatively small catches. In 1973, sampling will be conducted biweekly with floating gill nets to determine their effectiveness in catching fish in the surface plume and control areas. Two nets will be fished at elevated temperatures and one will be fished at ambient temperatures. Each 50-m monofilament net will consist of three sections of equal length but different mesh sizes (12-mm, 25-mm, and 50-mm bar mesh).

THERMAL-PREFERENCE INVESTIGATIONS

Introduction

Temperature-preference studies, by indicating the species which may aggregate in areas of warm water, provide insight into the effect that thermal discharges have on aquatic animal populations. Attraction of fish to the discharge may cause long-term exposure to the effluent, which could result in increased or decreased growth rates and/or fecundity, dependent on the species and food availability.

Materials and Methods

Fish specimens for thermal-preference experiments were collected in the Hudson River near Indian Point by beach-seining and trap-netting and were handled in the same way as fish for other laboratory experiments (Texas Instruments Incorporated, 1973a).

A vertical temperature gradient was established in an epoxied aluminum tank (approximately 0.9 m x 0.9 m x 2.4 m) having a 2.5-cm-thick plexiglass front for observations. Filtered river water of ambient temperature flowed into the bottom of the tank through a PVC diffuser system at a rate of approximately 16 mℓ/sec. A heat-exchanger of 0.6-mm stainless-steel tubing about 8.5 m long formed an S-shaped pattern close (5 cm) to each of the three side walls. The countercurrent heat-exchange system heated water to progressively higher temperatures as water moved from the inlet 2.25 m vertically to an overflow pipe. The vertical temperature gradient was varied by controlling the temperature of water entering the exchanger (55 to 65°C) and the flow rate through the exchanger (1 to 20 mℓ/sec). Temperatures in the gradient ranged from ambient (13°C in May) to 30 to 42°C. A stable gradient was established after 6 to 12 hr.

A dye study demonstrated the lack of horizontal currents and the linear flow of water through a gradient of 13 to 33°C. Although the dye diffused from a 1-cm layer at a depth of 0 to 20 cm to a layer > 50 cm thick at 80 to 130 cm above the tank bottom, the dye-marked water remained distinct, with clear water above and below, as it moved through the tank. Water temperatures at various positions at a given depth in the gradient differed < 0.3°C.

The positions of fish in the tank were recorded 1 hr after the test specimens were introduced into the isothermal water column of ambient temperature. This control observation period was followed by initiation of the temperature gradient and thermal-preference observations. An observation consisted of recording the positions of fish 10 times at 2-1/2-min intervals; before and after each observation period, water temperatures were measured by thermistor probes at 12 depths (20-cm intervals). Preference observations continued at intervals, dependent on the time required for establishing a stable gradient. All observations were made from within a blind structure at a distance of 3 m.

Results

A preliminary analysis of three complete experiments suggests that thermal selections by white perch in spring depend on ambient acclimation temperatures and are independent of fish length. Three fish ($\bar{x}$ TL = 120 mm) from an ambient temperature of 17°C selected 27°C, while two groups ($\bar{x}$ TL = 121 and 71 mm) from 19°C and 20°C respectively preferred 29°C. The preference value is defined here as the mode in fish distribution about a thermal location and represents the temperature most frequented by the majority of the fish in a given test (Figure IV-2). Fish commonly (but less frequently) moved between ambient temperatures and 30 to 32°C.

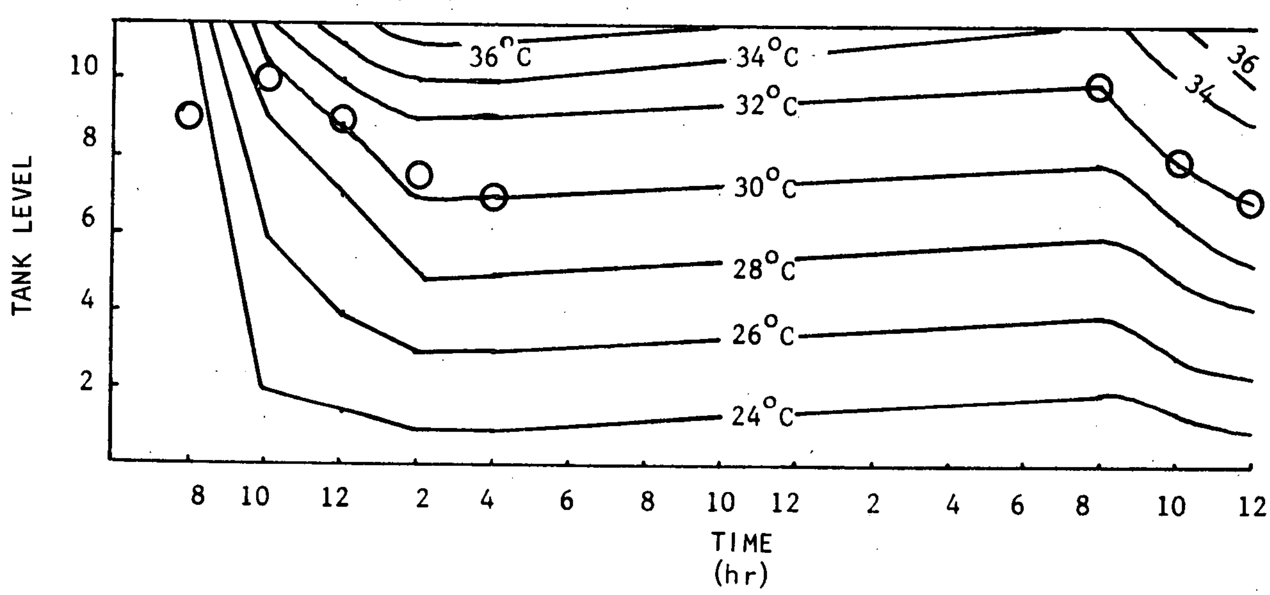


Figure IV-2. Positions (Modes) of Young White Perch and Temperatures in Vertical Gradient, July 3, 1973 (0 Mode of Temperatures Selected)

In the first preference test, white perch selected temperatures which increased from 24°C to 27°C during a 6-hr period of observations, while water temperatures were changing from ambient to the stable gradient condition. In the other tests, temperature selections varied only 1°C in 4 to 7 hr of observations, which were started in a stable gradient about 16 hr after the thermal changes were initiated.

Results will be verified with further replicates conducted under standard operating procedures.

Discussion

The temperature selections probably represent high preference values for the spring season because fish had sufficient time in the gradient to progressively acclimate to high temperatures at an individually imposed rate. Acclimation rates and temperature selections should be similar to those of fish which aggregate in the thermal plume. The small number of preference experiments can only suggest trends which must be supported and confirmed by further investigation. Comparisons with the results of other temperature-preference studies will be made in the next annual report.

The large vertical temperature gradient appears to operate satisfactorily and promises to be an excellent apparatus for determining the behavioral response of organisms to the thermal gradient produced by the Indian Point facility and other possible heat sources.

THERMAL-AVOIDANCE INVESTIGATIONS

Introduction

The avoidance response of organisms to waters of elevated temperatures reduces the possibilities of direct mortality from thermal exposure but may exclude a species from a habitat otherwise available to the population. Information on thermal avoidance defines one of the behavioral responses of organisms to waters of elevated temperatures and helps explain any temperature-related causes of changes in local species composition, distribution, and movement near the discharge area at Indian Point. Upper avoidance temperatures will be determined seasonally for each important fish species. Results will suggest thermal-discharge levels which would be safely tolerated by given species.

Materials and Methods

Collection techniques, holding facilities, and the thermal-avoidance apparatus design were described in the 1972 annual report (Texas Instruments Incorporated, 1973a). Because white perch and striped bass were unavailable in the study area during the winter months due to low river temperatures and ice conditions, thermal-avoidance information was gathered on other ecologically important species: tomcod during January and February; spottail shiners and smelt during March and April; and alewives during April and May. White-perch and striped-bass experiments were initiated in April and May, respectively. Each experiment used fish of uniform length to minimize the potential effect of size difference on behavior.

The standard observation procedure (Texas Instruments Incorporated, 1973a), supplemented frequently with maximum turnaround temperature observations, was used to determine the upper avoidance temperature, which is defined as the temperature or temperature range (usually < 0.5°C) which causes repeated explicit movement of the fish school to some lower temperature in the thermal gradient. Gift and Westman (1971) defined upper avoidance temperature as that causing a fish's ability to discriminate slight temperature differences to be a meaningful activity, i.e., the temperature which creates sufficient stress to cause temperature to be a directive factor. Areas with temperatures above the upper avoidance temperature are usually interpreted as an unacceptable environment. An upper avoidance temperature was representative of the school behavior and not individual behavior because movements of an individual often affect the behavior of the entire school. The maximum (or minimum) turnaround temperature is defined as the maximum (minimum) temperature at which the fish school reverses swimming direction. Preferred temperatures are determined by recording both maximum and minimum turnaround temperatures.

The control-period observation procedure used for the spring 1973 thermal-avoidance tests (except for spottail shiners) was described in the 1972 annual report (Texas Instruments Incorporated, 1973a). An additional procedure for spottail shiners consisted of recording the section nearest the inlet or outlet at which the school reversed its swimming direction.

The test-period observation procedure for striped bass, white perch, and alewife before avoidance consisted of 10 consecutive observations of fish positions 1-min apart at alternate 10-min intervals, while maximum turnaround temperatures were recorded continuously after avoidance behavior was observed. Consecutive maximum and minimum turnaround temperatures were recorded for 5 min at alternate 15-min intervals and for 10 min at alternate 10-min intervals for spottail shiners and smelt, respectively, for the test duration. Experimental procedures for tomcod were described in the first annual report (Texas Instruments Incorporated, 1973a).

The acclimation-temperature/avoidance-temperature relationship during rising and falling field temperatures will be examined by linear regression analysis for those species on which sufficient data have been accumulated (data from two consecutive seasons). This method will permit comparison of the upper avoidance temperatures of the important Hudson River fish species.

Results

Striped Bass. Between May 31 and June 22, 1973, nine thermal-avoidance experiments were conducted with three medium (> 150 to 600 mm) and 38 small (≤ 150 mm) striped bass. The ranges of acclimation and avoidance temperatures for all fish were 14.0°C to 21.2°C and 21.3°C to 29.0°C, respectively (Table IV-3).

Table IV-3
CHRONOLOGICAL SUMMARY OF THERMAL-AVOIDANCE EXPERIMENTS WITH STRIPED BASS

Date (1973)	No. of Fish per Test	Size Range (mm)	Acclimation Temperature (°C)	Upper Avoidance Temperature (°C)
5/30	3	165-200	14.0	26.0
5/31	2	90-105	14.4	27.0
6/6	4	76-115	16.1	21.3
6/7	6	81-105	16.6	28.7
6/8	5	80-99	17.0	25.0
6/11	6	88-110	18.7	28.0
6/12	3	110-120	19.1	27.0
6/21	6	85-105	21.2	28.5
6/22	6	75-105	21.2	29.0

Preliminary data analysis indicated no relationship between acclimation temperature and avoidance temperature (Table IV-3). Results will be statistically analyzed after summer testing when a sufficient number of tests have been completed.

The behavior of specimens under the control conditions was quite variable. Generally, fish which were inactive or moved slowly during the control showed only slightly increased activity under test conditions. Fish moved slowly toward the outlet and the coolest trough temperatures as the upper avoidance temperature moved through the trough. Those fish which were moderately or very active during the control gradually increased their swimming activity as temperatures increased and confined their movements to a temperature range below their upper avoidance temperature for approximately 0.5 to 1 hr. After the initial avoidance reaction, fish frequently entered temperatures progressively higher than their upper avoidance temperature and eventually exhibited a secondary avoidance to a temperature several degrees higher than the upper avoidance temperature. Swimming rates were always more rapid in the direction of decreasing temperatures than in the opposite direction. The number of fish per school ranged between two and six.

During the test period, salinity was always $< 0.1\ ^{o}/oo$. Ambient dissolved-oxygen concentrations ranged from 7.0 to 8.3 ppm; pH, from 7.2 to 7.7.

White Perch. Between April 5 and May 29, 1973, 15 thermal-avoidance experiments were conducted with small ($\leq$ 100 mm), medium (101 to 150 mm), and large (> 150 mm) white perch. The ranges of acclimation and avoidance temperatures were 6.5 to 15.0°C and 15.0 to 26.0°C, respectively; the upper avoidance temperature increased as acclimation temperature increased (Table IV-4 and Figure IV-3). Statistical analysis showed a significant (0.01 level) linear relationship between acclimation temperature and avoidance temperature.

Table IV-4

CHRONOLOGICAL SUMMARY OF THERMAL-AVOIDANCE EXPERIMENTS WITH WHITE PERCH

Date (1973)	No. of Fish per Test	Size Range (mm)	Acclimation Temperature (°C)	Upper Avoidance Temperature (°C)
4/5	5	170-200	6.5	15.0
4/6	6	165-203	6.7	15.5
4/9	6	155-185	7.5	18.0
4/10	6	167-205	8.0	20.0
4/12	6	169-200	7.0	17.0
4/26	6	111-126	10.5	20.0
4/30	6	114-126	11.0	22.0
5/1	6	115-125	11.0	22.0
5/10	6	105-121	12.9	23.0
5/15	5	114-121	14.8	26.0
5/16	6	59-76	14.2	23.0
5/18	2	66-77	15.0	23.5
5/21	3	65-76	14.8	24.5
5/29	4	61-71	14.3	24.0

A preliminary description of white-perch behavioral responses under control and test conditions was presented in the first annual report (Texas Instruments Incorporated, 1973a). Further behavioral responses were observed during the spring 1973 experiments.

All size classes of white perch displayed similar behavioral patterns during control and test periods. Fish never schooled closely during the control period but moved at slow or moderate rates throughout the trough in groups of two or more, seldom displaying a preference for either trough end. Slow-to-moderate swimming activity throughout the trough became slow movement or inactivity at the inlet end as fish preferred temperatures several degrees above ambient river temperature during the initial stages of the test period. Movement to the opposite trough end was infrequent until the maximum trough temperature became the upper avoidance temperature; fish then moved slowly to the outlet and returned more slowly, hesitating in stages as they approached the temperatures which they had initially avoided. This behavioral pattern continued and swimming activity increased as temperatures increased. Fish confined their movements to a progressively smaller area of the trough as the avoidance temperature moved toward the outlet. Fish seldom moved into a temperature greater than the avoidance temperature, and they became inactive or moved continuously in several sections nearest the outlet at experiment termination. The degree of association among fish did not change appreciably during the test period.

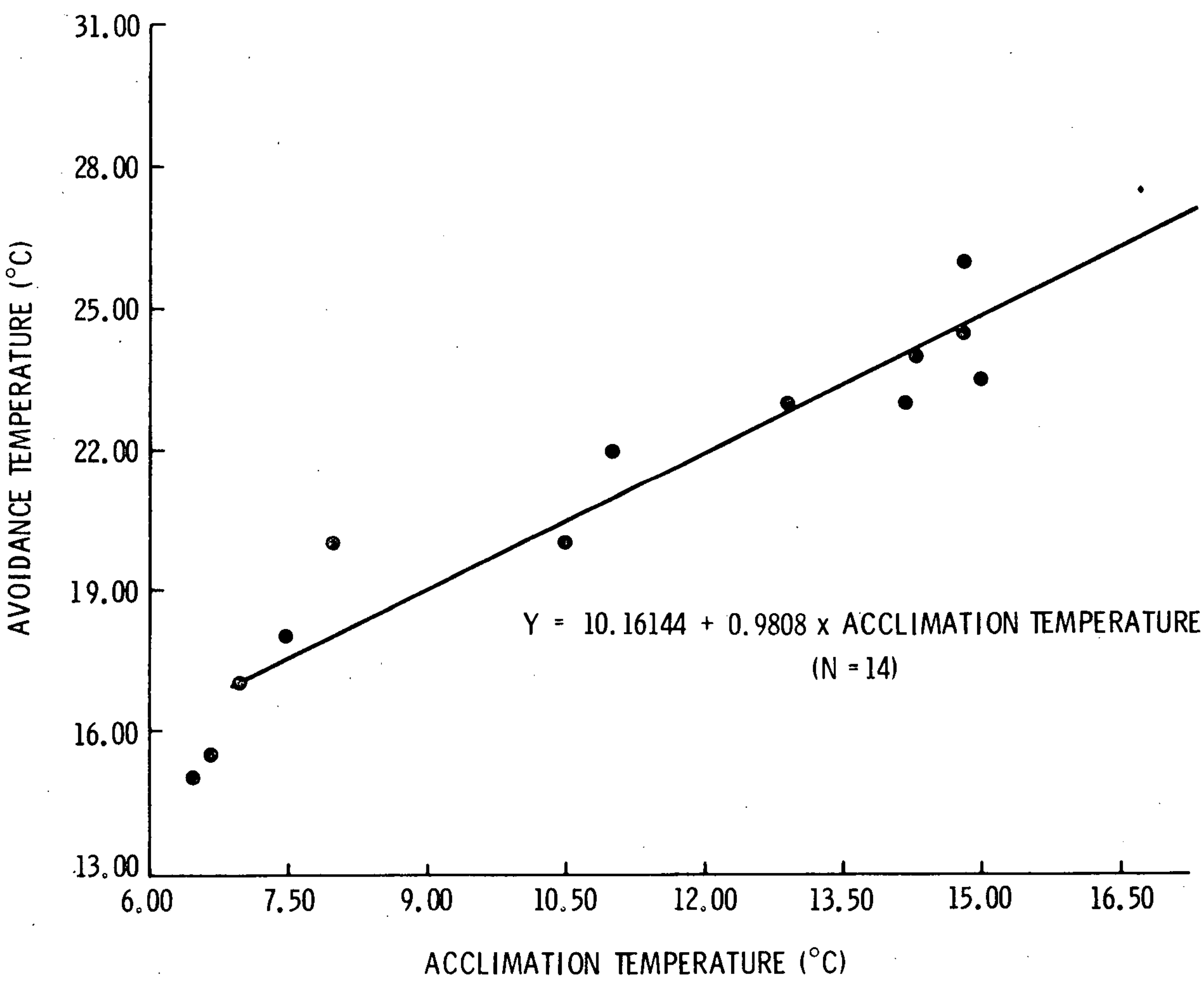


Figure IV-3. Acclimation-Temperature/Avoidance-Temperature Relationship for White Perch, April 5 to May 29, 1973

During the test period, ambient river temperatures ranged from 6.5°C to 15.0°C, salinity varied from < 0.1 ‰ to 3.4 ‰, ambient dissolved-oxygen concentrations ranged from 7.0 ppm to 10.9 ppm, and pH ranged from 6.7 to 8.5.

Tomcod. From December 15, 1972, to February 23, 1973, 31 thermal-avoidance experiments were conducted with small (≤ 150 mm) and large (> 150 mm) tomcod. Two experiments with large tomcod produced no conclusive results so were not included in the statistical analysis. Acclimation and avoidance temperatures ranged from 0.5 to 2.1°C and 9.9 to 17.6°C, respectively, and the upper avoidance temperature increased as acclimation temperature increased (Table IV-5 and Figure IV-4). Statistical analysis showed a significant (0.01 level) linear relationship between acclimation temperature and avoidance temperature.

The behavioral responses of this species under control and test conditions were first described in the 1972 annual report (Texas Instruments Incorporated, 1973a). Two additional behavioral responses were observed in 1973 experiments: fish commonly became more active at the outlet end when water temperatures increased to levels which they had initially avoided at the inlet trough end, and they frequently displayed tremors, twitching, and rapid movements at temperatures above the upper avoidance temperatures, indicating possible signs of thermal stress.

Spottail Shiners. From March 15 to April 4, 1973, eight thermal-avoidance experiments were conducted with 48 specimens (60 to 120 mm in total length). Acclimation and avoidance temperatures ranged from 3.0 to 6.3°C and 8.0 to 17.2°C, respectively (Table IV-6). Preliminary data analysis suggests that avoidance temperature increases with acclimation temperature. Results will be statistically analyzed when a sufficient number of tests have been completed.

Table IV-5

CHRONOLOGICAL SUMMARY OF THERMAL-AVOIDANCE EXPERIMENTS WITH ATLANTIC TOMCOD

Date	No. of Fish per Test	Size Range (mm)	Acclimation Temperature (°C)	Upper Avoidance Temperature (°C)
12/15/72	6	131-150	3.0	17.6
12/18/72	6	168-192	0.5	12.1
12/21/72	6	112-140	1.6	13.8
12/22/72	6	130-143	1.8	15.4
12/28/72	6	107-132	2.1	13.5
12/29/72	6	118-131	1.0	13.3
1/23/73	6	178-230	1.8	13.7
1/25/73	6	165-180	1.3	16.8
1/26/73	6	162-187	1.5	11.8
1/29/73	6	96-118	1.0	12.4
1/30/73	6	94-113	0.6	11.3
1/31/73	6	115-125	0.6	12.5
2/1/73	6	110-120	0.6	11.4
2/2/73	6	181-205	0.6	10.5
2/5/73	6	90-115	0.7	11.2
2/6/73	6	151-158	0.6	11.6
2/7/73	6	164-204	0.7	10.0
2/8/73	6	143-175	0.9	10.2
2/9/73	7	161-180	0.7	11.8
2/12/73	6	120-149	0.5	10.6
2/13/73	6	137-154	0.6	9.9
2/14/73	6	136-150	0.5	10.8
2/15/73	6	151-182	0.9	10.1
2/16/73	6	165-175	0.7	13.3
2/19/73	6	92-112	0.5	11.0
2/20/73	6	118-130	0.6	11.3
2/21/73	6	141-153	0.7	11.8
2/22/73	6	125-135	0.7	11.9
2/23/73	6	163-180	0.6	11.3

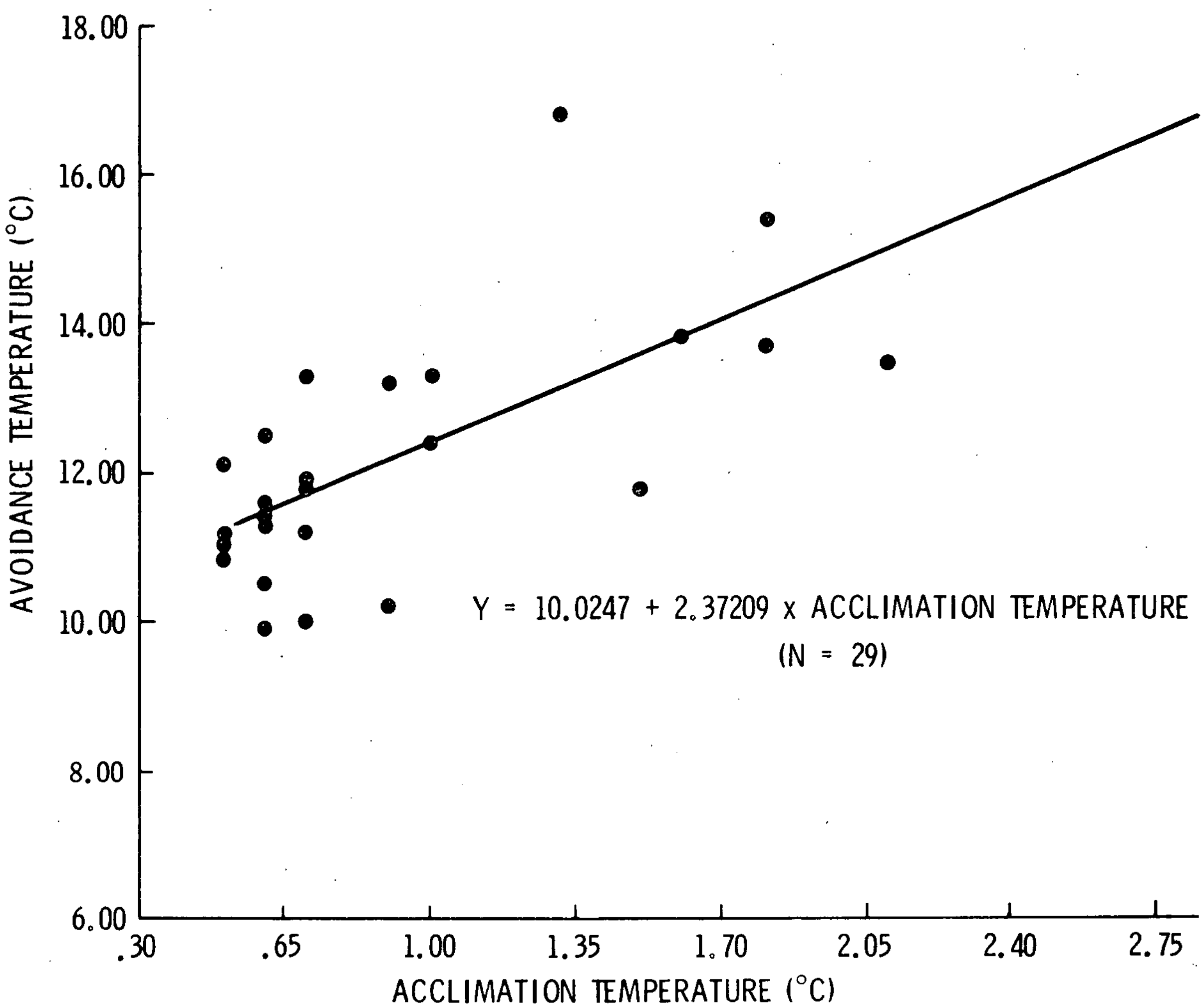


Figure IV-4. Acclimation-Temperature/Avoidance-Temperature Relationship for Atlantic Tomcod, December 15, 1972, to February 23, 1973

Table IV-6

CHRONOLOGICAL SUMMARY OF THERMAL-AVOIDANCE EXPERIMENTS WITH SPOTTAIL SHINERS

(1973)	No. of Fish per Test	Size Range (mm)	Acclimation Temperature (°C)	Upper Avoidance Temperature (°C)
3/15	6	82-108	3.0	8.0
3/21	6	100-104	5.5	16.1
3/22	6	87-102	5.0	14.9
3/23	6	85-112	4.8	14.7
3/26	6	90-100	5.8	15.8
3/29	6	73-120	6.0	17.8
3/30	6	60-104	6.0	16.5
4/4	6	91-110	6.3	17.2

Fish schooled closely at a moderate swimming rate throughout the trough under ambient-temperature conditions or were inactive in one or two schools at one or both ends of the trough, respectively. Fish preferred temperatures several degrees above ambient river temperature during the initial period of temperature increase in the trough. Swimming speed increased as maximum temperatures neared the upper avoidance temperature. The fish gradually confined their movements to a range of temperatures in the gradient below their upper avoidance temperature. This behavioral response caused specimens to slowly occupy a progressively smaller area of the trough as the upper avoidance temperature moved toward the outlet. The school frequently (but briefly) moved into temperatures progressively higher than the upper avoidance temperature after the initial avoidance response. The fish swam more rapidly when moving toward lower temperatures than when moving in the opposite direction and were extremely active at temperatures higher than the avoidance temperature and moderately active or inactive at near ambient temperatures. Hyperactivity, twitching, and darting were commonly observed, especially at higher gradient temperatures, although school breakup was infrequent.

During the test period, salinity varied from < 0.1 °/oo to 3.0 °/oo and pH ranged from 7.5 to 7.6. Ambient oxygen values were not monitored.

Smelt. Three thermal-avoidance experiments were conducted with 14 specimens (115 to 170 mm in total length) from March 27 to April 2, 1973. Acclimation and avoidance temperatures ranged from 6.0 to 6.2°C and from 16.0 to 17.0°C, respectively (Table IV-7). Results will be statistically analyzed when a sufficient number of tests have been completed.

Table IV-7

CHRONOLOGICAL SUMMARY OF THERMAL-AVOIDANCE EXPERIMENTS WITH AMERICAN SMELT

Date (1973)	No. of Fish per Test	Size Range (mm)	Acclimation Temperature (°C)	Upper Avoidance Temperature (°C)
3/27	5	115-140	6.0	17.0
3/28	5	131-170	6.0	16.9
4/2	4	137-150	6.2	16.0

Behavioral responses under control and test conditions were nearly identical to those described for spottail shiners. Smelt displayed no preference for above-ambient temperatures.

During the test period, salinity ranged from < 0.1 °/oo to 2.3 °/oo and pH varied from 7.5 to 7.6.

Alewives. Five thermal-avoidance experiments were conducted on 20 adult alewives between April 25 and May 7, 1973, with specimens ranging between 226 and 310 mm in total length. Acclimation and avoidance temperatures ranged from 10.6 to 12.5°C and 16.0 to 18.0°C, respectively (Table IV-8). Preliminary data analysis suggests that avoidance temperature increases with acclimation temperature. Results will be statistically analyzed when a sufficient number of tests have been completed.

Table IV-8

CHRONOLOGICAL SUMMARY OF THERMAL-AVOIDANCE EXPERIMENTS WITH ALEWIVES

Date (1973)	No. of Fish per Test	Size Range (mm)	Acclimation Temperature (°C)	Upper Avoidance Temperature (°C)
4/25	2	293-295	10.6	18.0
5/2	4	228-298	11.4	17.0
5/3	4	226-288	11.7	16.0
5/4	5	270-300	11.8	18.0
5/7	5	266-310	12.5	18.0
6/18	1	290	20.4	27.0

Alewives schooled very closely in five to eight sections of the trough under control conditions and did not commonly swim throughout the trough as did other species. Swimming activity increased as temperatures increased and the school moved progressively closer toward the outlet. Movement in the direction of decreasing temperatures was more rapid than movement in the opposite direction. The fish frequently (but briefly) entered temperatures greater than the upper avoidance temperature during the latter stages of the experiment. They became less closely associated within the school as swimming rates increased, and movements of individual fish affected the behavior of the entire school much more than during the control. Preference for above-ambient temperatures was not observed.

During the test period, salinity ranged from < 0.1 ^{o}/oo to 3.4 ^{o}/oo, ambient dissolved oxygen varied from 8.6 ppm to 9.3 ppm, and pH ranged from 7.2 to 7.7.

Discussion

Comparison of the upper avoidance temperatures determined for Hudson River fish and the theoretical maximum temperatures of the Indian Point plume (as determined by Quirk, Lawler, and Matusky Engineers, 1970) suggests that at their respective acclimation temperatures no species tested will be excluded from the river area influenced by the thermal plume of Units 1, 2, and 3 during spring. Additional seasonal thermal avoidance experiments and seasonal thermal plume sampling as the three units become operational are necessary to determine the seasonal effect of thermal discharge (second major objective).

Preliminary analysis of striped-bass data indicates no relationship between acclimation temperature and avoidance temperature during spring. Meldrim and Gift (1971) observed that the avoidance temperature of striped bass increases minimally with a large rise in acclimation temperature during the early summer months. Speakman and Krenkel (1972) showed that rising acclimation temperatures in early summer minimally affect the upper incipient lethal temperature of bluegill. The relationship between acclimation temperature and upper avoidance temperature will be more clearly defined when avoidance experiments at summer acclimation temperatures are completed.

Results of white-perch thermal-avoidance studies conducted during rising field temperatures were very similar to findings by Meldrim and Gift (1971). Upper avoidance temperatures may have been slightly higher, however, for similar acclimation temperatures. Additional experiments at summer acclimation temperatures will clarify this phenomenon.

There has been no attempt to analyze the acclimation-temperature/avoidance-temperature relationship for each size class of tomcod and white perch because the range of acclimation temperatures for each size class is small. Separate size class analyses will be conducted dependent on species availability at other ambient temperatures.

Estimating two parameters (acclimation temperature and avoidance temperature) over 5 to 10 replicates and a temperature range of < 10°C does not provide high precision and power on the test; therefore, after summer testing, linear-regression analyses for the acclimation-temperature/avoidance-temperature relationship during rising field temperatures will be conducted for those species which were tested at spring and summer ambient river temperatures.

Although it has not been possible to compare upper avoidance temperatures of each species at similar acclimation temperatures accurately from present data because of rapid change in ambient water temperatures during spring, several generalizations can be made. For similar acclimation temperatures: (1) striped bass avoided higher temperatures than did white perch, (2) American smelt and spottail shiners avoided nearly identical temperatures and avoided higher temperatures than did white perch, and (3) alewives avoided lower temperatures than did all other species which were tested.

Meldrim and Gift (1971) suggest that there is an inverse relationship between salinity and avoidance temperature for white perch and striped bass in the Delaware. A seasonal multivariant statistical analysis will be performed on all species discussed in this report to determine the effect of dissolved oxygen, salinity, pH, acclimation temperature, and size on the upper avoidance temperature.

The validity of short-term (less than 2 hr) thermal-preference information for selected species in a moving horizontal thermal gradient will be determined by comparing horizontal gradient results with those obtained from a stable vertical gradient. If results are similar, thermal-preference information from both gradients will be complementary. Thermal-preference tests in a stable vertical gradient will be conducted seasonally with white perch, striped bass, and other available species.

THERMAL-TOLERANCE INVESTIGATIONS

Introduction

Identification of the acute thermal response of striped bass and white perch is necessary as an initial step in defining the effect which temperature has on the physiological state of the species. Identification of the upper and lower lethal temperature limits will facilitate description of the zone of tolerance, i.e., the range over which temperature does not directly affect the organism's life span. The zone of tolerance, along with temperature-preference and -avoidance data, will permit definition of the potential thermal habitat for these fish. Studies of thermal tolerance, which began in the spring of 1973, will continue through the winter of 1974.

Materials and Methods

The thermal-tolerance apparatus was described in the 1972 annual report (Texas Instruments Incorporated, 1973); however, the plexiglass tubular chambers have been replaced by plastic screen dividers, a modification which allows more rapid mixing so that fish are more rapidly exposed to temperature shock and less time is required for cleaning.

Generally, 10 ambient-acclimated fish are placed in each of eight tanks; following a 1-hr adjustment period at acclimation temperature, water is introduced into each tank from the appropriate head box. Two ambient control tanks and two tanks at each of three test temperatures are established and maintained for the duration of the experiment. Equilibrium of test temperatures occurs in < 10 min, and temperatures are maintained $\pm 0.5\,^{\circ}C$. The condition of each fish is noted at decreasingly frequent intervals during the first 8 hr and during subsequent working days at 3-hr intervals for a total of 96 hr. Behavioral changes, equilibrium loss, death, and temperature are noted at each reading. The temperature at which 50-percent mortality occurs (TLm) after 96 hr is interpolated from a plot of test temperature vs percent mortality. (See Figure IV-5 for an example.)

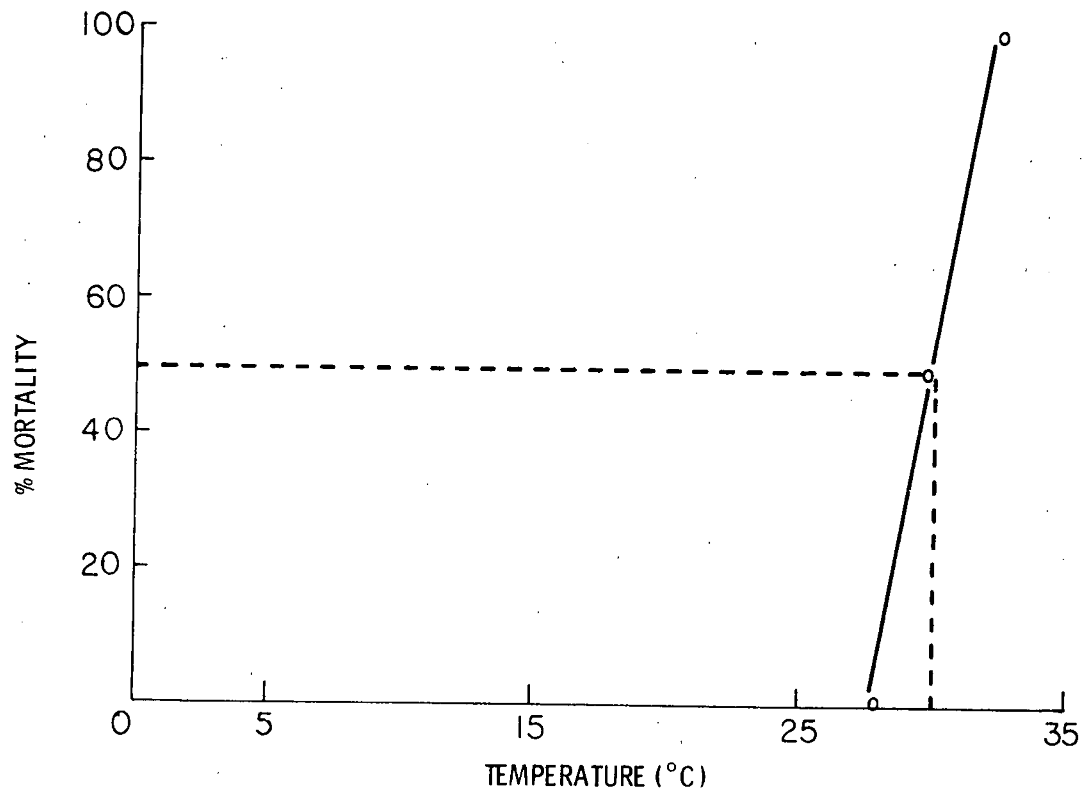


Figure IV-5. Estimate of TLm for White Perch

Results and Discussion

Fundulus diaphanus (banded killifish). Temperatures to 25°C (ΔT = +20°C) failed to cause death in 80 killifish acclimated to 5°C. It is predictable that plant operations (thermal) will not acutely stress this very hardy species.

Morone americana (white perch). TLm determinations for 423 white perch gave spring values ranging from 22.8°C to 30.2°C for fish acclimated to temperatures from 8°C to 20°C (Table IV-9). Such values are in the range previously reported for white perch (McErlean and Brinkley, 1971). An acclimation-temperature change of 2°C resulted in a 1°C change in TLm (Figure IV-6). Generally, a 3°C change in acclimation temperature causes a 1°C change in TLm (Fry, 1971). White perch appear to adjust their upper lethal temperature more rapidly to changing acclimation temperatures than do other species. Published studies of TLm (e.g., Brett, 1956, 1952; Fry et al, 1946; Hoff and Westman, 1966) generally use laboratory-acclimated fish and ignore any effects due to season; however, season does affect thermal relations in fish (Zahn, 1963; Sullivan and Fisher, 1952), and photoperiod changes the thermal tolerance of goldfish (Hoar and Robertson, 1959). A selective advantage for thermal lability (i.e., rapid adjustment in TLm) during the rapidly changing temperatures of spring seems possible. It is advantageous for a fish to live at temperatures that allow rapid energy transfer. Growth, activity, and reproduction occur more rapidly at higher temperatures up to a critical maximum. Rapid adjustment in TLm theoretically permits a fish to inhabit temperatures at which he can maximize energy transfer during rising temperatures. Gonadal development occurs in spring — and a greater energy transfer affords a greater reproductive potential. Also, TLm determinations over an annual cycle may give insight into seasonal changes in TLm.

Table IV-9

SUMMARY OF TLm EXPERIMENTS ON WHITE PERCH FOR SPRING OF 1973

Date (1973)	No. of Fish	Size Range (mm)	Ambient Temperature (°C)	TLm (°C)	TLm (ΔT°C)
4/16	73	130-240	8.0	22.8	14.8
4/24	42	101-168	10.0	24.1	14.1
4/24	40	150-212	10.0	25.1	15.1
5/7	80	106-190	12.0	26.9	14.9
5/14	40	57-79	14.0	27.1	13.1
6/11	80	106-137	18.5	28.8	13.3
6/18	48	57-84	20.0	30.2	10.2

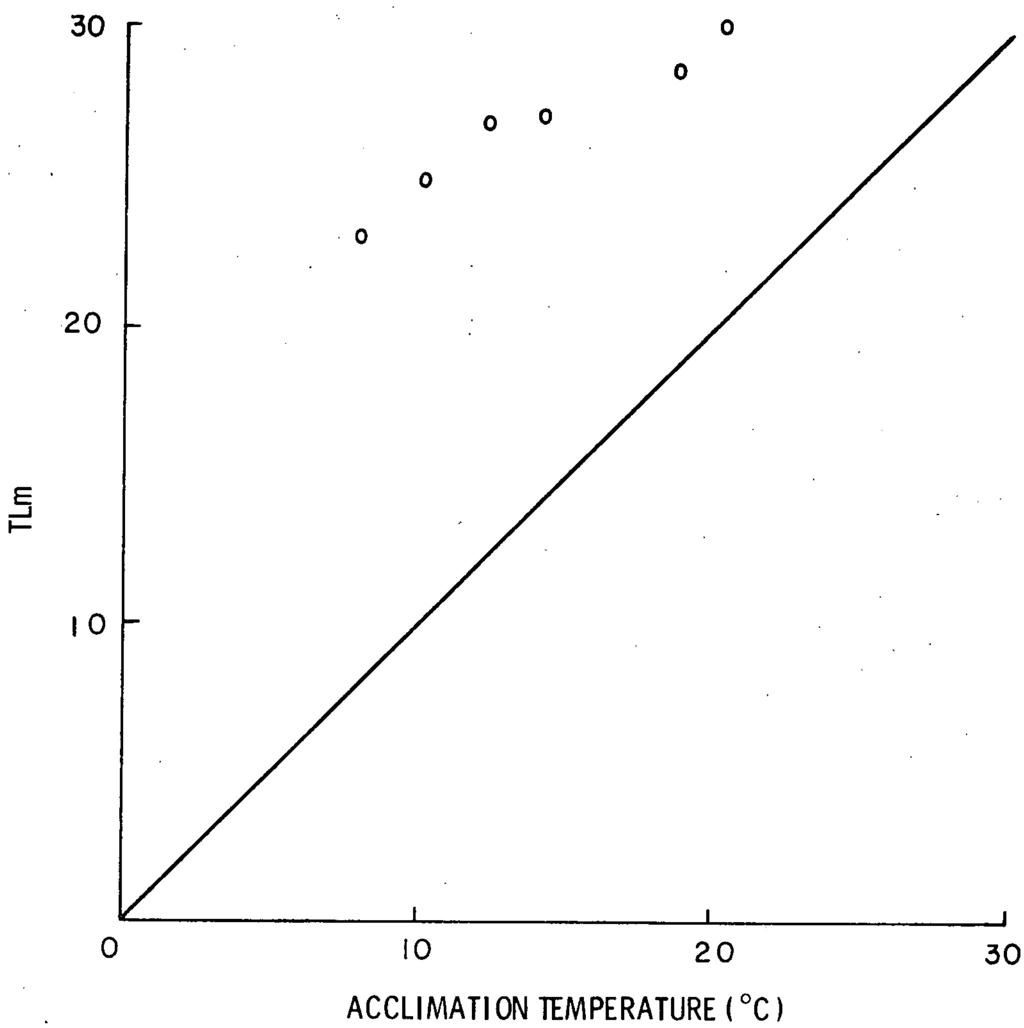


Figure IV-6. Acclimation Temperature Vs TLm for White Perch

Upper thermal tolerance of white perch was calculated by the method of McErlean et al (1969) (Figure IV-7). The upper zone of thermal tolerance of 392 $^{\circ}C^{2}$ lies between that of cold-water salmonids and warm-water teleosts (Brett, 1956); Hoff and Westman (1966) found similar values for three species of estuarine fish - the silverside, the winter flounder, and the northern swellfish. Further work with estuarine species is necessary to understand the full significance of intermediate thermal tolerance. The possible effects of thermal discharge on Hudson River white perch will be discussed in the next annual report.

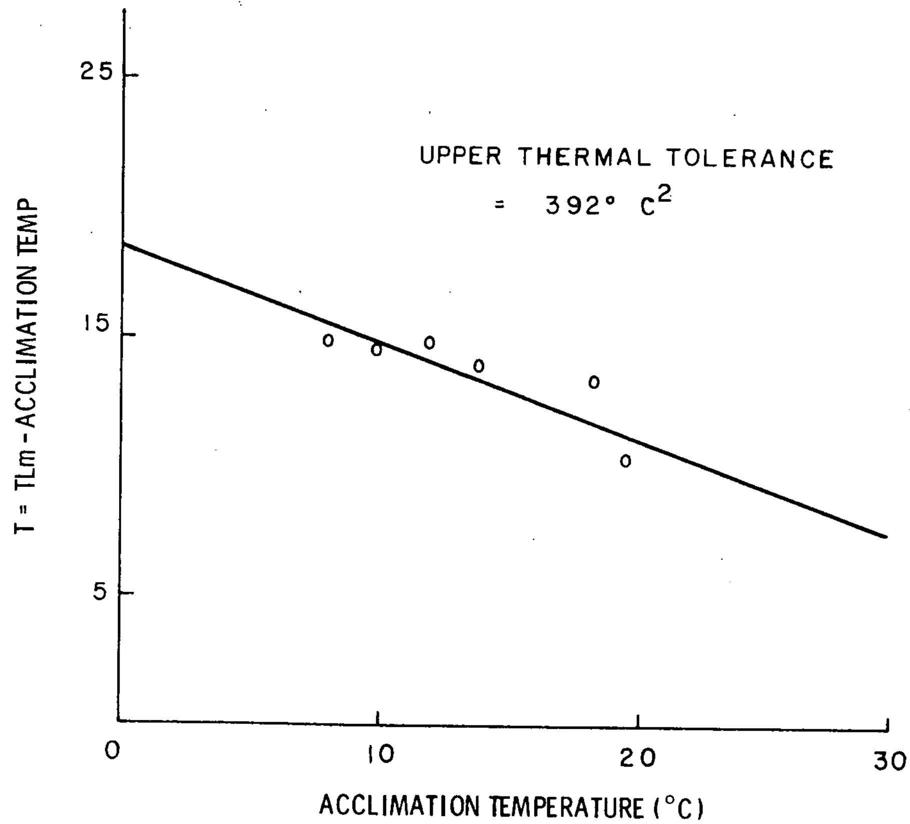


Figure IV-7. Upper Thermal Tolerance Zone for White Perch

Note:

The zone of thermal tolerance is defined as that range of temperature over which there is no direct effect of temperature on the life span of the organism. The lethal effect is directly due to temperature and not an effect of temperature altering some other factor (e.g., metabolic rate) and thus indirectly causing death. Since the upper and lower lethal temperatures (TLm) are a function of acclimation temperature, it is necessary to consider acclimation temperature in describing the zone of thermal tolerance. Practically, one plots upper and lower lethal temperature as a function of acclimation temperature and the area encompassed by those curves is the zone of thermal tolerance. Since it is an areal expression, the units are $°C^2$. Zones of thermal tolerance are species specific and reflect the broadness of an organism's ability to survive temperature variations.

CHAPTER V

FISHERIES POPULATION ECOLOGY

FISHERIES SAMPLING PROGRAM

Introduction

The 1973 fisheries sampling program is designed to provide information for various aspects of the Indian Point ecological study: fish are provided for use in physiological and behavioral experiments, age and growth studies, tag-survival experiments, meristic and morphometric determinations, fecundity studies, and food-habit analysis, and tagged fish are provided for assessing fish movements and fish-population estimation. The distribution of catches in the river provides information on the spatial distribution and movements of selected fish species.

Beach Seining

Since April of 1973, beach-seining operations have been carried out in an extensive area of the Hudson River. Beaches have been sampled in a stratified random design from RM 12 (km 19) to RM 152 (km 243) by beach-seining operations of both the Indian Point and Cornwall projects. (The Cornwall project is a research effort that is directly comparable in methodology to the Indian Point study.) In addition to this stratified random beach seining, standard beach-seining stations have been sampled weekly in the vicinity of Indian Point and Cornwall. Daytime catches from all beach-seining stations have been combined by region without regard to tidal stage. Beach seining was not feasible throughout much of the winter and was therefore infrequent during the months of January, February, and March; in the months that followed, however, beach seines were used frequently as a means of tag recovery and obtaining fish for tagging, physiological and behavioral studies, age and growth studies, and food-habit determinations.

Bottom Trawling

Ice floe in the river permitted only infrequent sampling of standard trawling stations during the first 2 months of 1973. A series of boat and/or winch breakdowns prevented complete sampling in March, but standard bottom trawling was resumed on a weekly basis during the week of April 2. After April 16, standard trawling stations were sampled biweekly. In the intervening weeks, a bottom-trawling program extending axially from RM 29 (km 47) to RM 61 (km 98) was conducted; these axial trawling stations were instituted in order to obtain trawling data and potential tag recoveries from a larger portion of the river. Larger otter boards and a faster trawling speed were employed to improve the efficiency of the axial trawls over that of the standard bottom trawls.

Surface Trawling

The surface trawl previously used was modified during April 1973. Two boats towed the net at the surface at the same stations used for standard station bottom trawls. Because of the ice floe's magnitude in winter, surface trawling was infrequent during the months of January, February, and March. Surface trawling was resumed on a regular basis in May, and samples are currently being taken biweekly.

Trap Netting

Traps were used in a variety of applications throughout the first half of 1973. Box traps provided fish for marking, physiological and behavioral studies, and fecundity studies. Traps also served as another means of tag recovery. Trapping was infrequent in the winter months, and a large-scale trapping program was not begun until May. Most trapping was done in shallow areas of the river, and traps were staked rather than anchored as they had been in the past. In addition to the box trap nets, a pound net was used from March 24 until June 6; it was set first in Croton Bay and later just north of the Lovett power plant in the hopes that large striped bass would be caught with this net for use in migration studies.

Gill Netting

Large-mesh gill nets were fished heavily between March and mid-May to obtain large striped bass for tagging, stomach analysis, age and growth studies, and meristic and fecundity studies. Gill nets also served as a means of tag recovery.

Electrofishing

Electrofishing operations were used intermittently to sample shallow areas inaccessible to either beach seines or traps.

Materials and Methods

Beach Seining. Three types of beach seines are used in the Indian Point fishery program, as indicated in Table V-1. The small 15-m beach seine, which is used primarily to obtain young-of-the-year fish for laboratory use, is set parallel to the shore and pulled straight in. The large 31-m beach seine is used weekly at the standard beach-seining sites and is also used in beach-seine surveys, obtaining fish for tagging, recapturing tagged fish, and obtaining fish for laboratory use. Except for 1 day a month when samples are taken over 24 hr covering each tidal stage, standard beach-seining sites are sampled at low tide. The large seine is deployed by fixing an end of the net on shore and setting the rest of the net in a semicircle along the shore; the net is then pulled in from shore. The 62-m haul seine is used to obtain fish for marking and to recapture tagged fish as well as to supply fish for laboratory use; its deployment is identical to that of the 15-m seine.

Table V-1

BEACH-SEINE DIMENSIONS

Dimensions	Seines		
	Small	Large	Haul
Length	15.3 m	31 m	62 m
Wing			
Depth	1.3 m	3 m	3 m
Length	7.7 m	12.5 m	28 m
Mesh (stretch)	0.5 cm	1.8 cm	1.8 cm
Material	Knotless nylon	Knotless nylon	Knotless nylon
Bunt			
Depth	—	3.8 m	3.8 m
Length	—	6 m	6 m
Mesh (stretch)	—	0.7 cm	0.7 cm
Material	—	Knotless nylon	Knotless nylon
Float line			
Diameter	0.6 cm	0.6 cm	0.6 cm
Material	Polypropylene	Polypropylene	Polypropylene
Float			
Size	4 x 8 cm	4 x 8 cm	4 x 8 cm
Material	Spongex	Spongex	Spongex
Number	51	100	200
Lead line			
Diameter	1 cm	1 cm	1 cm
Material	No. 10, braid-covered, lead core	No. 10, braid-covered, lead core	No. 10, braid-covered, lead core
Weight	3.2 kg	6.4 kg	12.8 kg

Bottom Trawling. Two **types** of bottom trawls have been used in the Indian Point fishery program, as indicated in Table V-2. The small 13.5-m bottom trawl is used to sample the standard trawling stations (Table V-3) as well as the axial trawling stations (Table V-4) and is used occasionally at other locations in the river to recapture tagged fish. The bottom trawl is deployed with enough cable to provide a minimum 1:3 ratio of depth to cable. Depth is measured by an electrical echo-sounder; the cable is marked at regular intervals. When sampling standard trawling stations, the net is equipped with doors measuring 0.8 m x 0.4 m and is towed against the tide at a speed of 1.0 m/sec for 10 min; when sampling axial and other stations, the net is equipped with doors measuring 0.8 m x 1.2 m and is towed against the tide at a speed of 1.3 m/sec for 5 min. Bottom trawling is always performed in daylight, since time of day does not appear to affect trawl catches (Texas Instruments Incorporated, 1973a). Satisfactory standard methods for operating the large 29-m bottom trawl have not yet been developed.

Table V-2

TRAWL DIMENSIONS

Dimensions	Trawls		
	Small Bottom	Large Bottom	Surface
Total length	13.5 m	29 m	15 m
Head rope			
Length	7.8 m	14.2 m	5.3 m
Diameter	1 cm	1 cm	1 cm
Material	Nylon	Wire	Nylon
Float size	4 x 8 cm	10 x 10 cm	12 x 14 cm
Float number	6	40	8
Float material	Spongex	Spongex	Spongex
Spreader bar			
Length and diameter	–	–	3.33 m x 33 mm
Float size	–	–	16 x 40 cm
Float number	–	–	2
Float material	–	–	Spongex
Foot rope			
Length	9.3 m	17.5 m	5.3 m
Diameter	1 cm	1 cm	1 cm
Material	Nylon	Wire	Nylon
Weights	13.2 m of 0.6-cm galvanized chain	21 m of 0.6-cm galvanized chain	38-9 link tickler chains of 0.6-cm galvanized chain
First section			
Length	10 m	24 m	2.1 m
Mesh (stretch)	3.8 cm	7.4 cm	4.3 cm
Second section			
Length	–	–	3.3 m
Mesh (stretch)	–	–	3.5 cm
Third section			
Length	–	–	3.0 m
Mesh (stretch)	–	–	3.0 cm
Fourth section			
Length	–	–	3.7 m
Mesh (stretch)	–	–	2.5 cm
Cod end			
Length	3.5 m	5 m	2.9 m
Mesh (stretch)	3.2 cm	3.2 cm	4 mm
Liner mesh (stretch)	0.6 cm	1.6 cm	–
Trawl doors			
Standard station	0.8 x 0.4 m	–	–
Other	0.8 x 1.2 m	0.9 x 1.2 m	–

Table V-3
STANDARD TRAWLING SITES FOR REGION I

Station	RM	Depth (m)	Tow Course* (°)	Location**	
				Latitude	Longitude
1	43	9.3	031	41°16'57"	73°57'17"
2	43	4.6	350	41°17'12"	73°56'38"
3	42	4.6	031	41°16'25"	73°58'16"
4	42	15.5	043	41°16'14"	73°57'36"
5	41	12.4	024	41°15'42"	73°58'03"
6	39	12.4	336	41°14'04"	73°57'55"
7	40	4.6	304	41°14'36"	73°57'28"

*True course given is for upriver towing; tows are routinely made against the tide, so a tow course of 010° would be 190° during incoming tide.

**Refers to midpoint of tow.

Surface Trawling. The surface trawl used previously in the Indian Point program was modified in the spring of 1973 (Texas Instruments Incorporated, 1973a) to provide a better system for sampling pelagic fish. (The resultant net is described in Table V-2.) The net is towed against the tide at a speed of 1.0 m/sec for 10 min. Two boats, each attached to one vertical spreader bar by 33 m of 1-cm nylon line, pull the net. The surface trawl is currently used on a biweekly basis only at the standard trawling stations (Table V-3). Sampling is always during daylight.

Trap Netting. Two sizes of box-type trap net are routinely used, and a pound net was used experimentally in 1973 during the striped-bass spawning season. These gear are described in Table V-5. The small and large box traps are set in depths to 3 m with the wings 45° to the long axis of the box and consequently angled 90° to each other. The lead on the small trap is directed along the long axis of the box between the two wings. The wings, the leads, and the box itself are staked to the river bottom whenever possible;

Table V-4

SAMPLING SITES FOR AXIAL BOTTOM-TRAWLING PROGRAM OF INDIAN POINT ECOLOGICAL STUDY

Station*	Depth (m)	Tow Course** (°)	Location***	
			Latitude	Longitude
29-3	4.6	002	41°06'00"	73°52'38"
29-2	9.3	002	41°06'00"	73°53'04"
31-2	9.3	004	41°07'52"	73°52'55"
31-1	4.6	355	41°07'43"	73°53'11"
33-3	3.1	359	41°09'18"	73°53'35"
33-2	9.3	326	41°09'43"	73°54'05"
35-3	3.1	332	41°11'18"	73°54'48"
37-3	4.6	341	41°12'37"	73°56'03"
37-2	9.3	341	41°12'20"	73°56'55"
39-1	3.1	343	41°41'07"	73°58'05"
39-2	9.3	342	41°13'55"	73°57'55"
39-3	21.8	337	41°14'17"	73°57'53"
41-2	15.5	008	41°15'30"	73°58'15"
42-1	4.6	031	41°16'25"	73°58'16"
42-3	15.5	043	41°16'14"	73°57'36"
43-1	9.3	031	41°16'57"	73°57'17"
43-3	4.6	350	41°17'12"	73°56'38"
44-2	24.8	311	41°17'39"	73°57'22"
44-1	15.5	316	41°17'52"	73°57'54"
46-3	12.4	330	41°18'58"	73°58'43"
48-3	15.5	022	41°20'41"	73°57'38"
49-1	26.0	006	41°21'48"	73°57'38"
54-1	18.6	342	41°24'56"	73°57'57"
54-2	9.3	340	41°24'56"	73°57'48"
55-3	9.3	338	41°25'56"	73°58'22"
57-1	4.6	337	41°27'12"	74°00'30"
57-2	9.3	337	41°27'15"	74°00'19"
59-1	12.4	356	41°29'00"	74°00'08"
59-3	3.1	005	41°28'55"	73°59'36"
61-2	9.3	000	41°30'42"	73°59'40"

*First number refers to river mile; second number refers to position in river, with 1 = west side, 2 = midriver, 3 = east side.

**True course given is for upriver towing; tows are routinely made against the tide, so a tow course of 010° would be 190° during incoming tide.

***Refers to midpoint of tow.

Table V-5

TRAP-NET DIMENSIONS

Dimensions	Trap Nets		
	Small	Large	Pound
Lead			
Number	1	—	1
Length	15.3 m	—	61 m
Depth	1.8 m	—	2.4 m
Mesh (stretch)	2.3 cm	—	15.2 cm
Material	Knotless nylon	—	Knotted nylon
Wing			
Number	2	2	2
Length	7.4 m	7.4 m	10.6 m
Depth	1.8 m	1.8 m	3.7 m
Mesh (stretch)	2.3 cm	9.7 cm	7.6 cm
Material	Knotless nylon	Knotted nylon	Knotted nylon
Box			
Size	0.9 x 0.9 x 1.8 m	1.2 x 1.2 x 2.3 m	1.8 x 1.8 x 2.2 m
Mesh (stretch)	1.5 cm	1.5 cm	1 cm
Material	Knotless nylon	Knotless nylon	Knotless nylon
Frame material	3.5-cm dia aluminum tubing	3.5-cm dia aluminum tubing	1.5-cm steel rod
Heart			
Mesh (stretch)	—	—	7.6 cm
Length	—	—	4.6 m
Width	—	—	3.0 m
Material	—	—	Knotted nylon
Throat size	15 cm	15 cm	30 cm
No. of openings	1	142	1

when it is not possible, anchors are used to hold the gear in position. The lead is always directed toward shore. These types of traps are operated daily to supply fish for laboratory use, to provide a supply of fish for tagging, and to provide recaptures. The pound net, which has been set only twice in an attempt to catch large striped bass, is set in a fashion similar to the box traps except that it must be staked at all corners so it will retain a rectangular shape since there is no rigid frame comparable to that of the box traps; in addition, a triangular heart is formed from the wings at the opening of the pound. A pound net was diagrammed in the 1972 annual report (Texas Instruments Incorporated, 1973a).

Gill Netting. Six types of gill nets of varying depth and mesh size but all of braided nylon (Table V-6) are available for use in the fishery sampling program; these nets are routinely fished during striped-bass spawning runs (when they are checked hourly) but only occasionally during the rest of the year (when they are checked daily). Gill nets are set either parallel or perpendicular to the current between two anchors or stakes in depths ranging from 3 to 11 m; their primary use has been to obtain large striped bass. Sets have been made from Croton Bay in the south to Peekskill Bay in the north.

Electrofishing. Used in an attempt to capture large striped bass, the electrofishing unit consists of a variable-voltage gasoline-powered generator which provides electricity to two whip-antenna electrodes mounted on the bow of a specially designed flat-bottomed boat; the generator itself is a 3000-w ac/dc generator with voltage varying from 0 to 250 and amperage from 0 to 10. This fishing unit is used occasionally in shallow areas which are inaccessible to other gear.

Fish Processing. Standard station fish-handling procedures were modified this June to allow accurate separation of young-of-the-year fish data for all species from that of the older age groups; this was accomplished by modifying the size classes used in subsampling the catch. Size classes previously used were 0 to 50 mm, 50 to 125 mm, 125 to 250 mm, and >250 mm; the new size classes are 0 to x mm, x to 150 mm, 150 to 250 mm, and > 250 mm, where x is a variable such that age-0 fish will always be < x and age-1 fish > x. (This variable changes seasonally and is different for each species.)

Table V-6

GILL-NET DIMENSIONS

Gill Net	Type	Length (m)	Depth (m)	Panel No.	Stretch Mesh (cm)
1	Floating	91.4	2.4	1	12.7
2	Sinking	91.4	3.6	1	20.3
3	Sinking	91.4	1.8	1	15.2
4	Sinking	91.4	2.4	1	15.2
5	Sinking	91.4	2.4	1	20.3
6	Sinking	30.5	2.4	1	5.1
		30.5	2.4	2	12.7
		30.5	2.4	3	20.3

Results

Beach Seining. Standard station beach-seining catches of 12 important species from the Indian Point region are summarized by month in Appendix B, Table B-1. The catch per unit effort (C/f) for both white perch and striped bass showed an overall increase from April to June, but spottail shiners declined over the same time period. Total catches with the standard 31-m beach seine have been combined for each 10-mi (16-km) interval of the river and a mean C/f calculated for each interval. Data for an extensive area of the river are available for April and May.

As shown in Figure V-1, beach-seine catches of both striped bass and white perch were concentrated in the lower reaches of the estuary in April. During May, beach-seine catches of white perch were higher in almost every sampled area of the Hudson. Furthermore, many areas in the upper reaches of the river, which provided few white perch during April, showed very high catches in May; striped-bass catches in May were also generally higher than those in April, and striped bass were found in many upriver beach seine areas from which they were absent in April.

Bottom Trawls. Bottom-trawl catches of 10 important species from the Indian Point region's standard stations (Table V-3) have been summarized by month in Appendix B, Table B-2. From April to June, striped-bass C/f remained at about the same level but white-perch C/f increased, as did Atlantic tomcod with more than a ninefold increase from May to June. Hogchoker C/f declined during the spring.

White perch and striped bass captured in standard station bottom trawls and standard station beach seines have been used to calculate the age- and length-frequency distributions of each species in each gear. These distributions are presented in Figures V-2 and V-3. In general, beach seines caught younger and smaller white perch than did the bottom trawls for the same time period. Bottom-trawl catches of striped bass were too small to permit meaningful comparison of the two gears.

The axial bottom-trawling program provided catches from a more extensive area of the river, but only 4 weeks of data are currently available for analysis. As shown in Figures V-4 and V-5, catches of white perch and striped bass appeared to be concentrated in the more downriver trawling stations during the last week of April; however, many of the upriver stations were not sampled during that week. During the week of May 8, there was a larger catch of both white perch and striped bass, particularly at the more upriver trawling stations; by June 6, the catch of both species in axial trawls had dropped to almost zero. The axial trawl catch of white perch recovered somewhat the week of June 19, but striped-bass catches remained low.

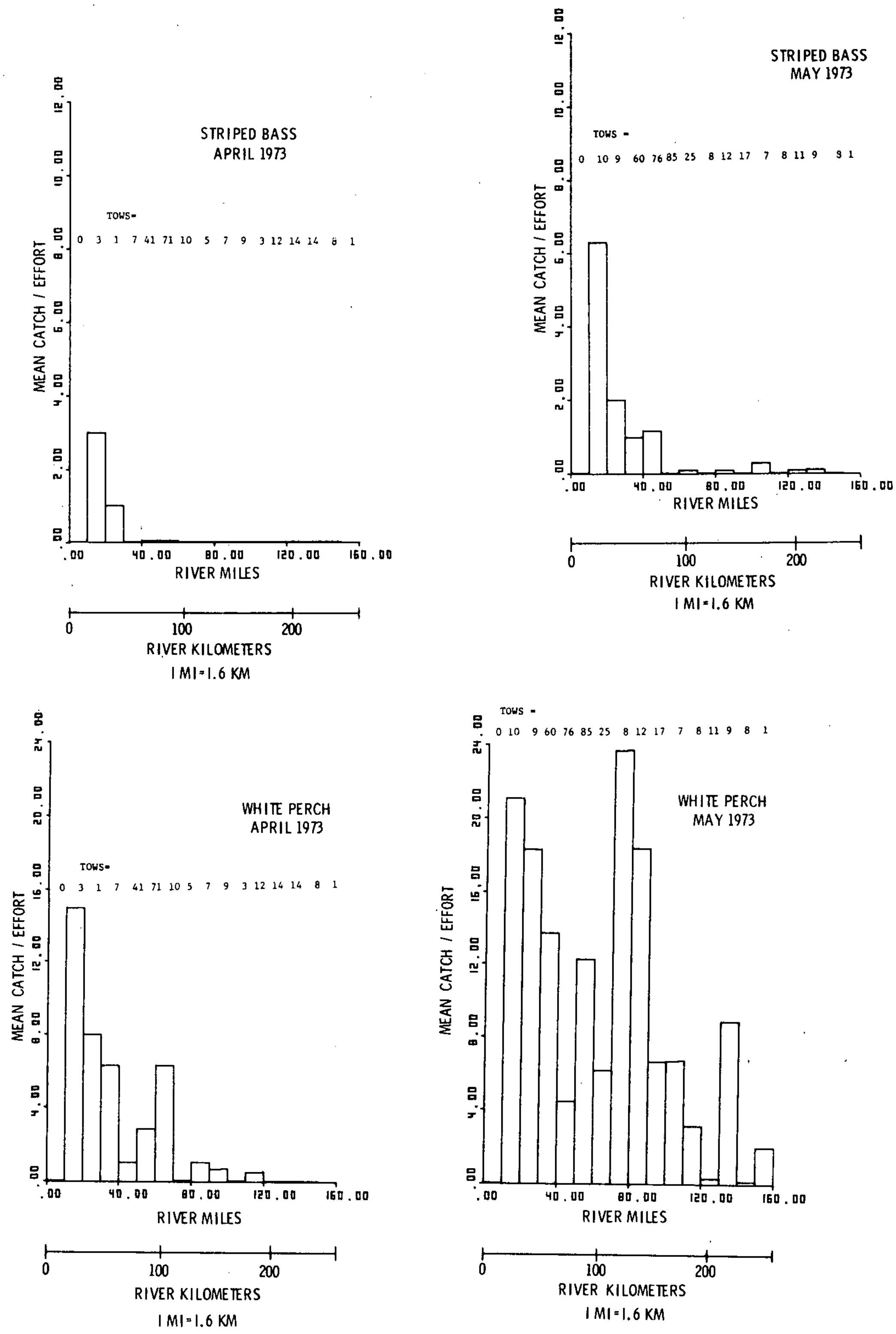


Figure V-1. Spatial Distribution of Daytime Beach-Seine Catches of White Perch and Striped Bass, April and May 1973

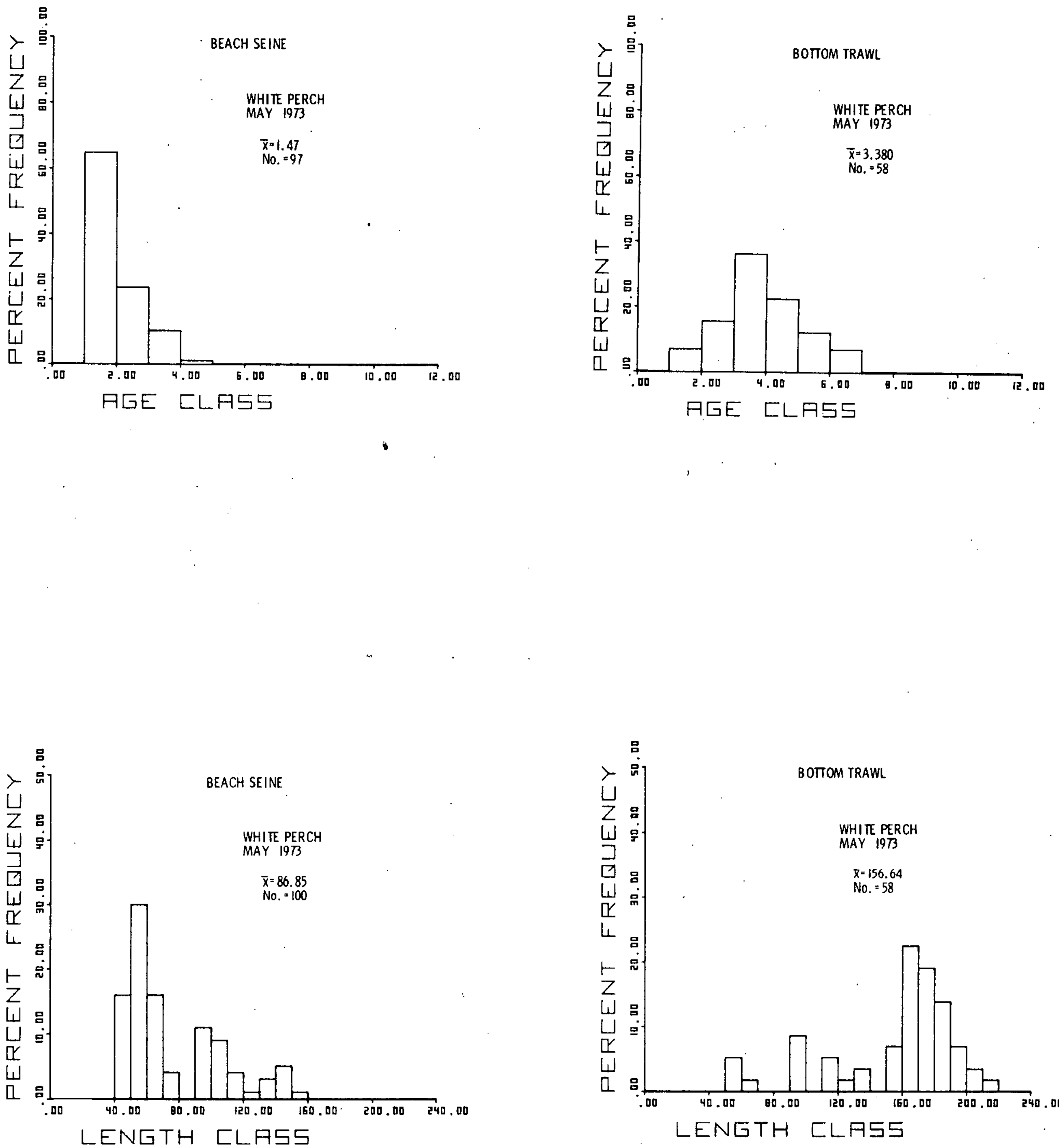


Figure V-2. Age- and Length-Frequency Distributions of Beach-Seine and Bottom-Trawl Catches of White Perch, May 1973

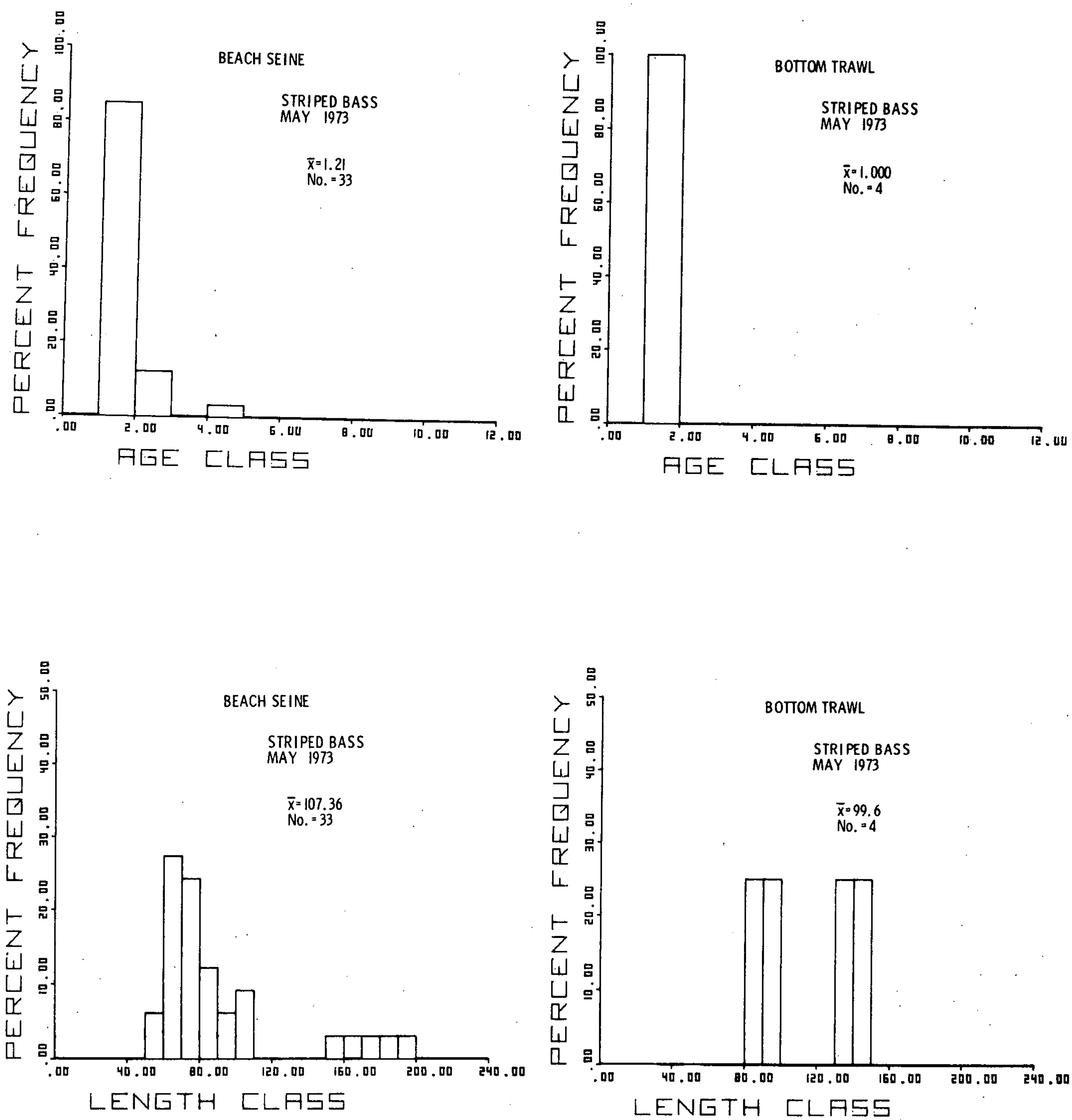


Figure V-3. Age- and Length-Frequency Distributions of Beach-Seine and Bottom-Trawl Catches of Striped Bass, May 1973

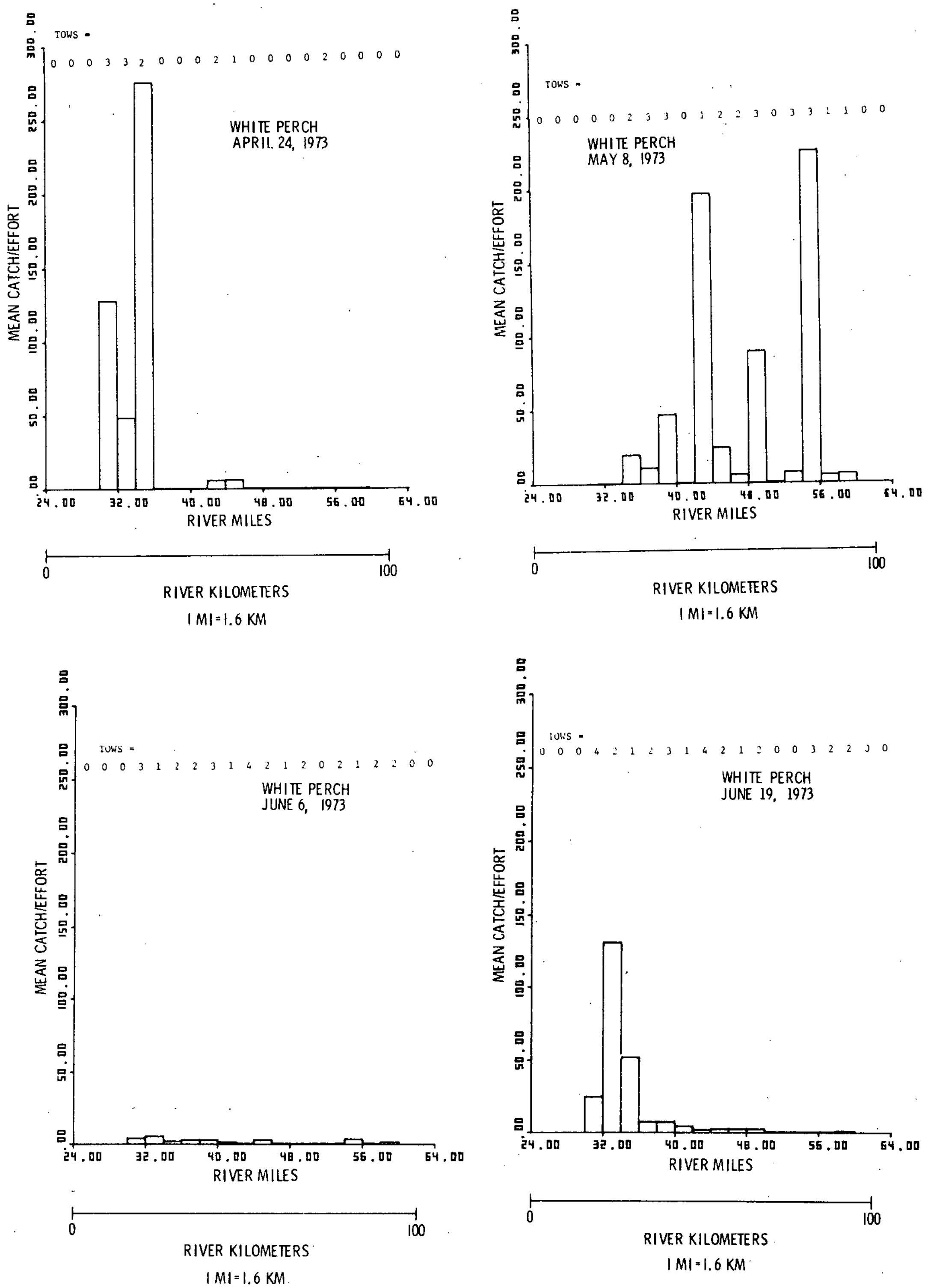


Figure V-4. Spatial Distribution of Axial Trawl Catches of White Perch

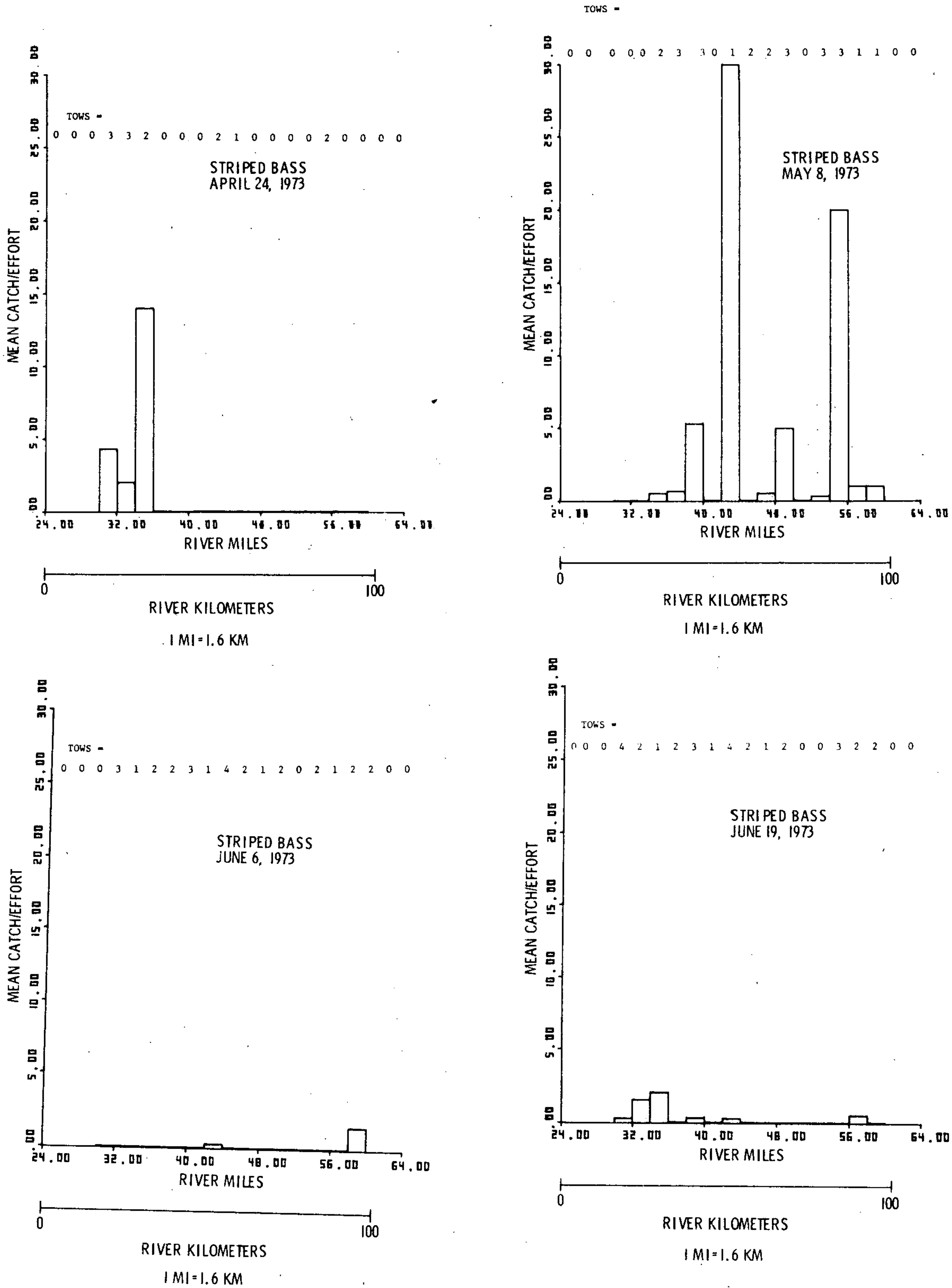


Figure V-5. Spatial Distribution of Axial Trawl Catches of Striped Bass

Surface Trawling. The distribution of surface-trawl catches during 1973 has been patchy, with times of very low and very high catches. Table B-3 in Appendix B summarizes by month the catches of the seven most abundant species in 1973 surface trawls. Three species (bay anchovy, blueback herring, and bluefish) showed substantial catch-per-effort increases from May to June.

Trap Netting. White perch were generally the most abundant species in box traps, with relatively few striped bass being captured by this gear. White perch C/f in traps was particularly high during June, but striped-bass catches remained low. No large striped bass were taken in the pound net. Alewives were the most abundant species taken by the pound net.

Gill Netting. Gill-net catches were extremely variable in terms of species and numbers caught. White perch were often abundant in gill-net catches, and large striped bass were taken regularly during the spawning season.

Electrofishing. The most abundant species in the electrofishing catches was the white perch, with large striped bass being taken only occasionally.

Discussion

The April-May increase in beach-seine catches of both white perch and striped bass most likely reflects an onshore movement of both species during this time period. The trend toward increased beach-seine catches of both species in an upriver direction over this 2-month period may be indicative of an upriver migration. The spatial distribution of the axial trawl catches in April and May also showed an apparent upriver increase from late April to early May, which lends support to the idea of an upriver migration at this time. Mansueti (1961) notes that white perch in the Patuxent River show extensive upstream movements in the spring; preliminary returns of tagging data in the present study also indicate an upstream migration of mature white perch from April to May. The precipitous decline in the axial trawl catches of both species from the first week in May until the first week in June was likely the result of an onshore movement of both species in the latter portion of May and early June and, as stated earlier, beach-seine catches of both species were higher in May. The increased trap-net catches of white perch in June are also indicative of increased movement at this time. The time of this onshore and upriver movement coincides well with the white-perch spawning season.

TAG/RECAPTURE PROGRAM

Introduction

The tagging program's objective is to provide estimates of several of the population-dynamics parameters required for impact assessment. Two of the parameters directly obtained from tagging results are population numbers and geographical distribution; from these, as well as the impingement record at Indian Point for the same time period, one can estimate the area of plant influence and percentage of the background population impinged. Other parameters that can be subsequently estimated include mortality, recruitment, and production rates. The integration of these parameters with the results from all the other aspects of the study provides the basis for an overall assessment of ecological impact.

Results to date permit us to begin here to assess impingement impact, and this initial assessment is presented (i.e., percentage of the white-perch population impinged during a finite time interval).

A substudy to assess the usefulness of tagging large (> 400 mm) striped bass that overwinter in the lower river and to investigate their migratory habits was also undertaken. Previous studies had tagged fish primarily in the saltwater environment, with a few recoveries being obtained from the Hudson River. Depending on the success of these efforts to recover a meaningful number of tags and collect useful data, a recommendation as to the desirability of continuing the program will be made but, at the moment, we do not anticipate that such a program could provide an accurate quantitative assessment of the older striped-bass age groups within the Hudson population. While such an assessment would be desirable it is not essential to an evaluation of plant effects on the bass population which can be determined by ichthyoplankton and entrainment studies and population statistics through the first year of life.

Tagging mortalities have been significant in the past (Texas Instruments Incorporated, 1973a), so additional survivorship experiments have been conducted. The major problem in handling fish has been the occurrence of secondary fungal infections, but we are looking for techniques that will minimize this problem. Two treatments — a salt solution and a formalin solution — are being evaluated. The formalin solution has proved effective in controlling fungus in aquarium-held fish (semiclosed system); the treatment using both short-term and long-term doses appears effective. The application of these solutions in the recovery water after tagging is being evaluated for its effectiveness in the field program. Also, Carlin tags, which are similar to Floy fingerling tags but use a different method of attachment, have been evaluated in field operations and survivorship experiments for two reasons: to investigate their use as an alternative to the Floy fingerling tags (which are time-consuming to apply) and because the New York State program was initially planning to use this type.

Method and Materials

A detailed description of the standard operating procedures can be found in the 1972 semiannual and annual reports (Texas Instruments Incorporated, 1972 and 1973a) and will not be repeated here; only minor changes have occurred, and they will be noted where pertinent.

The majority of the large striped bass used for tagging were collected via gill nets. These nets were tended frequently and the fish removed in an expeditious manner. The fish were anesthetized, tagged with a Dennison tag, and released upon recovery from the anesthetic. Location, date, gear data, size, age, and conditions were recorded and entered into the data files.

The primary methods of marking fish during 1973 have been with the Dennison anchor tag, the Floy fingerling tag, and by fin-clipping. The three methods were applied to fish according to total length: the 1972 year class, fin clip; the 1971 year class, Floy fingerling; and the 1970 year class and older, Dennison tag. The white-perch age groups were separated by approximate lengths of ≤ 100 mm, 100 to 130 mm, and > 130 mm. Survivorship for each combination of tag and species is being evaluated once every 4 weeks during the 1973 sampling season. The fish are segregated by size into three groups: small (0 to 100 mm), medium (100 to 150 mm), and large (> 150 mm).

All experiments are conducted in river holding pens 1.2 m x 1.2 m x 1.2 m constructed of 13-cm stretch mesh, with a maximum of 26 fish being placed in each pen. The fish are collected with a mixture of each of the gears used in the tagging operations, i.e., 50 percent from traps and 50 percent from beach seines per pen.

Daily observations for the first 2 weeks, as well as triweekly observations for the final 2 weeks, ascertain the number of dead fish, their size, the tag type and number, and the ambient water temperature. The pens are scrubbed daily to retard attached growth and to clear debris that might obstruct water flow. All fish used in the experiments are transported and handled according to the methods described in the 1972 annual report (Texas Instruments Incorporated, 1973a) except for the holding-tank treatment. To prevent fungal and other infections, salt is routinely added to the water in the recovery tank to achieve a concentration of 10 percent. The holding time is not extended beyond the time needed for the fish to recover from the effects of the anesthetic. Also being evaluated is treatment with low concentrations of formalin (250 and 125 ppm) in the holding tanks; in this case, the holding time is extended to approximately 30 min.

Marking devices tested include the fin clip (double), the Floy fingerling, the Carlin tag, and the Dennison anchor tag. To date, due to the natural scarcity of small white perch and striped bass of any size during this time of the year, most of the experimental subjects have been perch that are > 100 mm. Smaller ones will be evaluated as they become available.

Based on the 1972 feasibility study, additional efforts to increase the probability of random mixing of the tagged fish in the population were recommended. To achieve this, the tagging crews changed the standard operating procedures to more widely redistribute the fish after tagging: on alternate weeks, all tagging crews released tagged fish at locations within the same river mile but not at the original capture site; during the intervening weeks, the fish were released at the site of capture. Increased trawl fishing was conducted to secure tag recoveries from the habitats where tagging was not feasible.

Results

Tag Returns. During the present season, 13 tagged striped bass and 111 white perch (80 tags and 31 fin clips) have been recovered. This includes tags reported in sports fishery, commercial fishery, intake-screen collections, and the Cornwall and Indian Point studies; 36 of these were tagged and released during the 1972 tagging efforts. Table C-1 of Appendix C lists the tag recoveries with the associated data on dates, locations, gear, species, and length. These recoveries of white perch are more than adequate to estimate populations numbers with reasonable confidence.

Returns from sports fishermen are extremely valuable in determining the migratory range of striped bass. Figure V-6 shows locations of recaptures of striped bass released primarily in Croton Bay (one fish was released near Cornwall, New York). Of the 149 tagged striped bass greater than 400 mm in length, 11 were caught in sports fishery. These results indicate that sports fishery caught at least 7.4 percent of the tagged population and probably of the older age groups of the Hudson River stock during March, April, May, and June, which is an instantaneous fishing rate of 0.31 assuming that the present level of exploitation continues over the remainder of the year. At first glance this is an unexpectedly high fishing rate. This number is a minimal estimate because we also assume that there was no tagging mortality on these large fish. (One fish, in fact, was caught by a fisherman the same day on which the tag was applied indicating that the time until recovery and resumption of normal behavior is short.) The majority of striped-bass recoveries from the saltwater sports fishery was from the western end of Long Island Sound, one from New Bedford, Massachusetts, and one from Fire Island (south shore of Long Island). Raney (1952) previously characterized the Hudson population as being relatively restricted to Long Island Sound, especially its western portion.

Very few of the younger age classes of striped bass have been caught during 1973, a trend that is also reflected in the white-perch population.

Table V-7 presents the total number of striped bass caught; of these, 367 were tagged and released and 218 of those were < 400 mm. None of those small fish nor any of the 1972 released bass have been recovered. In Appendix C, Figures C-1, C-2, and C-3 respectively summarize the striped-bass tagging efforts by river mile (kilometer), by total length, and by month.

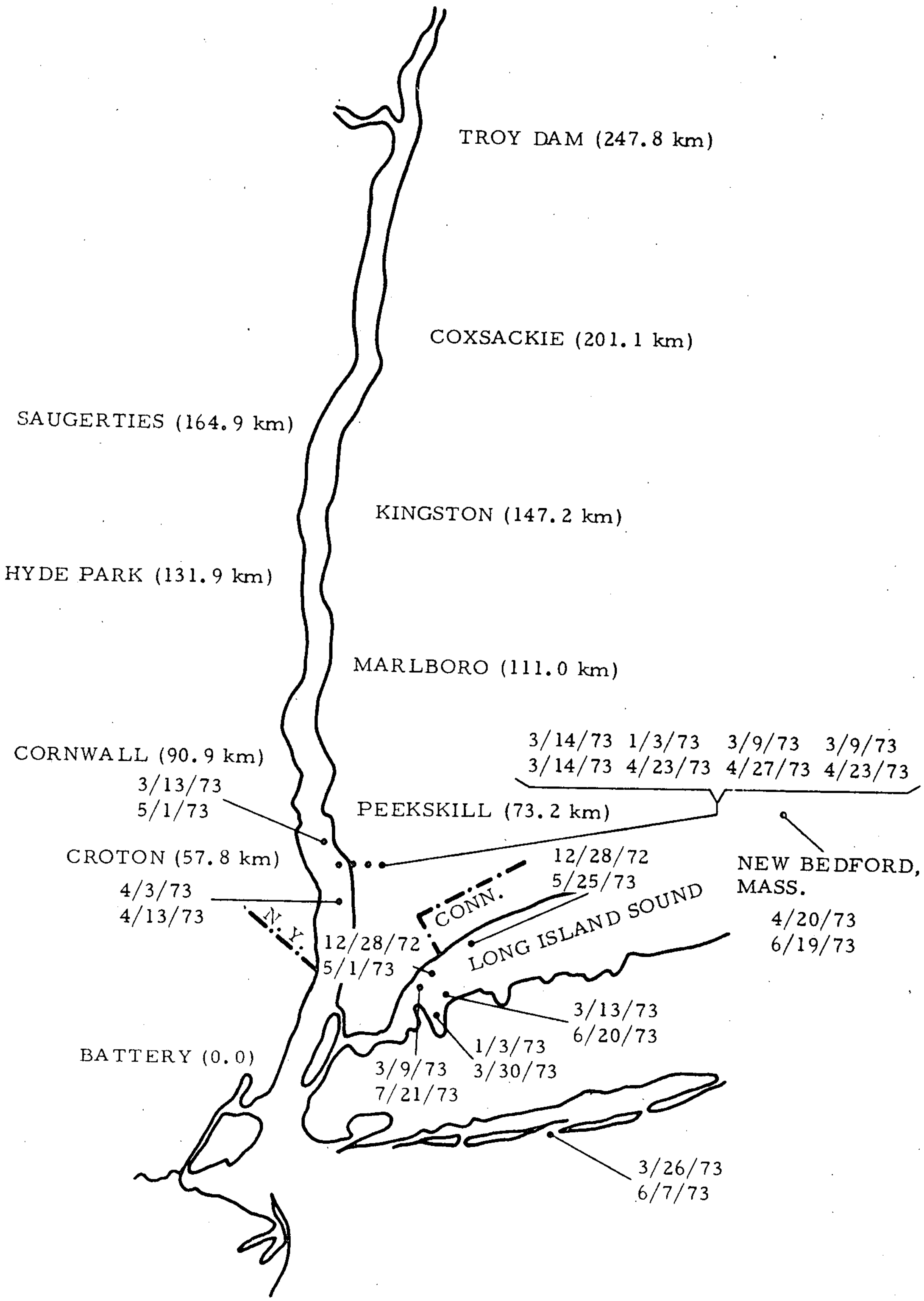


Figure V-6. Release (Upper Date Shown) and Recovery (Lower Date Shown) of Adult Striped Bass. All were tagged in Croton Bay except the New Bedford recovery, which was tagged near Cornwall, New York.

Table V-7

SUMMARY OF STRIPED-BASS CATCH STATISTICS

River Mile	Gear	Week											
		4/8	4/15	4/22	4/29	5/6	5/13	5/20	5/27	6/3	6/10	6/17	6/24
0-38	Beach seine		3	7	27	29	8	25	56	11		3	
	Trawl												
39-48	Beach seine		5		5	59	79	14	14	52	26	231	146
	Trawl				4		1		2		3		
	Trap				7	7	4	1		4	5	14	26
	Gill net		1		6	1		3			13		
	Electroshocker											3	
	Intake screens	59	14	5	650	5	3	7	1	14	5	3	7
49-60	Beach seine			4						4			2
	Trawl												
	Trap									2		2	
	Gill net		41	52	6	55	35	3		7	12		
61-151	Beach seine						1	2	5				12
	Trap												
	Gill net			11	8			2			1		3
	Total	59	64	79	713	156	131	57	78	94	65	256	196

In contrast to the situation with young striped bass, the white-perch tagging program has been more immediately successful. Table V-8 lists the 1973 recoveries of fish marked in 1972, and Figures V-7 through V-10 show the recapture locations for white perch that migrated into a different section of the river. Upon inspection of these data, it is clear that there is mixing throughout the area of marking in the estuary (from the George Washington Bridge in the south to Troy Dam in the north) during winter and spring. In Appendix C, Figures C-4, C-5, and C-6 respectively summarize the white-perch tag release data by river mile, total length, and month. The following summarizes the fin-clipped white-perch releases (fish < 100 mm) by area of release (RM) and by month:

	River Mile			
Month	0-37	38-48	48-60	60-150
May	0	35	2	1
June	86	1330	175	0

Table V-9 summarizes catch statistics for the period of April 8 through June 30, and Figures V-11 and V-12 summarize recoveries by total length and river section respectively.

Another highly encouraging result is the occurrence of multiple recaptures: two fish have been recaptured twice. This permits additional estimation procedures (Seber, 1965; Jolly, 1965) that are independent of some of the restrictions imposed on the other estimation techniques; also, it is indicative of good survival after handling and provides additional data on growth rates, migration patterns, etc. This will be analyzed in more detail as more multiple recaptures occur with time.

Two of the white-perch tags returned by fishermen were taken in tributary streams in the Beacon-Newburgh area — one from Moodna Creek and one from Fishkill Creek. This tributary-type migration is interesting and is possibly associated with alewives spawning in these areas (the white perch being a predator of the eggs). This might be a more general foray-type behavior into these habitats. A better evaluation will be possible when more information has been collected.

Table V-8

1972 MOVEMENT OF WHITE PERCH RECOVERED IN 1973

Month Recovered	Recovery Location	No.	Month Released	Region Released	Movement	Length (mm)
Jan	Intake	2	Oct	Ossining	Upstream	80, 120
Feb	Intake	3	Sep	I	—	64, 110, 113
	Intake	2	Oct	Ossining	Upstream	52, 66
	Intake	1	Oct	III	Downstream	67
	Intake	1	Oct	I	—	103
	*Intake	1	Oct	I	—	128
Mar	Intake	1	Sep	I	—	66
	Intake	2	Oct	Ossining	Upstream	75, 67
	Intake	1	Oct	I	—	72
	Intake	2	Oct	III	—	76, 110
	*Intake	1	Oct	I	—	154
Apr	Ossining	1	Oct	Ossining	—	122
	Region I	1	Oct	I	—	130
May	Cornwall	1	Sep	III	—	149
	Intake	1	Oct	Ossining	Upstream	156
	Cornwall	2	Oct	III	—	112, 138
	Ossining	1	Nov	Ossining	—	130
Jun	Region I	2	Oct	I	—	117, 127
	Intake	1	Oct	I	—	—
	Region I	2	Oct	III	Downstream	77
	Ossining	2	Oct	III	Downstream	124, —
	Hyde Park	1	Oct	III	Upstream	97
	Cornwall	1	Oct	II	Upstream	164
	Cornwall	1	Oct	Ossining	Upstream	156

*Tagged individuals

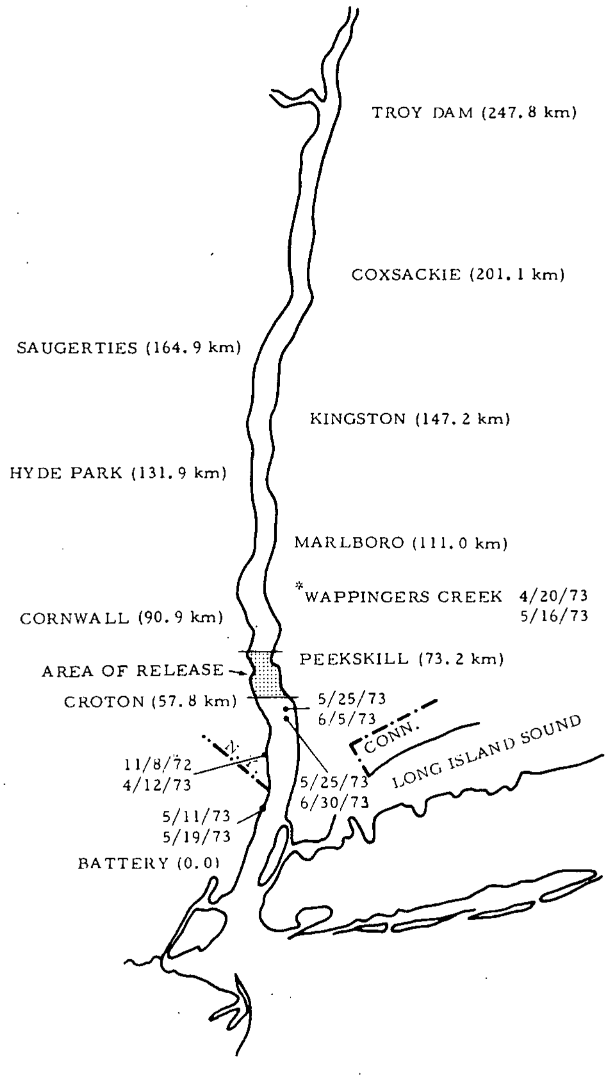


Figure V-7. Adult White-Perch Releases in Region I (Upper Date Shown) and Recoveries outside Region (Lower Date Shown)

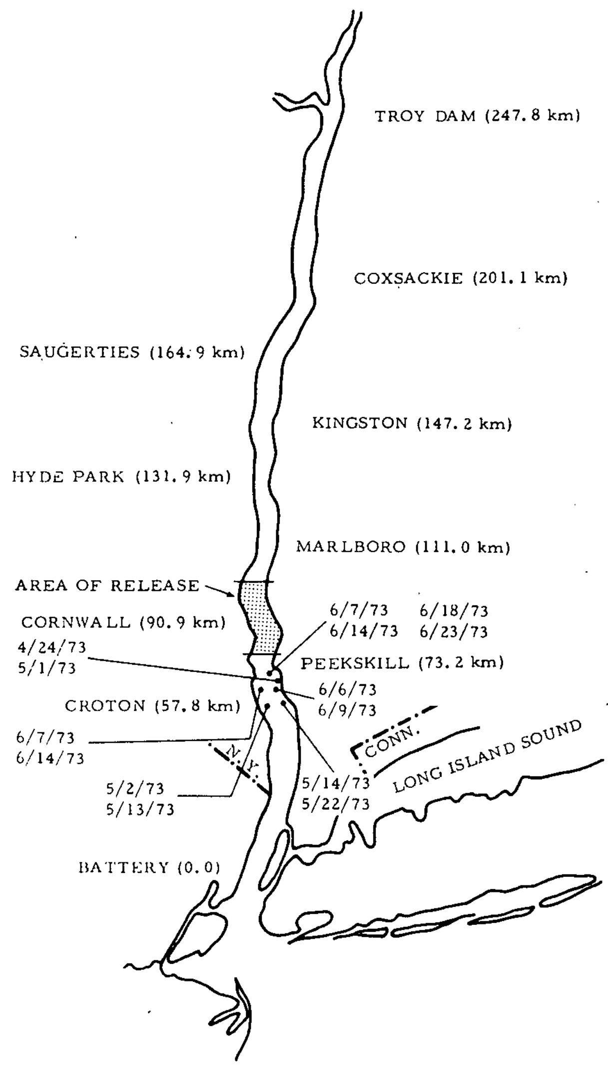


Figure V-8. Adult White-Perch Releases in Cornwall Region (Upper Date Shown) and Recoveries outside Cornwall Region (Lower Date Shown)

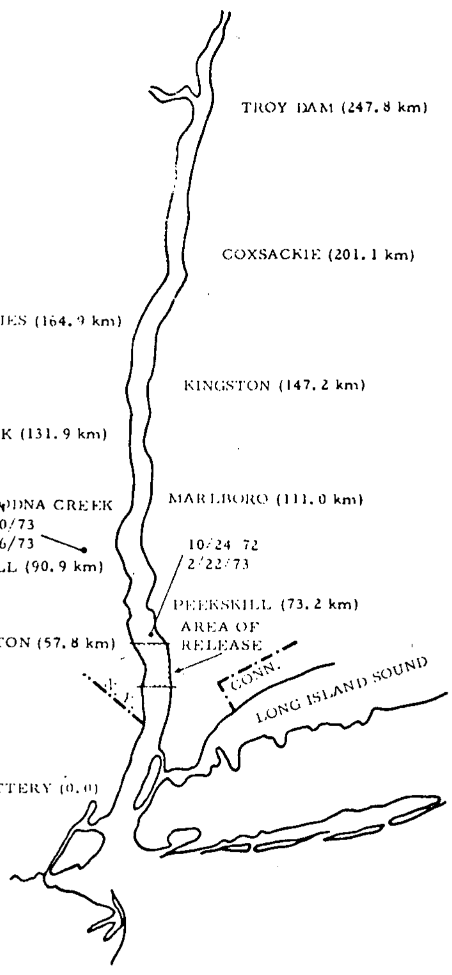


Figure V-9. Adult White-Perch Releases in Ossining Area (Upper Date Shown) and Recovery outside Ossining Area (Lower Date Shown)

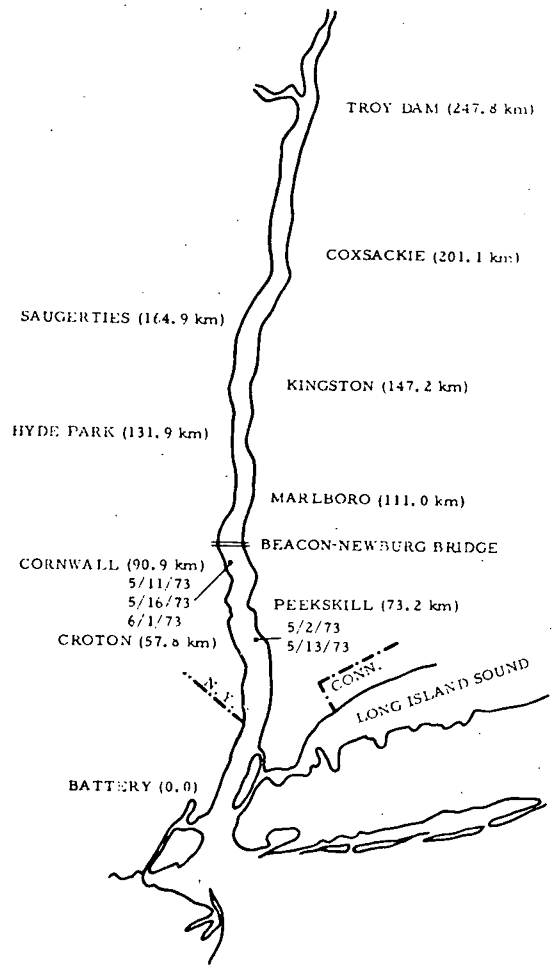


Figure V-10. Adult White-Perch Releases above Beacon-Newburgh Bridge (Upper Date Shown) and Recoveries below Bridge (Lower Date Shown)

Table V-9

SUMMARY OF WHITE-PERCH CATCH STATISTICS

River Mile	Gear	Week 4/8	4/15	4/22	4/29	5/6	5/13	5/20	5/27	6/3	6/10	6/17	6/24
0-38	Beach seine		26	32	90	112	112	610	308	243	20	9	283
	Trawl			1,151		39				19		412	
39-48	Beach seine	188	57	25	10	262	107	297	285	910	1,079	974	1,635
	Trawl	12	9	17	99	437	5	7	12	20	67	53	100
	Trap	78	71	189	232	320	412	108	305	921	2,118	1,761	1,804
	Gill net				122						4		301
	Electroshocker											271	
	Intake screens	3,300	2,142	1,372	15,258	2,562	1,411	416	165	348	242	138	72
49-60	Beach seine	5	34	189	161	320	347	424	648	1,782	365	858	505
	Trawl		13		48	981	1					7	
	Trap	11	4						2	5			
61-151	Beach seine		49	28	168	49	239	307	266	67	39	46	104
	Trap									25			
	Total	3,594	2,405	3,003	16,188	5,082	2,634	2,169	1,991	4,340	3,934	4,529	4,804

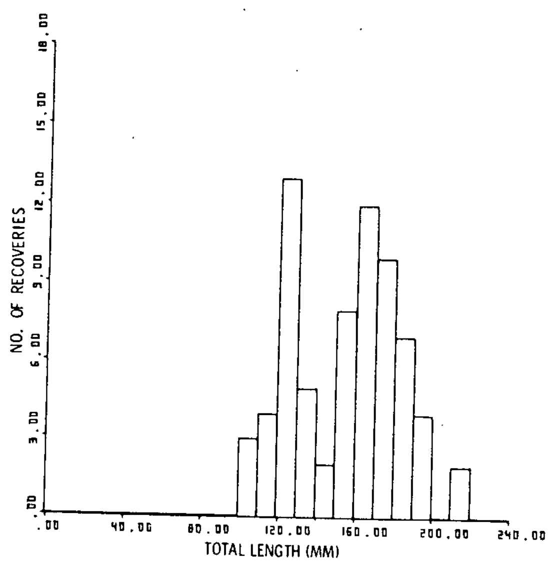


Figure V-11. Tagged White-Perch Recoveries Summarized by Total Length

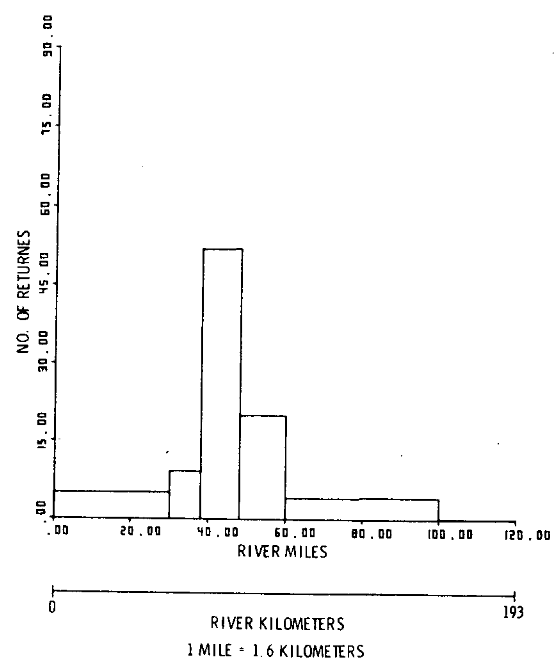


Figure V-12. White-Perch Tag Returns Summarized by River Mile

Survivorship. The collection of striped bass was insufficient to evaluate tagging mortalities, so survivorship experiments with white perch were initiated during May. Weather and equipment difficulties, however, prevented a successful evaluation of tagging mortalities for May, but June experiments were more successful. The majority of the white perch in the experiment were > 100 mm in length. Water temperatures ranged from 20°C to 22°C; salinities, from 0.08 °/oo to 0.09 °/oo.

Certain physical difficulties in holding the fish in the river pens were encountered. Occasional high winds produced wave action which was violent enough to wash the fish out of the pens or at least to cause physical stress. However, pen covers have now been constructed, which should rectify the majority of these problems.

Table V-10 summarizes survival values for the experiments. Very poor survival resulted with Carlin tags, possibly because of the rather large puncture wound they inflict during application. Fungal growth on all fish continues to be the major problem, but treatment with a dilute concentration of formalin has proved effective in controlling fungal infections in the aquaria. The applicability of this technique to the routine tagging operations is being evaluated, but initial results are not encouraging.

Table V-10

SURVIVORSHIP OF WHITE PERCH IN HOLDING PENS DURING JUNE 1973

Tag Type	Size (mm)	n	Percent Survival	Duration (days)
Fin clip	≤ 100	25	64	5
Carlin	100-150	14	0	4
Floy	100-150	13	69	7
Dennison	≥ 150	25	40(24)	7(28)

Population Estimates and Zone of Plant Influence. White-perch population can be estimated by using 1973 recoveries from the 1972 tagging operations; this method estimates the population at the time of tagging, but natural mortality cannot be directly estimated at this time.

There have been 34 marks and tags recovered from the 1972 efforts (Table V-8). These recoveries indicate considerable migration during the winter season between tagging and recapture; i.e., the tags should be randomly mixed in the population. They also indicate that the population subjected to impingement has a range at least as large as the 1972 study area, i.e., at least from RM 30 to RM 60 (km 48 to 96). The total of the impingement and research catches through June 1973 is 90,675; hence, the Petersen estimate is

$$N = \frac{(M + 1)(C + 1)}{(R + 1)} = \frac{9031 \times 90676}{35} = 23,400,000$$

with a 95 percent confidence limit of 17,200,000 to 34,800,000 based on a Poisson distribution. Again, this estimate is for the fall season of 1972, and these fish came from at least river km 48 to 96. Ancillary tagging information from 1973 suggests that this is the population estimate for the entire riverine portion of the estuary.

Inspection of the recoveries indicates that 19 of the fish (56 percent) were older than 1 year (> 110 mm, June 1973), while the majority of the 1972 tagging was on the 1972 year class; however, approximately two-thirds of the impingement was of the 1972 year class, which suggests a differential survival for the two size groups, so size-specific population estimates are necessary. Correcting the catch and release data to exclude the 1972 year class, an estimate comparable to the latter estimate is

$$N = \frac{(46998 + 1)(2890 + 1)}{(19 + 1)} = 6,794,000$$

with a 95 percent confidence limit of 4,579,000 to 11,878,000. This is the estimate of the 1971 age class and older fish present in the study area (probably the entire estuary) during the fall season of 1972.

An estimate of the fish present in the study area during the spring of 1973 can be obtained by using the 1973 tag and recovery data. Table V-11 summarizes the white-perch catch, recoveries, and number of marks in the population on a weekly basis. A Schumacher-Eschmeyer regression estimate based on the total catch (impingement plus fishing) is

$$\frac{1}{N} = \frac{\sum M_t R_t}{\sum C_t M_t^2} = 0.7250 \times 10^{-6} \qquad N = 1,379,000$$

with a 95 percent confidence limit of 989,000 to 2,277,000. This estimate is for the area between the Troy Dam and the George Washington Bridge but is biased toward the center of that area. It probably underestimates the outer portions of the range and probably has a slight bias toward the beach and shoal areas. By using only the > 100-mm white perch from the screens (approximately one-third of the total impingement), an estimate of the older age groups can be calculated. (At this time, the river collections were not corrected for the length distribution, so the catches of small white perch were relatively low.) The estimate of the population of fish longer than 100 mm was 1,347,000 (935,000 to 2,410,000). This cannot yield a direct estimate of mortality of the 1971 age class and older fish because of the spatial distribution problem and the probable biases just discussed (i.e., do not subtract 1,347,000 from 6,794,000). The tag-recovery data indicate that an accumulation of fish from throughout the estuary resided in the study area at times during the winter season and was then apparently redistributed during the spring.

Table V-11

CATCH AND TAGGING DATA FOR WHITE PERCH, APRIL, MAY, AND JUNE 1973

Week (beg.)	Catch Total	Corrected*	Tags Recovered	Tags at Large**
4/8	3,594	1,383	1	16
4/15	2,405	970	0	65
4/22	3,003	2,084	0	135
4/29	16,188	5,965	1	240
5/6	5,082	3,294	2	369
5/13	2,634	1,561	6	590
5/20	2,169	1,857	9	1,141
5/27	1,991	1,927	7	1,969
6/3	4,340	4,198	15	2,925
6/10	3,934	3,820	12	3,628
6/17	4,529	4,463	8	4,054
6/24	4,804	4,769	11	4,473

*Impingement catches of fish > 100 mm

**Tag releases corrected for survivorship

An encouraging third estimate of the population over 100 mm was obtained by using the June recoveries of the April-May releases, i.e., 2 months of tagging followed by 1 month of recovery efforts; on this basis, the Petersen estimate was 1,568,000 (1,077,987 to 2,379,967) based on 26 recoveries. This estimate applies to the population within the study area as of June 1 and has the same potential bias as the Schumacher-Eschmeyer estimate; it also excludes the 1972 year class.

At this time, we cannot directly estimate the white-perch population size for the 1972 year class for the spring 1973 period; we have recovered zero marks from the 1972 year class marked in 1973. However, a first approximation can be calculated from the May standard station CPUE data, the age distribution, and the area sampled. The estimation equation for the fraction of the total population in the Indian Point region that is from the 1972 year class is

$$F = \frac{TCPUE \times P2T \times 1/AT\ AD + BSCPUE \times P2BS \times 1/ABS \times AB}{TCPUE \times 1/AT \times AD + BSCPUE \times 1/ABS \times AB}$$

where

F = fraction of population from the 1972 year class

TCPUE = bottom-trawl CPUE

BSCPUE = beach-seine CPUE

P2T(P2BS) = fraction composition of 1972 year class in bottom-trawl (beach-seine) catches

AT(ABS) = area sampled by trawl (beach seine)

AD(AB) = total area in Indian Point region in deep (shore) zones

Thus,

$$F = \frac{3.38 \times 0.075 \times 1/242.8 \times 1464.15 + 1.47 \times 0.65 \times 1/6.88 \times 108.05}{3.38 \times 1/242.8 \times 1464.15 + 1.47 \times 1/6.88 \times 108.05}$$

$$= \frac{16.5347}{43.4686} = 0.3804$$

In other words, 38 percent of the white-perch population during May 1973 was from the 1972 year class. Applying this to the Schumacher-Eschmeyer and Petersen estimates, there were 827,000 or 963,000 white perch of the 1972 age class in the study area. These estimates are a first approximation of the yearling population and, at this time, no confidence bounds have been calculated.

Impingement Rates. Tag recoveries on the intake screens from the 1972 tagging operations can be used to estimate the percentage of the 1972 population impinged during the first half of 1973. Treating the tagged population as a closed population, the percent recapture estimates the percent impinged during the first 6 months of 1973, i.e., 19/9031 * 100 percent = 0.21 percent. This cannot be interpreted as the impingement rate *per se* because we have not accounted for natural mortality; this is a situation of competing mortality rates, natural and imposed. The fraction impinged is related to the population parameters as follows:

$$\frac{C_I}{N_t} = \frac{I}{Z}(1 - e^{-zt})$$

where

C_I = impingement

N_t = population size at beginning of period

I = annual impingement rate

Z = total annual mortality rate (natural plus fishing plus impingement)

e = base of natural logarithms

t = time measured in years

We will be able to estimate the impingement rate when we have an estimate of total annual mortality. At this time, it appears that the plant has impinged < 1 percent of the population present in the fall of 1972 and from January to June 1973; during the latter 6-month period, the plant was not under a normal operating regime, so the interpretation of this result is constrained by this factor.

Several other estimates of the percentage impinged can be obtained from the various population estimates which are summarized in Table V-12.

Table V-12

PERCENT OF ESTIMATED POPULATION IMPINGED AT INDIAN POINT DURING EARLY 1973

(The percentage of the fall population that was impinged was based on actual impingements from January through June, 1973 while the percentage of the spring population was based on impingements in April, May, and June, 1973.)

Source	No.	Impingement	Percent
Fall 1972 >100-mm population estimate	23,400,000	65,189	0.3
Spring 1973 >100-mm Petersen population estimate**	6,794,000	21,730*	0.3
Spring 1973 >100-mm Schumacher-Eschmeyer population estimate**	1,568,000	9,044*	0.6
	1,347,000	9,044*	0.7
Spring 1973 >100-mm CPUE estimate + >100-mm Petersen estimate	2,531,000	27,426	1.1

*Derived from the fraction of total impingement with length >100 mm.

**Containing biases discussed in text, probably being slight underestimates.

The first two estimates based on the 1972 population estimates are very similar to the value calculated from the tag returns; however, the two methods are not completely independent. The other three estimates are overestimates because we are assuming that population numbers remained constant; i.e., we really need to know the population size on April 1, but the actual estimates are for June 1. The spring 1973 total population estimate is the sum of the < 100-mm estimate based on the CPUE data plus the Petersen estimate for the > 100-mm segment of the population.

Discussion

The population estimate based on the 1973 recoveries of the 1972 marked fish indicates that the population estimates reported in the first annual report (Texas Instruments Incorporated, 1973a) were truly underestimates of the river population. The estimates based on the 1973 efforts will not be as biased as those made during the 1972 season.

Several factors not evident in the previous data contribute to the quality of the present estimates: an extended study area stratified by size (i.e., larger fish with individual tags and greater movement), greater migration within that area (i.e., random mixing), the transportation of fish away from the area of original capture (i.e., forced dispersal), and recovery of tags via several collection methods. With the addition of Cornwall program data to the present study data, we are no longer as concerned about the assumptions regarding a closed population; we are effectively covering the entire range of white-perch and the young striped-bass populations. This level of effort will better define the area of the impingement influence, the migratory behavior, and the total population estimates. Tag results indicate that the adults have greater range and tendency to become mixed during the winter and spring than observed during the fall of 1972; this is a somewhat self-explanatory observation, but it has direct bearing on the tagging studies. First, a region could be assumed to represent a closed population for relatively short periods of time, but the benefits of a wider area of coverage in terms of accuracy of estimation are obvious: the observed migrations during the spring almost preclude us from treating the populations in the study areas as closed. Second, the observed movement means that the assumptions regarding random mixing are less likely to be violated since we are covering the entire river.

The major cause of tagging mortalities still appears to be fungal infections. We are continually looking for procedures to increase survival rates. It does appear that the spring tag survivorship is sufficiently high to permit successful execution of the tagging program. The extremely low survival that is expected during July and August may be prohibitive to the quantitative objectives.

The reasons for the differences between the more accurate delayed 1972 population estimate made in 1973 and the 1973 population estimates cannot be fully explained at this time. In general, several factors indicate that the white-perch population may have low overwintering survival. The standard station CPUE data support this to a limited extent, but further analysis is required to remove the effects of the environmental variables. Another factor, one that produced the initially low localized estimates in 1972 reported in the 1972 annual report (Texas Instruments Incorporated, 1973a), could be operating to a lesser extent in 1973, i.e., incomplete mixing of the tagged fish in the total population. Subsequent estimates based on the April, May, and June releases will provide the basis for determining the degree to which this aspect is affecting the estimates. It appears that the best estimates may well occur following winter migration and mixing. Stratified estimates based on river section and size could resolve some of these apparent differences. Insufficient analysis time has prevented inclusion of these stratified estimates in this report, but they will be described in the 1973 annual report.

The lack of recoveries from the 1972 year classes of fish marked in 1973 cannot be explained at this time. The survivorship experiments indicate that tagging mortalities were not excessive; the fish apparently were not vulnerable to the beach seines until late May; consequently, only a short period of data collection was available for this report. However, based on the recovery percentages during 1972 and the present returns from the other age classes, we would have expected some recoveries. One possibility is that the 1972 results were strongly biased toward the beach-seine area and that, after the mixing period in the total population, we would not expect many recoveries. This leads us to the possibility that the 1972 year class is considerably larger than we have estimated. Subsequent tagging efforts should resolve this situation.

An evaluation of the significance of impingement is still somewhat premature at this point of the study. However, present observations generate some hypotheses about the possible significance of the impingement. One important aspect is the range over which the populations are subjected to impingement. The recovery of tagged fish from all parts of the estuary among the impinged fish indicates that the affected population is at least as large as that from the 1972 study area, which means that the percent impingement should be calculated based on the population ranging over a broad area. Another aspect is that the percent impingement appears to be very small compared with preliminary estimates of percentage changes in population size. The greatest weakness of these observations is that they were not made with the normal plant effect in operation; operation was at a low level during much of this period. However, it does appear that impingement, unless it increases dramatically, does not remove a large percentage of the population. The obvious aspect of the data is that impingement is a function of both plant operation and population size. As the study progresses we will better be able to evaluate the impingement rate mortality relative to the background mortality rate, e.g., is impingement competing significantly with the "normal" mortality factors?

BIOLOGICAL AND MORPHOLOGICAL CHARACTERISTICS OF WHITE PERCH AND STRIPED BASS

Age and Growth

Striped-bass and white-perch growth information is continuously being tabulated, and 1972 growth will be determined when annulus formation in 1973 has been completed for all age groups. This will be reported in the 1973 annual report.

Food Habits

Introduction. Food-habit investigations are being continued in 1973. Stomachs from samples of white perch and striped bass are collected monthly and the contents sorted, identified, counted, and measured by volume determinations. Size classes have been altered this year by adding a smaller class to evaluate larval and postlarval diets and by combining several other classes which were similar in 1972.

Materials and Methods. This year, food-habit studies have concentrated on fish from the Indian Point vicinity (Region I, RM 40 to 46, km 64 to 74) and the Cornwall area (Region III, RM 52 to 60, km 83 to 96). Region II is not being considered as a separate study area; however, Region III this year does include 6 km formerly considered in Region II.

The size-class breakdown for white-perch and striped-bass stomach analysis in 1973 is as follows:

Length (mm)	
White Perch	Striped Bass
0-50	0-50
51-75	51-115
76-150	116-200
151-200	> 200
> 200	

A detailed discussion of procedures used in this study was included in the first semiannual report (Texas Instruments Incorporated, 1972).

Results and Discussion. Stomachs from all fish collected during the first 5 months of 1973 were examined. Although sample sizes were small for February and March, 100 white-perch stomachs examined in January indicated that *Gammarus* was their predominant winter food. The isopod *Chiridotea* was the only other organism found in white-perch stomachs, but its occurrence was rare. Approximately one-half of the white-perch stomachs examined during the winter were empty.

Also examined were the stomachs of six large striped bass (> 500 mm) collected in Region I during the winter; in them were found three tomcod, three white perch, and the unidentifiable remains of four other fish. Two of the six stomachs were empty.

The occurrence of empty stomachs was noticeably less in April samples, indicating increased metabolic activity. The contents found in stomachs of white perch and striped bass collected in April and May were compared by means of an importance index (Texas Instruments Incorporated, 1973a) as presented in Tables V-13 and V-14. White-perch diets in April and May were noticeably different between Regions I and III. Calanoid copepods, *Gammarus*, and chironomid larvae were predominant in stomachs from Region I, and newly spawned eggs of alewives and blueback herring were clearly the most important food items in Region III. The majority of identifiable eggs belonged to the alewife. Cross-referencing with standard station catch information verified the predominance of alewives in locations where fish had been collected for stomach analysis. Fish eggs other than those of clupeids were occasionally observed in stomachs from both regions however, their occurrence and numbers were relatively unimportant.

Stomach contents of white perch collected in Region I during May 1972 indicate that *Gammarus* and chironomid larvae were the primary food items at that time; in May 1973, their importance was lessened by the abundance of calanoid copepods in the diet of all size classes.

Small striped bass (51 to 155 mm) collected in Region I during April and May fed primarily on calanoid copepods and *Gammarus*. *Neomysis* and *Daphnia* were also among the top five food items for striped bass during April, but neither was as important as the others. The majority of stomachs from large striped bass collected in both regions during April and May were empty, but those that had food items most often contained white perch and alewives.

The feeding patterns of larval and postlarval fish will be reported in the 1973 annual report.

Table V-13

COMPARISON OF MAJOR FOOD ITEMS OF WHITE PERCH BY INDEX OF IMPORTANCE,* HUDSON RIVER, REGIONS I AND III, APRIL-MAY 1973

Total Length (mm)	Region I				Region III			
	Apr		May		Apr		May	
51-75	Calanoida	42.46	Calanoida	45.48			Calanoida	64.69
	Gammarus	9.80	Chironomidae (L)	5.81			Chydoridae	3.21
	Chironomidae (L)	7.95	Cyclopoida	4.02			Chironomidae (L)	3.18
	Bosmina	3.63	Ostracoda	2.38			Ostracoda	3.18
	Harpacticoida	2.86	*Gammarus*	2.05			Cyclopoida	1.60
	n = 9		n = 48				n = 4	
76-150	*Gammarus*	31.55	Chironomidae (L)	32.92	*Gammarus*	29.61	Clupeidae eggs	31.85
	Calanoida	7.39	Calanoida	26.66	Clupeidae eggs	2.31	Chironomidae (L)	5.25
	Chironomidae (L)	5.01	*Gammarus*	1.76	Chironomidae (L)	1.47	Cyclopoida	4.07
	Chiridotea	0.84	*Leptocheirus*	0.42	*Chiridotea*	0.88	*Gammarus*	1.37
	Harpacticoida	0.14	Chironomidae (P)	0.28	Ceratopogonidae (L)	0.02	Harpacticoida	0.76
	n = 46		n = 8		n = 27		n = 113	
151-200	*Gammarus*	16.96	Calanoida	13.41	Clupeidae eggs	43.26	Clupeidae eggs	23.65
	Calanoida	9.30	*Gammarus*	12.06	*Gammarus*	5.01	*Gammarus*	7.18
	Chironomid (L)	1.89	Chironomidae (L)	0.74	*Chiridotea*	0.26	Chironomidae (L)	1.14
	Chiridotea	0.70	*Cyathura*	0.35	*Cyathura*	0.13	Calanoida	0.32
	Cyathura	0.15	*Neomysis*	0.17	Chironomidae (L)	0.12	*Cyathura*	0.08
	n = 22		n = 6		n = 27		n = 49	
> 201	Spottail shiner	69.59	Calanoida	22.03	Clupeidae eggs	43.23	Clupeidae eggs	89.74
	Gammarus	30.41	*Gammarus*	14.68	Spottail shiner	2.78	Chironomidae (L)	5.32
			Chironomidae (L)	2.30	American eel	1.33		
			Leptocheirus	1.47	Ceratopogonidae	0.60		
			Harpacticoida	0.31	*Gammarus*	0.36		
	n = 1		n = 16		n = 8		n = 1	

Note: (L) = larvae; (P) = pupae; n = number of stomachs containing food.

*Importance index = $\left(\frac{\%\ \text{volume} + \%\ \text{number}}{2}\right)\left(\frac{\%\ \text{frequency occurrence}}{100}\right)$

Table V-14

COMPARISON OF MAJOR FOOD ITEMS OF STRIPED BASS BY INDEX OF IMPORTANCE, HUDSON RIVER, REGIONS I AND III, APRIL-MAY 1973

Total Length (mm)	Region I				Region III			
	Apr		May		Apr		May	
51-115	Calanoida	27.85	*Gammarus*	40.54	—		—	
	Gammarus	7.43	Calanoida	3.57				
	Neomysis	4.86	Clupeidae eggs	0.45				
	Daphnia	2.17	Chironomidae (L)	0.27				
	Chironomidae	0.96	*Chiridotea*	0.22				
	n = 9		n = 12					
116-200			*Gammarus*	29.51			*Gammarus*	56.25
			Tessellated darter	15.70			Chironomidae (L)	6.25
			Cyathura	1.44				
			n = 3				n = 4	
> 201	White perch	47.81	White perch	20.00	Alewife	63.95	—	
	Alewife	2.95	Alewife	16.67				
	Atlantic tomcod	0.65	*Gammarus*	1.67				
	n = 7		n = 6		n = 4			

Note: (L) = larvae; n = number of stomachs containing food.

Striped-Bass Reproduction

For information concerning the reproductive potential of striped bass present in the Hudson River from March to June 1973, 70 males ages 2 to 10 and 78 females ages 2 to 14 were obtained and their gonadal condition examined. Specimens were captured between RM 39 and RM 59 (km 62 to km 95) and, to increase the sample size, striped bass of selected sizes were also purchased from commercial fishermen within the same geographic boundaries. The study's basic objectives were to

- Determine various stages of sexual maturity using the gonadal condition as an index
- Determine the age at which both sexes attain sexual maturity
- Determine the percent maturity for each sex by age class
- Determine an index of fecundity for females using egg counts
- Collect information pertaining to resting gonads and egg retention after spawning

Materials and Methods. Sexual conditions of males and females were determined initially by visual inspection at time of capture. Because all fish were not captured immediately prior to the spawning season, a small percentage of the sample was not clearly definable as being mature or immature. Several stages of developing gonads were intermediate and, for this reason, a ratio was calculated for each fish by dividing the gonad weight by the total body weight and used as an index to help define maturity (Vladykov and Wallace, 1952). All gonad weights were made to the nearest 0.1 gm after they had been preserved in 10 percent formaldehyde and later blotted dry.

Fecundity estimates were obtained for 39 mature striped bass. An aliquot (cross-section) was removed from the medial part of the right ovary of each fish and weighed to the nearest 0.01 gm. The eggs considered as being mature in each aliquot were separated and counted individually. Egg diameters were also measured and recorded. The number of eggs per gram was multiplied by the total ovary weight to attain an estimate of total eggs.

Results and Discussion. Field observations and egg and larvae data indicate that striped-bass spawning in 1973 occurred in our study region from approximately the first week in May through the first week in June, when water temperatures ranged from 9.8°C to 18.5°C. Peak spawning occurred around May 15, when water temperature approximated 15 to 16°C.

The stage of sexual development (maturity or immaturity) of females was determined chiefly by examining egg diameters, mature egg distribution throughout the ovary, and the ratio of ovary weight to body weight. All examined females were categorized into one of four groups based on egg diameter and distribution. In the first group, all eggs had a constant diameter ranging from 0.4 to 1.2 mm (depending on capture date) and were uniformly distributed throughout the ovary; these fish were considered mature. A second group had eggs of two distinct sizes: < 0.1 mm and larger maturing eggs ranging from 0.2 to 0.4 mm; these fish were collected in March and early April when ova were still in the early to mid-developmental stages, so actual stage of maturity of this group was not readily determined by examining egg diameters. The final evaluation included the use of an ovary-/body-weight ratio (Table V-15). With one exception, a complete dichotomy of ratio values exists for April and May fish 7 years and older when compared with those in age groups 3 to 5. The majority of older fish judged by egg-diameter criteria to be mature were characterized by having ratios which did not exceed 1/20. With only one exception, no mature fish over 7 years old exceeded a 1/37 ratio. In comparison, all fish between ages 3 and 5 considered immature by virtue of small eggs always exceeded a 1/96 ovary-/body-weight ratio, the one exception being an 8-year-old fish captured in March (ratio, 1/90); because of its early capture date, egg diameters were small (0.2 to 4 mm), but the general appearance of the ovary (robust and containing uniform egg sizes throughout) suggested sexual maturity by May. An extrapolated ovary-/body-weight ratio for a May capture of the same fish would have approached the 1/37 of known mature fish for that month, thereby lending support to our decision of maturity. By using the 1/90 ratio for maturity in March and egg diameters, we were able to classify all 6-year-old females, regardless of early capture dates and subsequent intermediate nature of the ovaries. The third category of females was clearly immature; their ovaries contained no eggs larger than 0.1 mm. Ovary-/body-weight ratios for these fish never exceeded 1/96.

Table V-15

OVARY-/TOTAL BODY-WEIGHT RATIOS AND PERCENT MATURE OF AGE GROUPS 3-14 FOR 57 STRIPED BASS COLLECTED MARCH-MAY, 1973, IN HUDSON RIVER

Age	Month	Sample Size	Ovary-/Total Body-Weight Ratio	Percent Mature
3	Apr	1	1/215	0
4	Mar Apr	7	1/258 1/96, 1/119, 1/121, 1/179, 1/182, 1/195	0
5	Mar Apr	9	1/106, 1/157 1/101, 1/119, 1/128, 1/154, 1/155, 1/162, 1/182	0
6	Mar May	3	1/86, 1/139 1/16	67
7	Apr May	8	1/10, 1/18, 1/21 1/11, 1/16, 1/18, 1/37, 1/37	100
8	Mar Apr May	15	1/90 1/7, 1/10, 1/9, 1/9, 1/11, 1/11, 1/13, 1/15, 1/23 1/10, 1/11, 1/11, 1/12, 1/14	100
9	Apr May	9	1/8, 1/9, 1/9, 1/11, 1/11, 1/14 1/7, 1/8, 1/8	100
10	Apr May	3	1/10 1/6, 1/11	100
11	--	—	—	—
12	May	1	1/20	100
13	—	—	—	—
14	Apr	1	1/10	—

Spent ovaries were easily distinguished by the presence of a thickened ovarian wall surrounding a gel-like matrix and containing scattered mature eggs between 1.0 and 1.2 mm.

Determination of maturity for male striped bass was not always easy; no fish over 3 years old was obviously immature and, at the same time, several fish had testes which were noticeably underdeveloped when compared with those of other fish of the same age and general size. We were unable to draw conclusions from testes-/body-weight ratios since there was no clear demarcation for mature and immature gonads (Table V-16). No references were found to explain the irregularities, and such possibilities as a resting condition, premature senility, or abnormalities in the population remain unanswered. The early capture date and the physical appearance of the testes rule out the possibility of a spent condition. In a genetic contribution sense, this group of fish did not have the same potential for biological success.

Table V-16

TESTES-/TOTAL BODY-WEIGHT RATIOS AND PERCENT MATURE OF AGE GROUPS 3-10 FOR 50 STRIPED BASS COLLECTED MARCH-MAY, 1973, IN HUDSON RIVER

Age	Month	Sample Size	Testes-/Total Body-Weight Ratio	Percent Mature
3	Apr May	3	1/21, 1/42 1/72	100
4	Mar Apr	10	1/83, 1/131, 1/472 1/14, 1/17, 1/35, 1/69, 1/109, 1/207, 1/560	60*
5	Apr	6	1/14, 1/34, 1/37, 1/60, 1/76, 1/575	83*
6	Apr	8	1/9, 1/11, 1/11, 1/12, 1/14, 1/15, 1/29, 1/454	88*
7	Apr	9	1/10, 1/11, 1/13, 1/14, 1/17, 1/19, 1/51, 1/67, 1/518	89*
8	Apr	10	1/9, 1/10, 1/12, 1/12, 1/13, 1/14, 1/16, 1/16, 1/18, 1/25	100
9	Apr May	3	1/16, 1/24 1/19	100
10	Apr	1	1/14	100

*More correctly classified as normal contributors. (See text for further explanation.)

Age at Maturity. The percentage of females in various age groups which were found to be mature is included in Table V-15. Nine 5-year-old females were all immature, while two of three 6-year-old striped bass were adjudged mature. All females 7 years and older were mature.

Our findings differ somewhat from those of earlier studies in other bodies of water compiled by Raney (1952), as shown in Table V-17. The principal difference is at least an extra year for maturity of females in the Hudson River population; no females less than 6 years old were mature. No 2-year-old males examined from a sample of several hundred specimens were mature. Of the three 3-year-old males collected all were mature. In age-group 4, however, only 60 percent of the fish were obviously mature; the remainder of the 4-year-old sample, although not immature, would contribute in a minimal manner (if at all) in the 1973 spawning season. In each of the next three age groups (5 to 7), one specimen in the respective samples of 6, 8, and 9 was characteristic of the "noncontributors."

Table V-17

AGE AT MATURITY FOR FEMALE STRIPED BASS COLLECTED FROM VARIOUS LOCATIONS

Investigator	Year	Location	Sample Size	Percent Maturity of Various Ages
Merriman*	1941	Connecticut	109	4 years, 25% 5 years, 75% 6 years, 95% ≥ 7 years, 100%
Vladykov and Wallace*	1938	Chesapeake Bay	—	May mature by age 4 Practically all mature by age 5
Jackson and Tiller*	1952	Chesapeake Bay	—	Female bass become spawners by age 4 or 5
Scofield*	1931	California	—	4 years, 35% 5 years, 87% 6 years, 98% > 7 years, 100%
Calhoun*	1948	Central California	—	Female striped bass "usually" spawn first time when 5 years old
Morgan and Gerlach*	1950	Coos Bay, Oregon	—	1-2 years, 0.0% 3 years, 18.2% 4 years, 67.9% ≥ 5 years, 100.0%
Present Study	1973	Hudson River	78	1-5 years, 0% 6 years, 67% ≥ 7 years, 100%

*Raney (1952)

Size at Maturity. Fork lengths of the immature 5- and 6-year-old females and mature 6- and 7-year-old females in this study ranged from 46.7 to 64.2 cm and from 49.8 to 79.0 cm, respectively, as shown in Table V-18. Vladykov and Wallace (1952) found in their sample from the Chesapeake Bay that 83 percent of the females between 50 and 56 cm were sexually mature; in his sample from Connecticut salt waters, Merriman (1941) found that approximately 75 percent of the females between 49 and 55 cm (fork length) were mature. Corresponding percent maturity figures for the fish examined in this study are 33% for females between 50 and 56 cm and 37% for females between 49 and 55 cm.

Table V-18

FORK LENGTH, SEXUAL CONDITION, AND AGE FOR 29 HUDSON RIVER FEMALE STRIPED BASS, AGES 3-7, MARCH-JUNE 1973

Fork Length (cm)	Age									
	3		4		5		6		7	
	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature	Immature	Mature
31	1	–	–	–	–	–	–	–	–	–
38	–	–	1	–	–	–	–	–	–	–
39	–	–	1	–	–	–	–	–	–	–
42	–	–	1	–	–	–	–	–	–	–
46	–	–	1	–	1	–	–	–	–	–
49	–	–	–	–	1	–	–	–	–	1
50	–	–	1	–	1	–	–	–	–	–
52	–	–	1	–	–	–	–	1	–	–
55	–	–	–	–	1	–	–	–	–	1
56	–	–	–	–	1	–	1	1	–	–
58	–	–	1	–	1	–	–	–	–	–
60	–	–	–	–	2	–	–	–	–	–
62	–	–	–	–	–	–	–	–	–	1
64	–	–	–	–	1	–	–	–	–	–
66	–	–	–	–	–	–	–	–	–	1
67	–	–	–	–	–	–	–	–	–	1
69	–	–	–	–	–	–	–	–	–	1
77	–	–	–	–	–	–	–	–	–	1
78	–	–	–	–	–	–	–	–	–	1
79	–	–	–	–	–	–	–	–	–	1

In summary then, our data indicate that many Hudson River female striped bass were not mature, in spite of having reached lengths previously associated with maturity.

The smallest mature males found by Vladykov and Wallace (1952) ranged from approximately 18.4 to 19.7 cm; they reported that practically all males > 25.4 cm were mature. The smallest mature male encountered in our study was 27.7 cm (fork length); however, as previously discussed, older and considerably longer males with testes that were irregularly underdeveloped were also encountered.

Resting Gonads. We did not encounter any females in our sample that had resting ovaries; however, the gonadal condition of several older males just discussed suggest a resting or senile condition for that sex.

Fecundity. Lewis and Bonner (1966) concurred with previous investigators in that they found mature ova in fecund striped bass were uniformly distributed throughout both ovaries. Examination of egg diameters from various parts of both ovaries indicated that our samples conformed with those of the earlier studies. We therefore based fecundity estimates on egg counts from one cross-section removed from the middle of the right ovary. The regressions of total number of ova on total body length (mm) and body weight (g) were linear. The following equations describe the relationships:

$$\text{No. of eggs} = \bar{y} + b\,(\text{length} - \bar{x}) = 1{,}353{,}517 + 4002.3\,(\text{length} - 853.8)$$

where

$\bar{y}$ = sample mean number of eggs

$\bar{x}$ = sample mean total length

sample size = 48

correlation coefficient = 0.82

$$\text{No. of eggs} = \bar{y} + b\,(\text{weight} - \bar{x}) = 1{,}379{,}737 + 161.0\,(\text{weight} - 7991.9)$$

where

$\bar{y}$ = sample mean number of eggs

$\bar{x}$ = sample mean total weight

sample size = 39

correlation coefficient = 0.87

The difference in the $\bar{y}$ value is a result of the different sample sizes. Figures V-13 and V-14 are graphic representations of the data point from which the equations were derived.

Lewis and Bonner (1966) also found linear relationships for both length and weight on total mature eggs for Roanoke River (North Carolina) striped bass; they pointed out that the apparent linearity for ova number and body length was questionable inasmuch as ova numbers were a function of volume and length was a linear function, and they attributed their findings to the variability of the measurement data.

We suggest that the majority of fish lengths examined in our study were in a small enough range so that the relationships measured by regression analysis were in fact reasonably linear.

Table V-19 includes the estimated mean number and range of mature ova for each age group and the various length classes of 41 striped bass examined in this study, and Table V-20 presents fecundity estimates for seven age groups and various weight classes of 39 striped bass. Weights were not obtained for two fish included in Table V-20; consequently, there are small differences in the weighted mean number of eggs for age groups 10 and 12.

For the sake of comparison with this study, striped-bass fecundity information reported by Lewis and Bonner (1966) was modified by calculating weighted mean lengths and weighted mean number of eggs for each age class (Table V-21). Both studies indicate much variability for both parameters within many age groups.

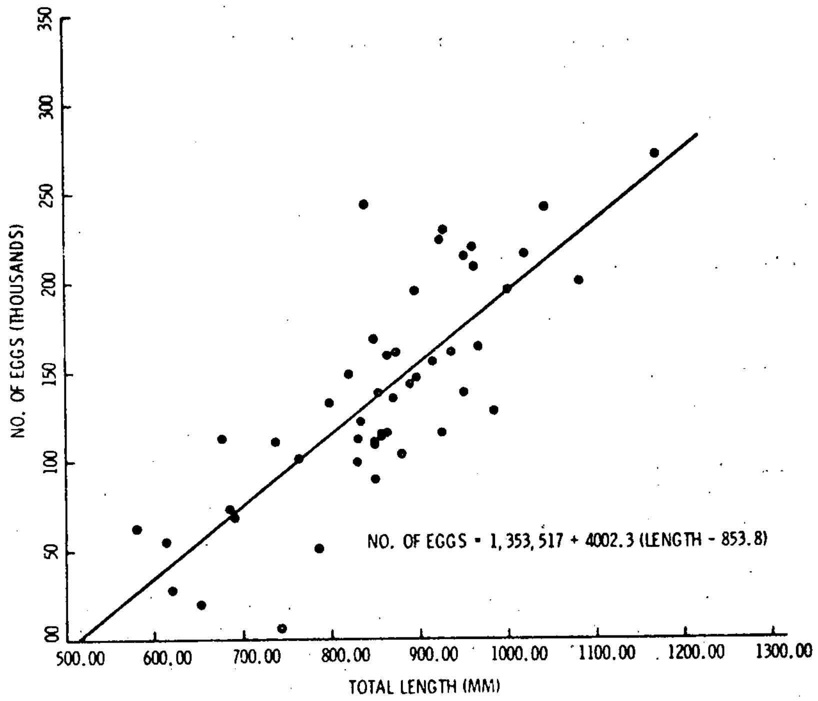


Figure V-13. Relationship between Total Body Length (mm) and Estimated Number of Eggs for 48 Striped Bass Collected in Hudson River, 1973

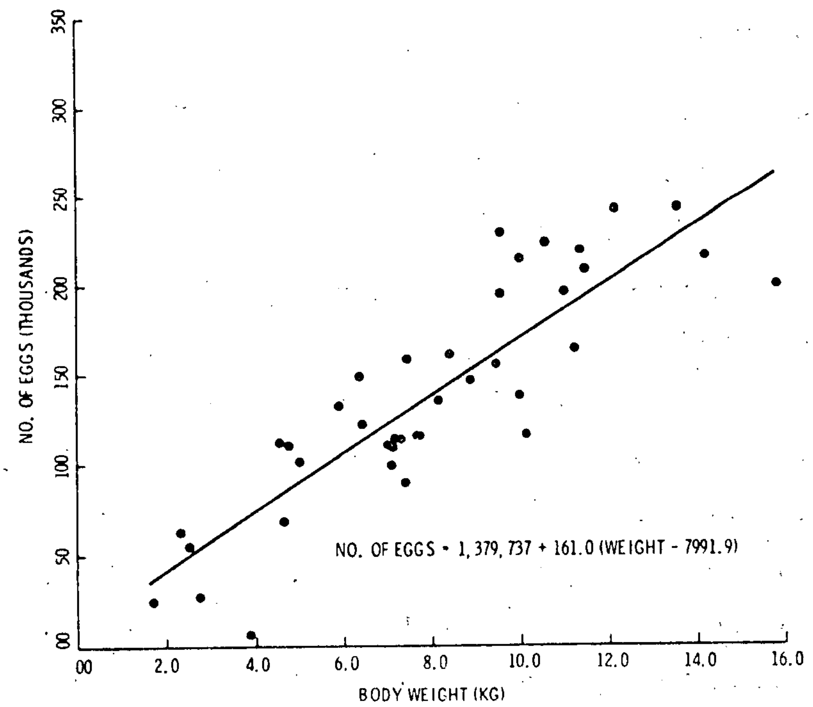


Figure V-14. Relationship between Total Body Weight (kg) and Estimated Number of Eggs for 39 Striped Bass Collected in Hudson River, 1973

Table V-19

MEAN OF ESTIMATED NUMBER OF MATURE OVA (THOUSANDS) BY AGE GROUP AND TOTAL LENGTH OF 41 STRIPED BASS, AGES 6-14, MARCH-JUNE 1973, HUDSON RIVER (weighted mean number of eggs and ranges included)

Total Length (cm)	Age Group								
	6	7	8	9	10	11	12	13	14
51-60	626(1)*	248(1)	—	—	—	—	—	—	—
61-70	276(1)	785(3)	—	—	—	—	—	—	—
71-80	—	723(3)	1317(1)	—	—	—	—	—	—
81-90	—	1124(2)	1325(8)	—	1424(1)	—	—	—	—
91-100	—	—	1951(4)	1752(3)	1368(1)	—	—	—	2189(1)
101-110	—	—	1953(1)	1469(6)	2286(2)	—	1994(1)	—	—
111-120	—	—	—	—	—	—	2707(1)	—	—
121-130	—	—	—	—	—	—	—	—	—
Weighted Mean No. of Eggs	451(2)	780(9)	1548(14)	1563(9)	1841(4)	—	2350(2)	—	2189(1)
Range	276-626(2)	59-1150(9)	958-2285(14)	891-2428(9)	1268-2416(4)	—	1994-2707(2)	—	2189(1)

*Numbers in parentheses represent sample size.

Table V-20

MEAN OF ESTIMATED NUMBER OF MATURE OVA (THOUSANDS) BY AGE GROUP AND TOTAL BODY WEIGHT OF 39 STRIPED BASS, AGES 6-14, MARCH-JUNE 1973, HUDSON RIVER (weighted mean number of eggs included)

Total Weight (kg)	Age Group								
	6	7	8	9	10	11	12	13	14
1.1-2.0	—	248(1)	—	—	—	—	—	—	—
2.1-3.0	451(2)*	548(1)	—	—	—	—	—	—	—
3.1-4.0	—	59(1)	—	—	—	—	—	—	—
4.1-5.0	—	930(3)	—	1112(1)	—	—	—	—	—
5.1-6.0	—	—	1317(1)	—	—	—	—	—	—
6.1-7.0	—	1098(1)	1350(2)	—	—	—	—	—	—
7.1-8.0	—	1138(2)	1088(4)	1237(2)	—	—	—	—	—
8.1-9.0	—	—	1602(1)	1401(2)	—	—	—	—	—
9.1-10.0	—	—	2123(3)	1546(1)	1368(1)	—	—	—	—
10.1-11.0	—	—	1777(3)	1855(2)	—	—	—	—	—
11.1-12.0	—	—	—	—	—	—	—	—	2189(1)
12.1-13.0	—	—	—	2428(1)	2416(1)	—	—	—	—
13.1-14.0	—	—	—	—	2156(1)	—	—	—	—
14.1-15.0	—	—	—	—	—	—	—	—	—
15.0-16.0	—	—	—	—	—	—	1994(1)	—	—
Weighted Mean	451(2)	780(9)	1548(14)	1563(9)	1980(3)	—	1994(1)	—	2189(1)

*Numbers in parentheses represent sample size.

Fecundity values for Hudson River striped bass are considerably higher than those reported by Lewis and Bonner (1966) for corresponding age groups after age 7, at which time body lengths for Hudson River fish are also noticeably longer. Generally, the number of estimated eggs increases with age.

Lewis and Bonner (1966) estimated the fecundity of their fish at approximately 80,000 eggs/lb of body weight, but their procedures for arriving at this figure were not reported. We calculated individual egg/body-weight ratios for the 39 specimens included in Table V-20, arriving at a grand mean of 173,900 eggs/kg (78,950/lb) of body weight.

Table V-21

WEIGHTED MEAN FORK LENGTHS (mm) AND ESTIMATED NUMBER OF EGGS (THOUSANDS) FOR STRIPED BASS OF VARIOUS AGES COLLECTED FROM ROANOKE RIVER, NORTH CAROLINA, AND HUDSON RIVER, 1973

		Age										
		4	5	6	7	8	9	10	11	12	13	14
Roanoke[1]	Weighted mean fork length (mm)	521.0	553.2	581.5	653.9	653.6	688.0	692.9	722.6	722.6	697.2	—
	Weighted mean No. of eggs (thousands)	345	438	615	752	820	909	910	964	1136	908	—
	Range in No. of eggs (thousands)	222-642	231-878	289-902	512-848	518-976	825-988	476-1082	815-1199	1136	908	—
	Sample size	63	15	9	17	14	11	6	4	1	1	—
Hudson[2]	Weighted mean fork length (mm)	467.0	559.9	550.9	656.3	808.9	927.2	889.5	—	1002.4	—	866.9
	Weighted mean No. of eggs (thousands)	—	—	451	780	1548	1563	1841	—	2350	—	2189
	Range in No. of eggs (thousands)	—	—	276-626	59-1150	958-2285	891-2428	1268-2416	—	1994-2707	—	2189
	Sample size	7	10	2	9	14	9	4	—	2	—	1

[1]Information in table calculated from data presented by Lewis and Bonner (1966).

[2]Present study.

Egg Retention. Egg retention in ovaries of fish collected near the end of the spawning season appears to be insignificant. The majority of spent ovaries were nearly void of mature eggs. One 9-year-old specimen (883 mm in total length) retained an estimated 39,000 eggs, which represents only 2.5 percent of the weighted mean fecundity estimate for that age group.

White Perch. Subsamples of white perch collected in our study area before and during the 1973 spawning season have been saved for later fecundity analysis. This work will be completed during the winter (1973-1974) and compared with findings from last year in the second annual report, which should appear in draft form in late March 1974.

Subpopulations

Introduction. A subobjective aimed at evaluating the significance of fish impingement at Indian Point was an investigation of the presence or absence of distinct subpopulations of white perch and striped bass in the study areas. Identification of resident or transient subpopulations in any of the study areas — and particularly in Region I — would be of special interest in determining the source of impinged fish and seeing if the ratios of the various morphometrics changed following plant operations. From this information and from tag returns, an evaluation that would help determine if impinged fish were primarily from a local population or a widely distributed one was envisioned. Secondarily, it was hoped that the subpopulation study would provide another indirect index (along with growth rate, fecundity, and length-to-weight ratio) of plant effect. This report describes the feasibility of this approach.

Methods. During 1972, white-perch and striped-bass subsamples collected in the original study area (i.e., Regions I, II, and III) were examined for morphometric and meristic characteristics; when possible, 50 specimens collected from each region in spring, summer, and fall were examined three times during the year. A scarcity of striped bass in Regions II and III during the late fall made their collection difficult; consequently, those samples were small and were excluded from the analysis.

Methods of obtaining counts and measurements were, for the most part, similar to those described by Hubbs and Lagler, 1947. When possible, 48 characteristics were recorded for each specimen examined, but gross anomalies occasionally prevented the use of all characteristics on every fish. The following characteristics were used:

(1) Interorbit/snout length ratio
(2) Interorbit/head length ratio
(3) Total/standard length ratio
(4) Head/standard length ratio
(5) Head length/head width ratio
(6)* Head width/standard length ratio
(7)* Orbit/standard length ratio
(8) Orbit/head length ratio

(9)* Snout/standard length ratio
(10) Postorbit/standard length ratio
(11) Postorbit/head length ratio
(12) Upper jaw/standard length ratio
(13)* Predorsal/standard length ratio
(14)* Fork/standard length ratio
(15) Body depth/standard length ratio
(16)* Caudal peduncle/standard length ratio
(17)* Caudal peduncle width/standard length ratio
(18)* Caudal peduncle width/caudal peduncle length ratio
(19)* Lateral-line scale count
(20)* Above-lateral-line scale count
(21)* Below-lateral-line scale count
(22) Base first dorsal fin/standard length ratio
(23) Base second dorsal fin/standard length ratio
(24) Base first dorsal fin/base second dorsal fin length ratio
(25)* Base anal fin/standard length ratio
(26) Anal spine count
(27)* Anal ray count
(28)* Second anal spine/standard length ratio
(29)* Second anal spine/base anal fin length ratio
(30) First dorsal spine count
(31) Second dorsal spine count
(32) Fourth spine of first dorsal fin/standard length ratio
(33) Fourth spine of first dorsal fin/base first dorsal fin length ratio
(34)* First spine of second dorsal fin/standard length ratio
(35) First spine of second dorsal fin/base second dorsal fin length ratio
(36) Second dorsal ray count
(37) Pelvic spine count

(38) Pelvic ray count

(39) Pelvic spine/standard length ratio

(40) Pelvic fin/standard length ratio

(41) Pelvic spine/pelvic fin length ratio

(42)* Pectoral ray count

(43) Caudal ray count

(44) Rudimentary caudal ray count

(45)* Gill raker count (lower arm of first arch)

(46) Pectoral fin/standard length ratio

(47) Sex

(48)* Caudal peduncle scale count (around)

In Appendix D, Tables D-1 through D-4 contain the sample sizes, means, and standard deviations of each characteristic for each seasonal and regional group.

For three of the characteristics examined for both species, no variation was found so they were excluded from the discriminant analysis. Those characteristics which were constant were the number of pelvic spines (1), pelvic rays (5), and rudimentary caudal rays (4). The number of anal rays was constantly 7 for white perch and was also excluded from the white-perch analysis. The remaining characteristics were treated using multivariate discriminant analysis with nine groupings of white perch and seven groupings of striped bass, each group having come from one of three seasons and one of three river regions. The results indicated all groups of both species were very significantly different ($\alpha = 0.01$).

A second trial used only those body characteristics (the 19 indicated by an asterisk in the listing) which were significantly different based on a univariate analysis. Results again indicated that each grouping for both species was very significantly different ($\alpha = 0.01$).

No further analysis of striped-bass meristic and morphometric data was performed, but there was a third treatment of the white-perch data. Five characteristics were chosen from the original 44 — lateral-line scales, anal rays, first dorsal spines, pectoral rays, and predorsal/standard-length ratios — for three reasons:

- All five characteristics can be easily measured or counted with a high degree of accuracy
- Four of the five characteristics had been examined by a previous investigator (Woolcott, 1962)
- An apparent difference in the number of first dorsal spines had been noted in field observations for white perch collected from Regions I and III during the summer of 1972

To reduce possible year-class variations from the samples, only one size group (130 to 160 mm) was used. This size restriction corresponded to fish in age-group 2, i.e., the 1970 year class.

Results of the third analysis indicated that six of the nine groups were still significantly different ($\alpha = 0.05$). The three seasonal groups collected in Region I were statistically different from each other and from every other group examined.

Discussion and Conclusions. Results of our multivariate discriminant analysis were of such a nature that no single resident subpopulation could be defined in any study area; indeed, the data revealed that the variance of each morphological and meristic characteristic (variable) was very small for most fish collected in the three different regions. Because of this tight data structure, the multivariate analysis may have shown all groups as significantly different while, in fact, the biological differences were small and the groupings were all part of a single and much larger population. On a more gross level, there appears to be no distinct subpopulations of white perch within the areas studied in the estuary. Gene flow appears to be occurring throughout the entire population.

Increasing numbers of tag returns from various parts of the estuary indicated considerable mixing in our study area as a result of seasonal (winter, spring) migrations and random movements.

In conclusion, neither species examined is sedentary in the vicinity of Indian Point or in the other study regions. It is apparent from these results that the approach used here will not meet the intended objectives. We recommend dropping the meristics studies on white perch and young striped bass and are thus discontinuing these efforts unless directed otherwise. Increased tagging efforts over the entire estuary and subsequent tag returns from impinged fish will more successfully determine the source of fish impinged at Indian Point. The results also indicate that the subpopulation approach should not be used as a population stress indicator.

Striped Bass, 1973

Renewed interests concerning the Hudson River's contribution of striped bass to the Atlantic fishery prompted collection of morphometric and meristic data on a sample of migrating adult fish. Recorded when possible for 165 specimens were total, standard, and fork lengths; scale counts along lateral lines; and number of pectoral, anal, and soft dorsal rays. Total lengths ranged from 342 mm to 1170 mm. All fish were captured between RM 39 and 59 (km 62 to 94) during the spawning migration. The information supplements our meristic findings on striped bass and provides a recent data base which can be compared to findings from past and future investigations.

Previous racial investigations of striped bass in bays and estuaries along the Atlantic coast were thoroughly reviewed (Raney and De Sylva, 1953; Raney, Woolcott, and Mehring, 1954; Raney and Woolcott, 1955; Lewis, 1957; Barkuloo, 1970; Morgan, Koo, and Krantz, 1973). In several reports there were references to a distinct Hudson River race or population despite the fact that some different meristic characteristics were examined.

Tables V-22, V-23, and V-24 compare our 1973 findings with those reported by Raney and Woolcott (1955) for both Chesapeake and Hudson River striped bass. Direct comparison of observed anal ray, soft dorsal ray, and lateral-line scale counts with respective values from previous literature was made by comparing the frequency distribution of each characteristic for both samples using a chi-square test. Highly significant differences ($\alpha = 0.01$) were found when each characteristic observed in this study was compared with the literature values given for the Chesapeake Bay (Raney and Woolcott, 1955). Chi-square analysis was also used to compare pectoral ray counts; again, the differences between the fish from the two bodies of water were highly significant ($\alpha = 0.01$). Because our pectoral ray counts were for the left fin only and the literature reported total ray counts (left and right fin), 25 striped bass were examined for differences in right and left pectoral-fin ray counts; in every case, the left pectoral count was either equal to or 1 greater than the right pectoral count. These results allowed us to compare our 1973 findings with the literature by combining their numbers from two classes of total pectoral rays and assigning the sum of these numbers to one-half of the larger class; e.g., where the literature showed one entry in class 27 and four entries in class 28 for total pectoral rays, the number of specimens in each class was combined (5) and this number then entered in class 14 of the single fin comparison table.

A character index (Table V-24) combining the number of anal, dorsal, and pectoral rays was also compared with literature values. For comparative purposes, left pectoral ray counts from our study were doubled. Chi-square analysis again showed highly significant differences ($\alpha = 0.01$) between the observed distribution of meristic data examined in the 1973 Hudson River specimens and the Chesapeake Bay specimens (Raney and Woolcott, 1955). Results of the same test using the character index indicated no significant differences for the observed Hudson River fish captured in 1973 and the Hudson River striped bass examined in the earlier study.

Table V-22

FREQUENCY DISTRIBUTION OF LATERAL-LINE SCALES IN STRIPED BASS, HUDSON RIVER, 1973

Scales	Hudson River 1973 (164 specimens)	Chesapeake Bay* (180 specimens)
53	2	1
54	2	—
55	3	2
56	7	9
57	11	14
58	11	14
59	13	26
60	20	31
61	26	27
62	27	33
63	14	13
64	15	8
65	9	2
66	4	—

*From Raney and Woolcott (1955)

It is interesting that there have been no apparent changes in at least four meristic characters of Hudson River striped bass in the past 20 years. Our findings strongly support earlier studies defining a morphologically distinct Hudson River population! The overlapping nature of meristic data from Chesapeake Bay and Hudson River striped bass does not permit us to exclude the real possibility that some small percentage of the fish captured in the Hudson spawning migration are from Chesapeake stock or vice versa. The marked similarity in the two Hudson samples collected nearly 20 years apart, however, suggests that the amount of gene mixture of the two races has been nearly constant and probably minimal, and/or the Hudson River environment of today is similar to that of 20 years ago.

Table V-23

FREQUENCY DISTRIBUTION OF ANAL, SOFT DORSAL, AND PECTORAL RAYS IN STRIPED BASS, HUDSON RIVER, 1973

	Rays	Hudson 1973	Chesapeake Bay*
Anal No. of Specimens: Hudson, 165 Chesapeake, 952	8	1	—
	9	1	—
	10	24	124
	11	131	825
	12	7	3
	13	—	—
	14	—	—
	15	1	—
Soft Dorsal No. of Specimens: Hudson, 165 Chesapeake, 951	10	19	7
	11	73	248
	12	69	687
	13	2	8
	14	1	1
	15	1	—
Pectoral† ** No. of Specimens: Hudson, 164 Chesapeake, 936	11	1	—
	12	1	—
	13	—	—
	14	23	5
	15	85	29
	16	51	209
	17	3	574
	18	—	112
	19	—	7

*From Raney and Woolcott (1955).

†Hudson River count is left pectoral.

**Chesapeake values were attained by combining the numbers from two classes of total pectoral rays and assigning the sum of these numbers to one-half of the larger class; from Raney and Woolcott, 1955.

Table V-24

CHARACTER INDEX COMBINING ANAL, DORSAL, AND PECTORAL RAYS OF STRIPED BASS FOR HUDSON RIVER IN 1973 AND COMPARING WITH PUBLISHED DATA

Character Index	Hudson River* 1973 (164 specimens)	Hudson River (Raney & Woolcott, 1955) (274 specimens)	Chesapeake Bay (Raney & Woolcott, 1955) (551 specimens)
45	1	—	—
46	—	—	—
47	1	—	—
48	1	—	—
49	—	1	—
50	8	5	—
51	16	13	1
52	13	27	5
53	34	49	9
54	44	74	25
55	18	59	80
56	23	23	127
57	3	22	219
58	2	1	55
59	—	—	27
60	—	—	2
61	—	—	1

*Number of left pectoral rays observed in 1973 doubled for comparison.

Ultimately, meristic information, long-range tagging programs, and race-specific biochemistry evaluations will contribute in determining the source of commercial catches of striped bass in the Atlantic. Findings indicate that meristic data (and the "subpopulation" approach) on mature stripers can be used to help evaluate the contribution of the Hudson population to the Atlantic fishery. We plan to continue these efforts in lieu of the subpopulation work on white perch and young striped bass.

Miscellaneous

TI's 1972 annual report (Texas Instruments Incorporated, 1973a) reported a significant difference between length/weight relationships for impinged vs river-caught fish during the fall season. This relationship was investigated for the 1973 spring season to see if the same difference persists for white perch; length/weight data on white perch from Unit-2 intake screens and from the standard stations were utilized in comparing the regressions of weight on length. For the standard-station collection, 454 fish were individually measured and weighed; the intake screens provided measurements on 3290 individual fish. The regression function used to fit the data was of the general form $W = A\ L^B\ E$ where W is the weight of the fish, L is its length, A is a constant, B is the power coefficient, and E is random error. Making a logarithmic transformation, the equation is linearized to give

$$\log_{10} W = \log_{10} A + B \log_{10} L + \log_{10} E$$

and $\log_{10} E$ is assumed to be normally distributed with mean 0 and variance σ^2.

Statistical comparison showed that the two equations were different in the intercept values (the impinged fish were again lighter per unit of length) but showed no significant difference in slopes ($\alpha = 0.05$). By visually inspecting the data, it appeared at first that the two samples represented different proportions of large and small fish, the larger size coming from the river and the smaller size from the intake screens. This might result in the observed difference of the intercept values. The regression analysis was repeated after samples were restricted to include only > 100-mm fish. Again, the difference in the regression equations was found to be due principally to the difference in the intercept values. From this comparison, one can conclude that the fish on the intakes are generally lighter but that the length/weight slope relationship is otherwise the same for both the river and the intake screen fish.

The separate regressions were obtained as follows:

$$\log_{10} W = -4.95796 + 3.06270 \log_{10} L \quad \text{(river sample, n = 261)}$$

$$\log_{10} W = -5.02559 + 3.06195 \log_{10} L \quad \text{(intake sample, n = 1220)}$$

These results are for the restricted samples and are directly comparable to the similar relationship reported for fish collected in October 1972 (Texas Instruments Incorporated, 1973a).

In Table V-25 are the regression coefficients and predicted weights for fish of various lengths. These results reaffirm that an impinged fish is consistently lighter than a river-caught fish of the same length. Theoretically, any changes in length/weight relationship throughout the winter should reflect the relative well-being of the fish. Separate regressions were fit to data from the monthly impingement collections of white perch at Indian Point. The relative length distributions were nearly constant throughout this period, and all length groups were included in the analysis. The regression coefficients and predicted weights are summarized in Table V-26. (Statistical comparison of these relationships shows that the December, February, March, and April regressions are significantly different in slope [$\alpha = 0.05$]. The March-May and April-May regressions are not significantly different.)

To coincide with the modes of the length distribution, three lengths were chosen: 70 mm representative of the 1972 year class; 110 mm, the 1971 class; and 150 mm, the pre-1971 classes. The interesting trend in the predicted weights is the decline in weight for the 1972 class and the nearly stable or slightly increasing weights for the older fish. One tentative explanation is that the smaller fish are under greater stress during the winter period. The predicted weights for the larger fish do not exhibit any clear trends at this time, but additional comparisons with the river fish will be examined.

Table V-25

REGRESSION COEFFICIENTS FOR LENGTH/WEIGHT REGRESSION AND PREDICTED WEIGHTS FOR IMPINGED AND RIVER WHITE PERCH (TOTAL LENGTH ≥ 100 mm) COLLECTED DURING FALL OF 1972 AND SPRING OF 1973

Season	Source	Regression Equation			Predicted Weight (gm)		
		Intercept (x 10^{-4})	Slope	Sample Size	110 mm	150 mm	175 mm
Fall	Intake	0.1714	2.913	87	15.2	37.4	58.6
	River	0.1191	3.0404	82	19.2	49.2	78.6
Spring	Intake	0.0943	3.0620	1220	16.8	43.4	69.6
	River	0.1102	3.0627	261	19.7	50.9	81.6

Table V-26

REGRESSION COEFFICIENTS FOR LENGTH/WEIGHT REGRESSION AND PREDICTED WEIGHTS FOR IMPINGED WHITE PERCH COLLECTED AT INDIAN POINT

Month Collected	Regression Equation			Predicted Weight (gm)		
	Intercept (x 10^{-4})	Slope	Sample Size	70 mm	110 mm	150 mm
12/72	0.09114	3.0598	2327	4.0	16.1	41.5
2/73	0.13652	2.9736	1616	4.2	16.0	40.4
3/73	0.05312	3.1799	4044	3.9	16.5	44.2
4/73	0.03693	3.2581	2492	3.8	16.5	45.4
5/73	0.04268	3.2162	646	3.1	15.7	42.5

CHAPTER VI

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APPENDIX A

MEAN CURRENT VECTORS
AND WIND OCCURRENCE

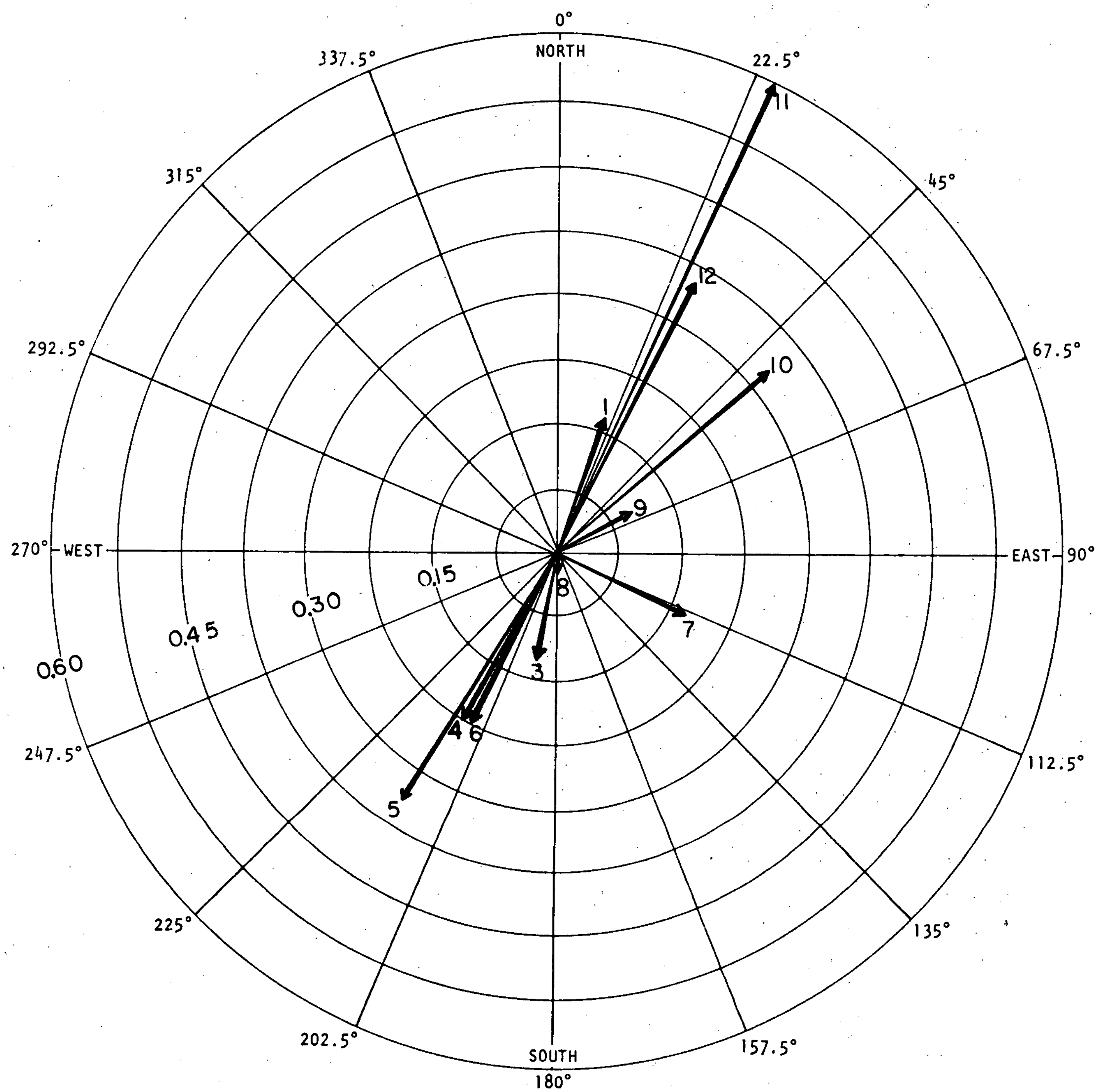

Figure A-1. Mean Current Vectors (m/sec) for Station 2, May 31, 1973

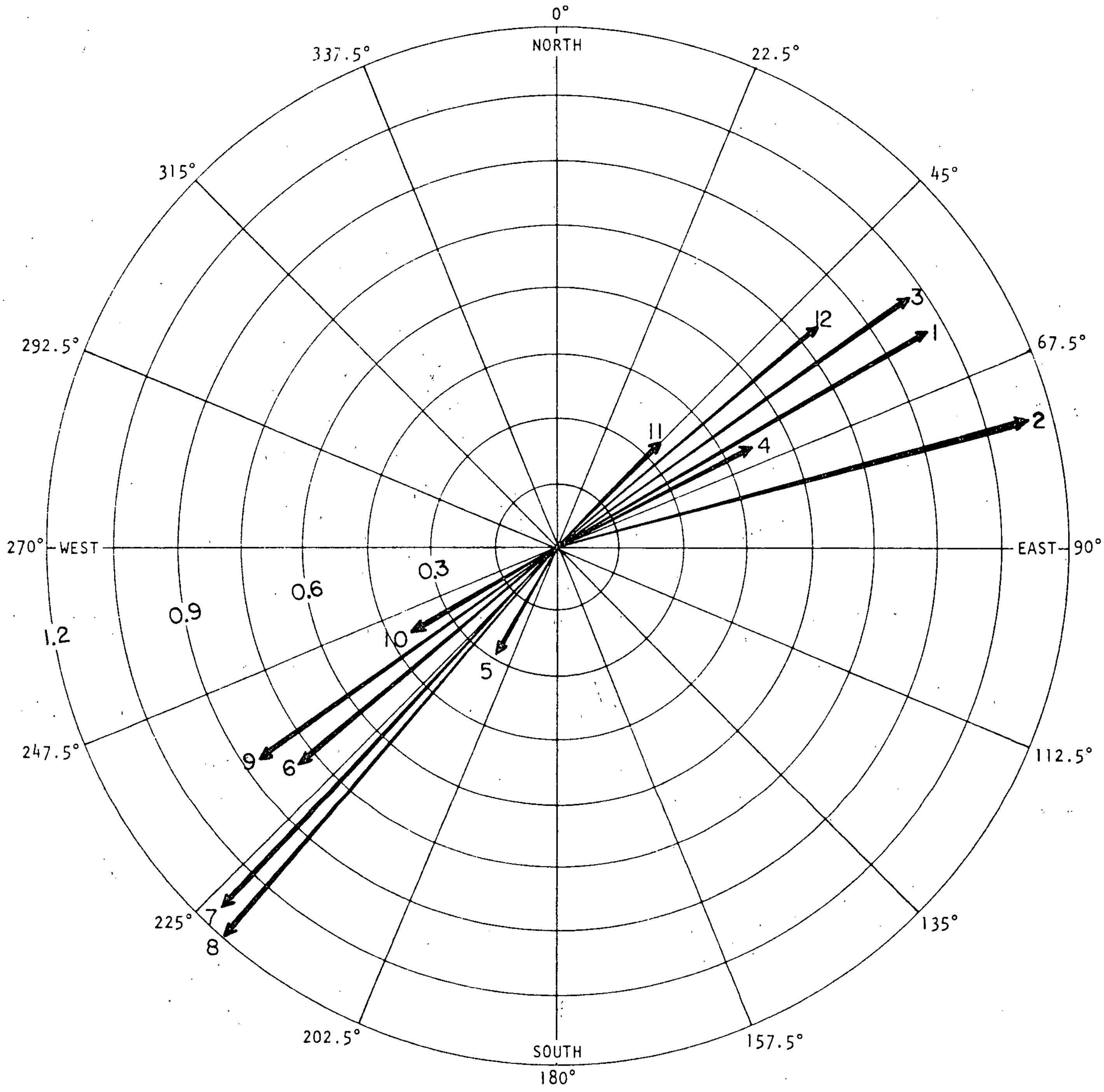

Figure A-2. Mean Current Vectors (m/sec) for Station 3, June 14, 1973

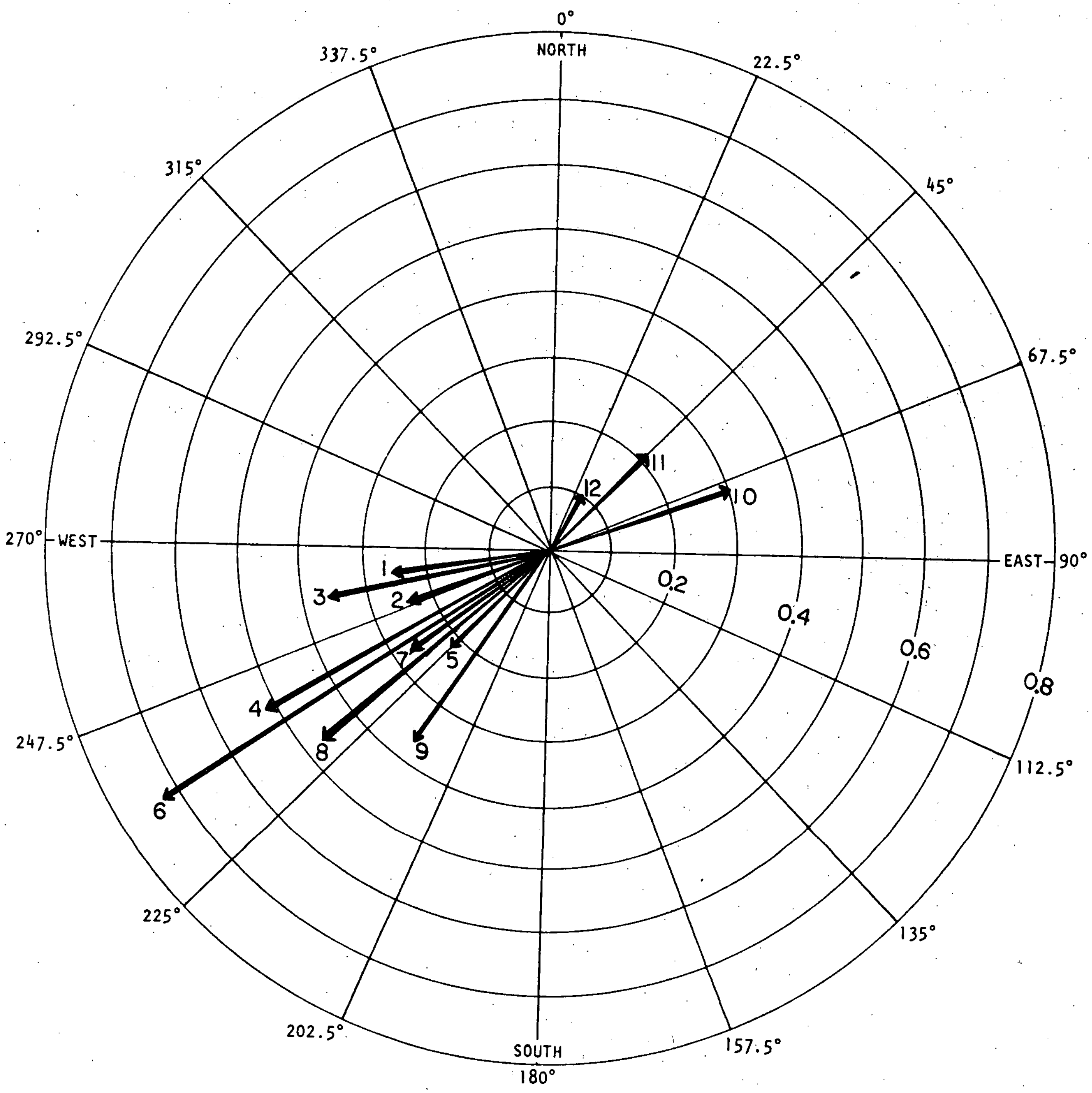

Figure A-3. Mean Current Vectors (m/sec) for Station 5, May 17, 1973

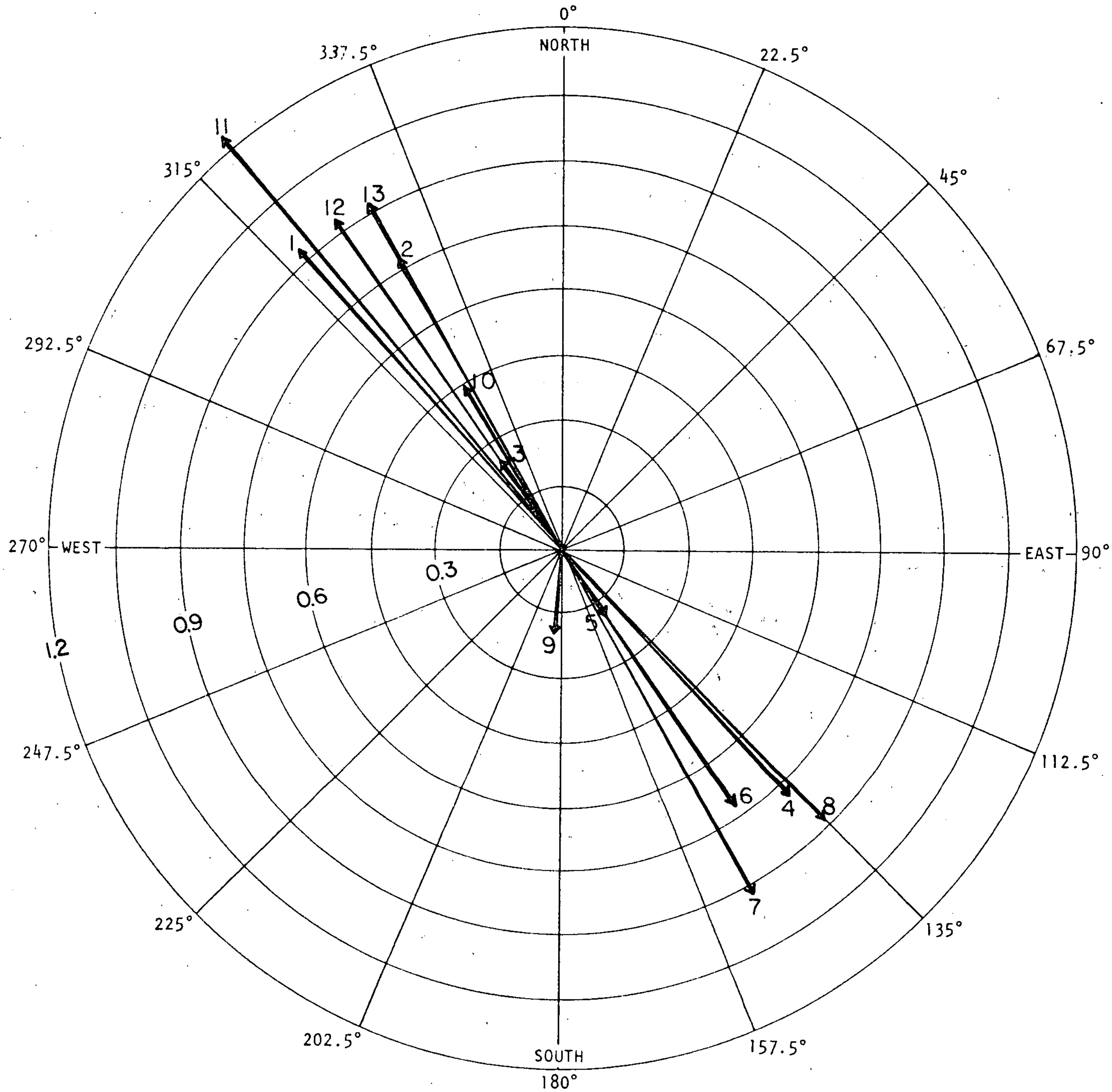

Figure A-4. Mean Current Vectors (m/sec) for Station 7, June 28, 1973

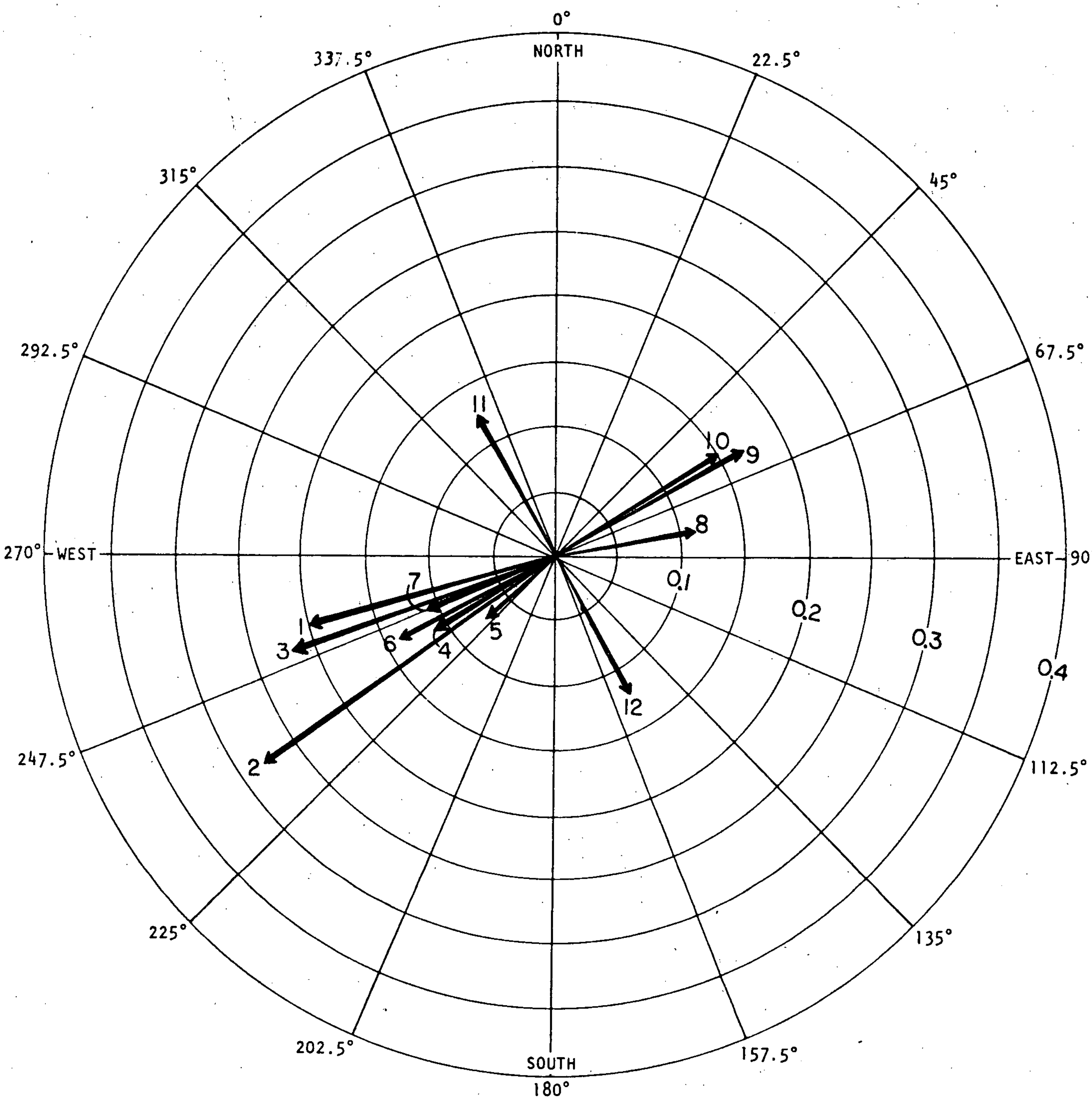

Figure A-5. Mean Current Vectors (m/sec) for Station 10, April 18, 1973

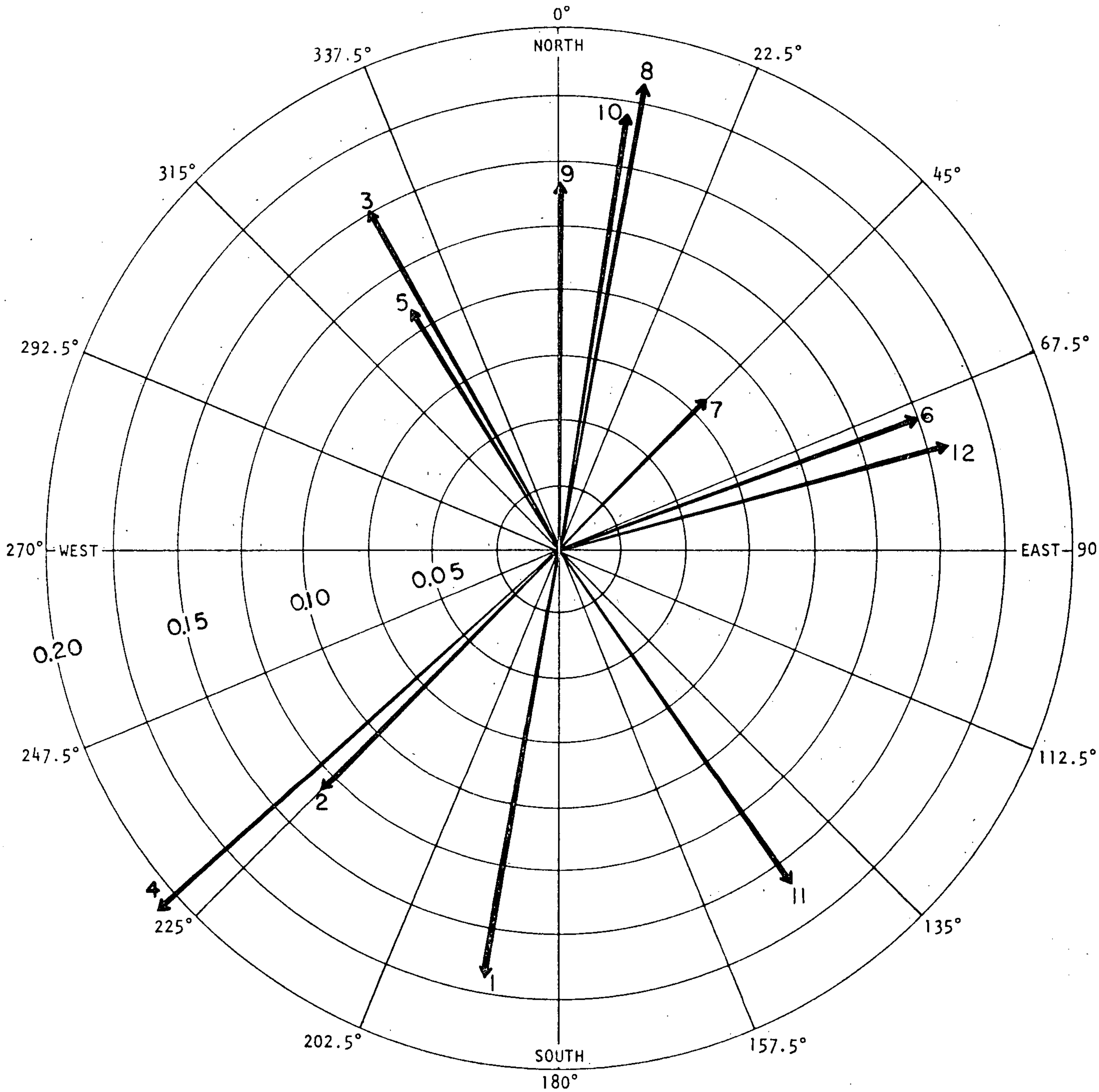

Figure A-6. Mean Current Vectors (m/sec) for Station 11, April 5, 1973

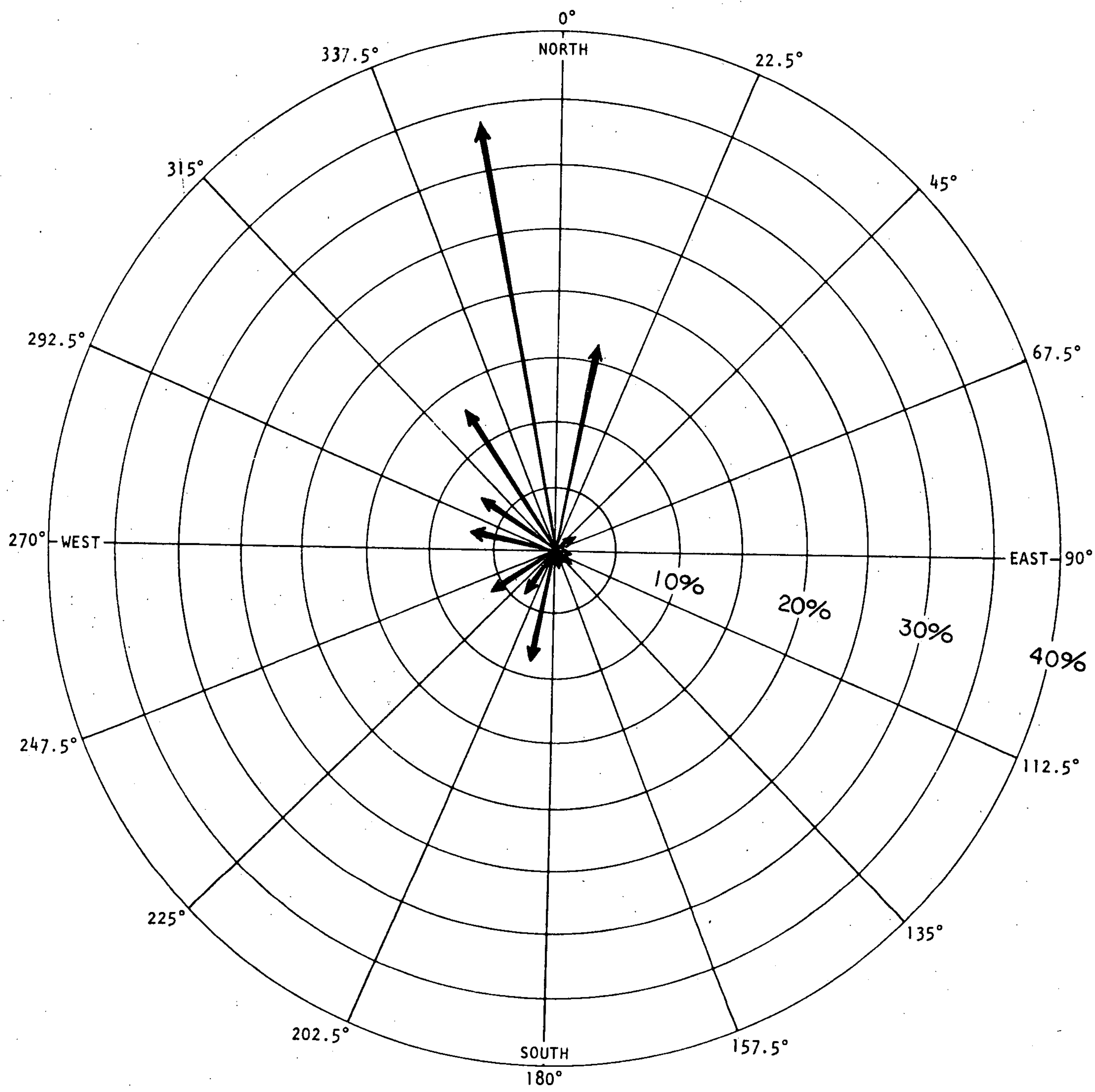

Figure A-7. Wind Occurrence for January 1973 in Terms of Percentage of Observations in Each Quadrant

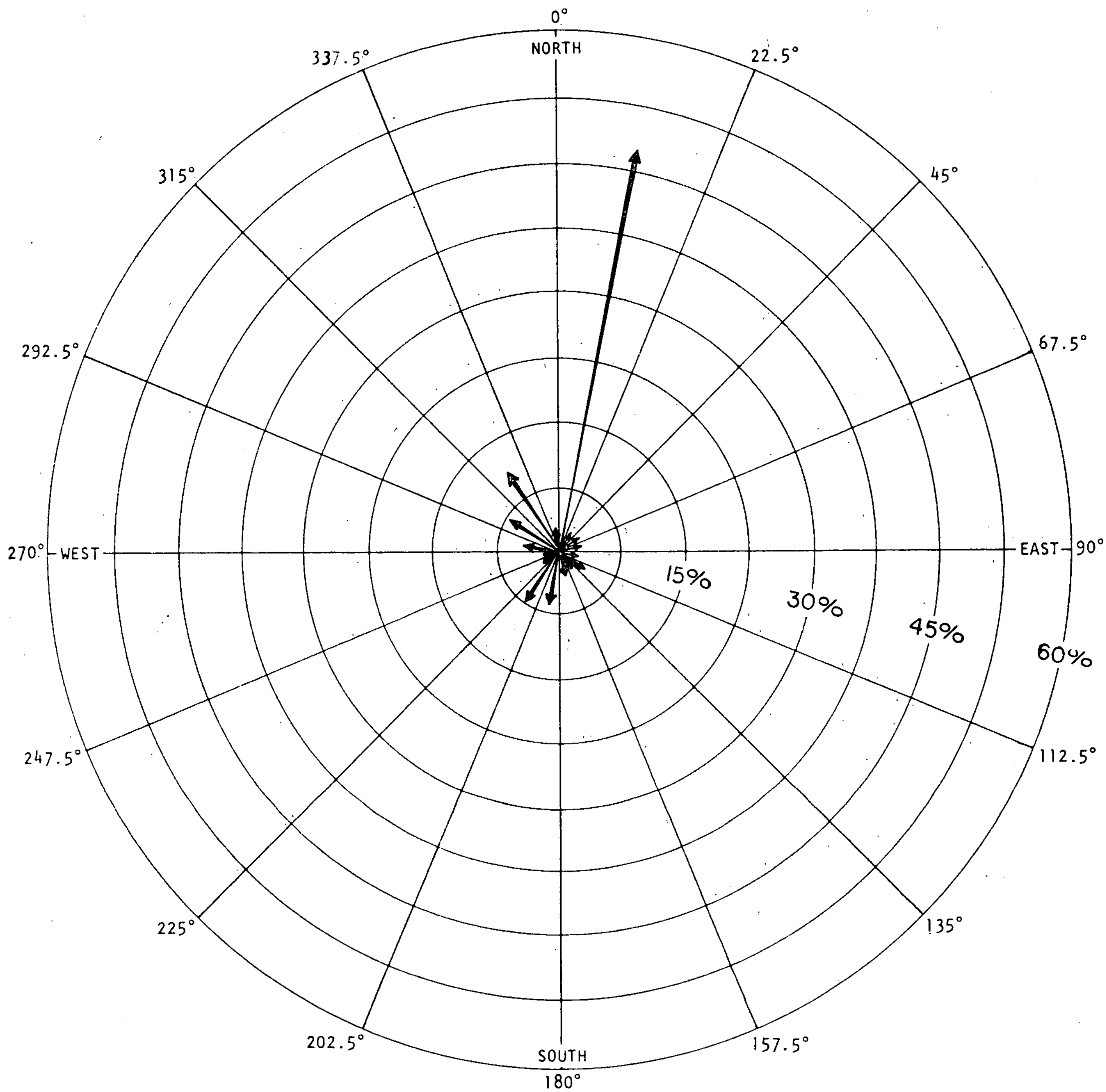

Figure A-8. Wind Occurrence for February 1973 in Terms of Percentage of Observations in Each Quadrant

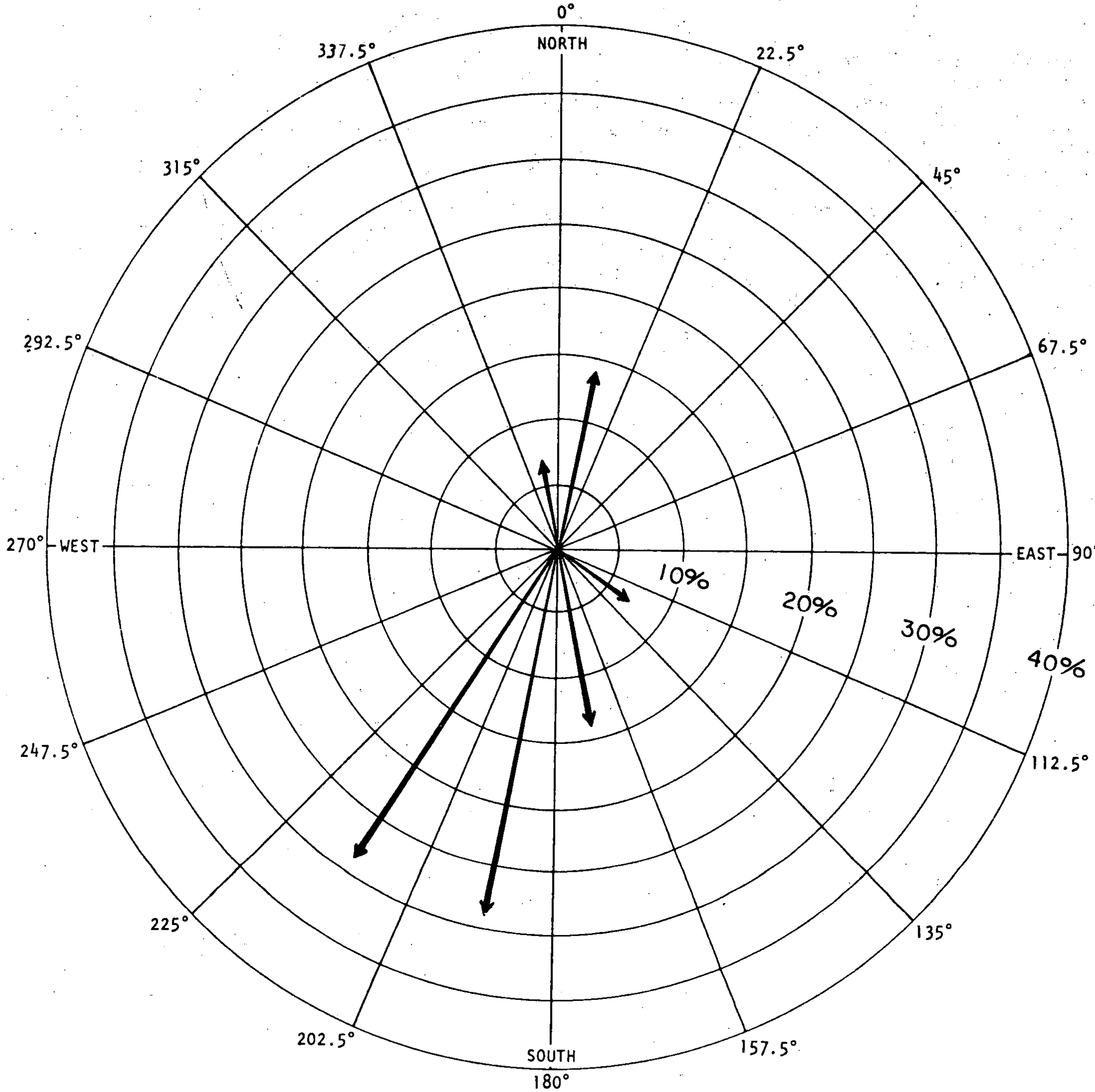

Figure A-9. Wind Occurrence for March 1973 in Terms of Percentage of Observations in Each Quadrant

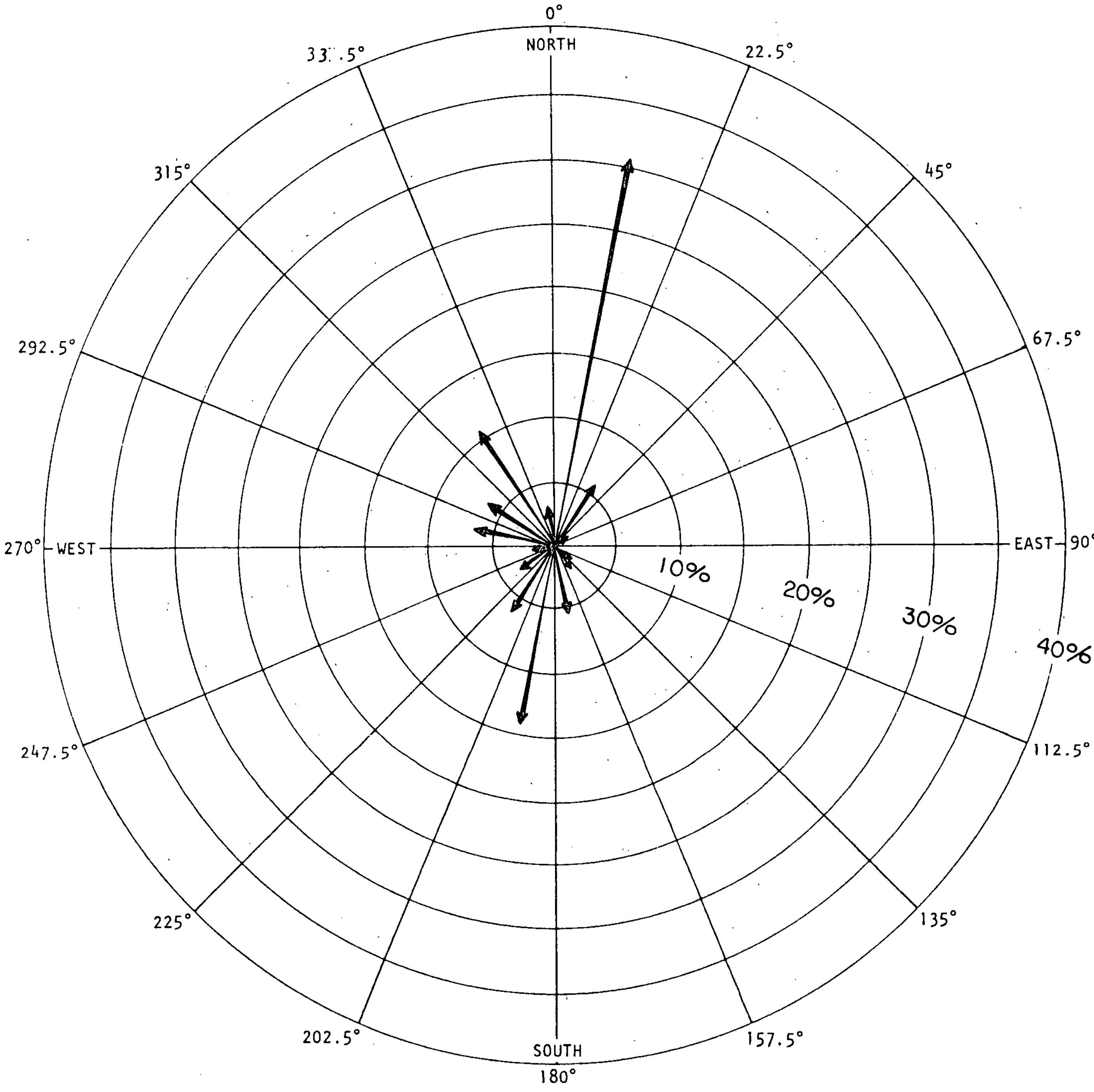

Figure A-10. Wind Occurrence for April 1973 in Terms of Percentage of Observations in Each Quadrant

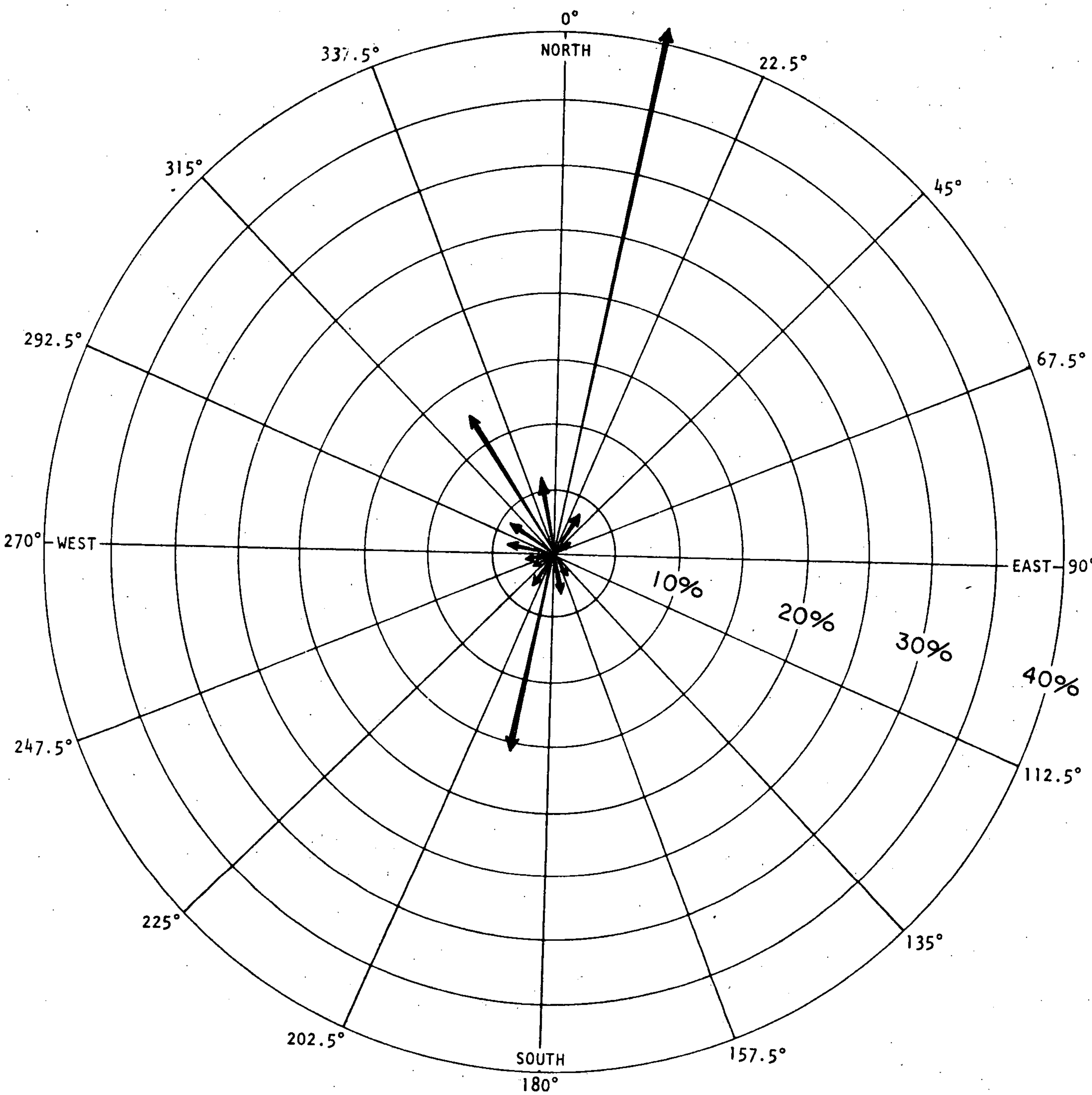

Figure A-11. Wind Occurrence for May 1973 in Terms of Percentage Observations in Each Quadrant

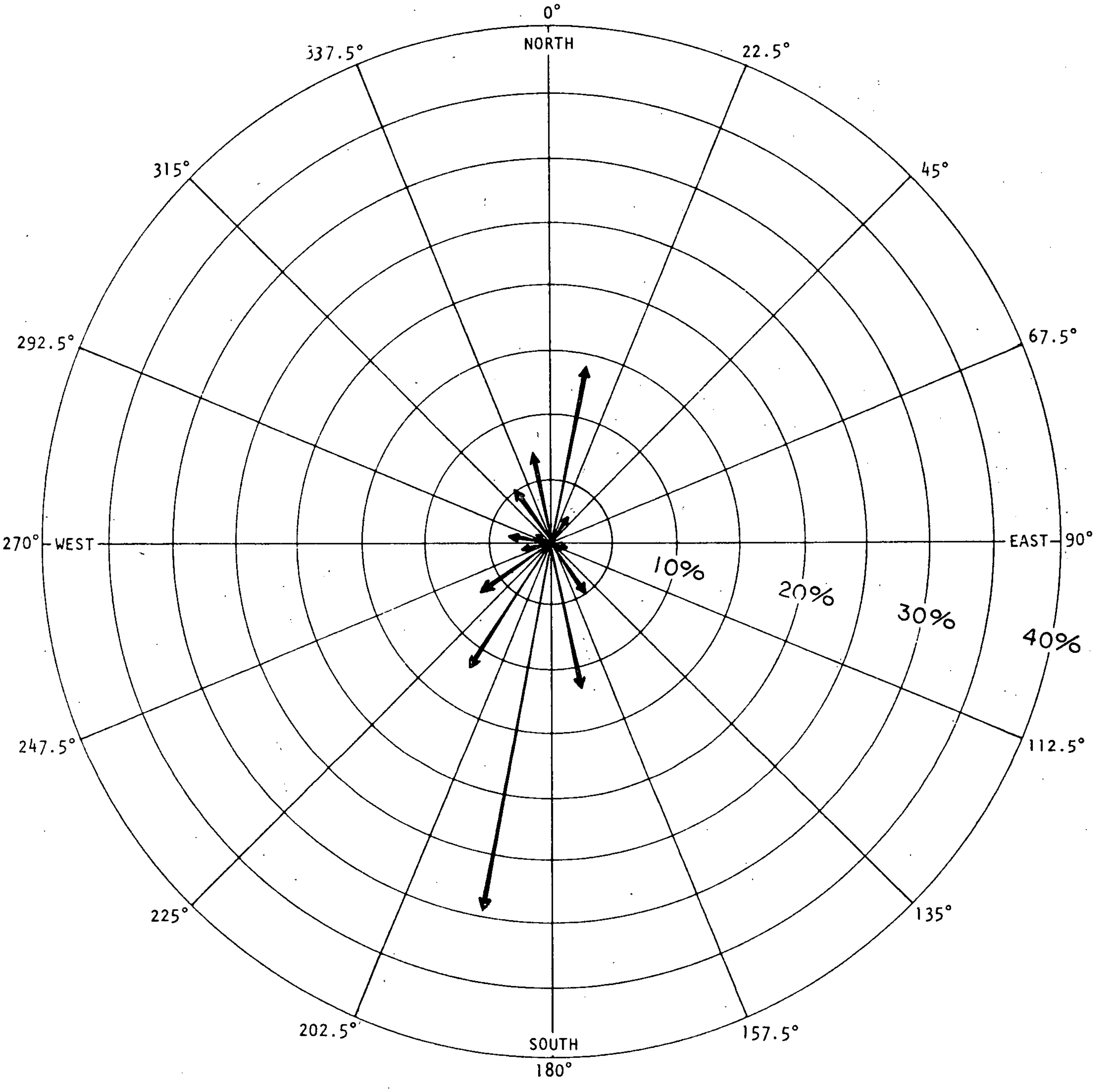

Figure A-12. Wind Occurrence for June 1973 in Terms of Percentage of Observations in Each Quadrant

APPENDIX B

FISHERIES POPULATION DATA
(FISHERIES SAMPLING PROGRAM)

Table B-1

BEACH-SEINE CATCHES FROM STANDARD STATIONS IN REGION I, 1973

Species		Jan			Feb			Mar			Apr			May			Jun		
		X̄	SE	n	X̄	SE	n	X̄	SE	n	X̄	SE	n	X̄	SE	n	X̄	SE	n
Alewife	C/f		NC			NS			NC		0.43	0.25	17	3.27	0.74	98	0.93	0.40	28
	Length										265.88	11.83	17	233.20	7.10	98	119.25	27.16	28
	Weight										196.47	13.51	17	143.62	7.54	98	30.48	9.93	28
Bay anchovy	C/f		NC			NS			NC			NC			NC		0.40	0.30	12
	Length																67.92	2.87	12
	Weight																2.58	0.47	12
Blueback herring	C/f		NC			NS			NC		0.78	0.42	31	3.07	1.55	92	3.43	1.67	103
	Length										79.61	2.83	31	97.51	1.71	68	105.19	6.16	65
	Weight										4.13	0.51	31	8.18	0.34	68	10.77	1.10	65
Tessellated darter	C/f		NC			NS		1.00	0.39	10	20.63	15.77	825	3.03	0.72	91	1.53	0.47	46
	Length							64.30	2.20	10	59.88	0.75	190	59.57	1.41	91	58.70	0.81	46
	Weight							2.40	0.31	10	2.40	0.07	190	2.22	0.10	91	2.35	0.13	46
Banded killifish	C/f		NC			NS		0.10	0.10	1	0.75	0.23	30	1.13	0.33	34	1.73	0.53	52
	Length							*	*	1	84.94	4.38	30	82.18	2.58	34	80.15	2.31	52
	Weight							*	*	1	6.89	0.67	30	6.74	0.59	34	6.46	0.55	52
Atlantic menhaden	C/f		NC			NS			NC			NC			NC			NC	
	Length																		
	Weight																		
Pumpkinseed	C/f		NC			NS		0.30	0.21	3	2.23	1.04	89	0.87	0.23	26	1.60	0.44	48
	Length							131.33	*	3	110.10	4.83	67	116.35	5.04	26	99.75	11.40	48
	Weight							44.67	*		30.96	2.38	67	37.65	4.28	26	25.21	3.72	48
American shad	C/f		NC			NS			NC			NC		0.10	0.07	3	0.07	0.05	2
	Length													133.67	*	3	*	*	2
	Weight													22.00	*	3	*	*	2
Atlantic silverside	C/f		NC			NS			NC			NC		0.07	0.07	2		NC	
	Length													73.00	*	2			
	Weight													3.00	*	2			
Spottail shiner	C/f	1.00	1.00	5		NS		0.40	0.27	4	29.50	10.77	1180	22.93	4.58	688	16.27	4.38	488
	Length	66.71	*	5				82.50	*	4	85.34	1.18	334	79.65	1.00	350	87.52	1.58	267
	Weight	2.14	*	5				4.50	*	4	6.26	0.23	334	5.47	0.20	350	7.34	0.24	267
Striped bass	C/f		NC			NS			NC		0.15	0.08	6	1.10	0.56	33	4.07	1.65	122
	Length										95.17	*	6	107.36	11.46	33	96.95	3.63	114
	Weight										8.07	*	6	34.88	20.57	33	10.41	0.82	114
White perch	C/f		NC			NS		0.10	0.10	1	1.28	0.51	51	3.37	1.30	101	23.03	10.01	691
	Length							*	*	1	116.00	5.44	51	88.73	3.67	94	92.71	2.19	357
	Weight							*	*	1	29.13	3.64	51	15.69	2.08	94	16.00	0.80	356
No. of tows			5			0			10			40			30			30	

X̄ =mean
SE=standard error
n =number of individuals
NC=none caught
* =insufficient data to calculate
NS = no seining

Table B-2

BOTTOM-TRAWL CATCHES FROM STANDARD STATIONS IN REGION 1, 1973

		Month																	
		Jan			Feb			Mar			Apr			May			Jun		
Species		$\overline{X}$	SE	n	$\overline{X}$	SE	n	$\overline{X}$	SE	n	$\overline{X}$	SE	n	$\overline{X}$	SE	n	$\overline{X}$	SE	n
Alewife	C/f		NC			NC			NT		0.12	0.08	2	2.62	1.26	55	0.50	0.25	7
	Length										242.50	*	2	118.62	4.81	55	92.71	*	7
	Weight										217.00	*	2	20.09	4.65	55	10.71	*	7
American eel	C/f		NC			NC			NT		0.24	0.14	4	0.43	0.43	9	1.64	1.13	23
	Length										377.50	*	4	423.56	*	9	389.70	11.80	23
	Weight										91.25	*	4	144.56	*	9	136.48	12.56	23
Bay anchovy	C/f		NC			NC			NT			NC		0.10	0.07	6	0.07	0.07	1
	Length													94.00	*	6	*	*	1
	Weight													6.00	*	6	*	*	1
Blueback herring	C/f		NC			NC			NT			NC		0.52	0.27	11	0.21	0.15	3
	Length													132.45	21.33	11	107.67	*	3
	Weight													42.27	23.00	11	11.33	*	3
Brown bullhead	C/f	0.10	0.10	1		NC			NT			NC			NC		0.14	0.14	2
	Length	*	*	1													199.00	*	2
	Weight	*	*	1													136.50	*	2
Hogchoker	C/f		NC		0.60	0.60	3		NT		1.71	0.95	30	0.86	0.52	18	0.29	0.19	4
	Length				103.00	*	3				93.73	3.07	30	94.22	3.56	18	87.75	*	4
	Weight				25.00	*	3				18.13	1.97	30	18.17	2.30	18	16.25	*	4
Spottail shiner	C/f	1.14	1.14	12		NC			NT		0.33	0.29	6	0.38	0.33	8	0.57	0.50	8
	Length	104.42	3.64	12							101.33	*	6	102.75	*	8	87.50	*	8
	Weight	10.33	1.10	12							9.33	*	6	11.50	*	8	7.75	*	8
Striped bass	C/f		NC			NC			NT		0.24	0.24	4	0.24	0.12	5	0.21	0.21	3
	Length										92.25	*	4	99.60	*	5	123.00	*	3
	Weight										7.75	*	4	18.20	*	5	25.00	*	3
Atlantic tomcod	C/f	11.70	3.14	164	1.80	1.20	9		NT		1.06	0.88	18	2.62	1.37	55	24.43	16.86	342
	Length	138.70	2.64	151	143.11	*	9				129.83	3.18	18	134.67	5.46	55	98.58	17.86	50
	Weight	27.32	1.57	151	23.00	*	9				21.72	1.81	18	32.62	2.50	55	12.71	2.93	50
White perch	C/f	10.27	6.00	73	1.20	0.80	6		NT		2.57	0.96	45	3.67	1.70	77	11.93	6.52	167
	Length	152.07	3.69	73	138.17	*	6				131.24	5.28	45	152.73	4.02	77	120.65	4.90	99
	Weight	59.72	4.25	73	53.90	*	6				40.23	4.73	45	62.97	3.97	77	39.18	3.42	99
No. of tows			15			5			0			17			21			14	

$\overline{X}$ =mean
SE=standard error
n =number of individuals
NC=none caught
* =insufficient data to calculate
NT = no trawling

Table B-3

SURFACE-TRAWL CATCHES FROM STANDARD STATIONS IN REGION 1, 1973

Species		Jan X̄	Jan SE	Jan n	Feb X̄	Feb SE	Feb n	Mar X̄	Mar SE	Mar n	Apr X̄	Apr SE	Apr n	May X̄	May SE	May n	Jun X̄	Jun SE	Jun n
Alewife	C/f		NC			NT			NT			NT		1.50	0.58	24	0.07	0.07	1
	Length													121.46	4.36	24	*	*	1
	Weight													15.88	1.62	24	*	*	1
Bay anchovy	C/f		NC			NT			NT			NT		0.38	0.26	6	9.43	7.53	132
	Length													77.83	4.54	6	73.32	1.94	43
	Weight													3.00	0.63	6	3.24	0.19	43
American shad	C/f		NC			NT			NT			NT		0.06	0.06	1		NC	
	Length													*	*	1			
	Weight													*	*	1			
Blueback herring	C/f		NC			NT			NT			NT		3.19	1.37	51	53.07	23.97	743
	Length													99.27	2.92	51	99.79	2.65	235
	Weight													8.20	0.77	51	8.79	0.33	235
Rainbow smelt	C/f		NC			NT			NT			NT		1.00	0.46	16	0.21	0.21	3
	Length													92.25	7.74	16	94.00	*	3
	Weight													4.88	0.51	16	6.33	*	3
Striped bass	C/f		NC			NT			NT			NT		0.06	0.06	1		NC	
	Length													*	*	1			
	Weight													*	*	1			
White perch	C/f		NC			NT			NT			NT		0.63	0.31	10		NC	
	Length													130.30	16.60	10			
	Weight													44.80	11.80	10			
Bluefish	C/f		NC			NT			NT			NT			NC		7.43	4.70	104
	Length																76.03	1.44	39
	Weight																3.85	0.23	39
No. of tows			2			0			0			0			16			14	

X̄ =mean
SE=standard error
n =number of individuals
NC=none caught
* =insufficient data to calculate
NT=no trawling

APPENDIX C

TAG RELEASE AND RECOVERY DATA

Table C-1

TAG RECOVERY DATA

No.	River Mile* (km)	Date Month	Date Day	Date Year	Gear†	Species**	Length (mm)
04A0029	064	05	10	73	12	35	0130
	064	06	15	↑	05	↑	0126
04A0105	067	↑	12		↑		0131
	↑		26				0125
04A0150	↓		12				0130
	067		13				0128
04A0268	064		08				0146
	064		21		↓		0138
04A0286	062	↓	08		05		0132
	064	06	08		15		0132
04A0407	062	05	08		15		0115
	064	↑	09		98		0000
04A0496	062		08		15		0114
	064		09		98		0000
05K0508	051		25		12		0122
	051	↓	29		12		0115
05K0804	062	05	25		14		0125
	↑	06	13		05		0122
05K0851		05	25		14		0163
		06	01		05		0162
05K0853	↓	05	25		14		0131
	062	06	13		05		0126
05K0903	064	↑	01		12		0155
	↑		07		12		0152
05K0993			01		12		0120
			14		14		0122
05K0996		↓	01		12		0135
		06	07		12		0128
0900815	↓	05	31	↓	05		0165
	064	06	21	73	05		
0902445	061	10	24	72	12	↓	0129
	067	02	22	73	99	35	0128

*Upper number in tag set refers to release; lower number to recovery date.

†Gear codes are as follows: 1, 2, 3, 4 — trawls; 5, 6, 7, 8, 9, 10 — trap nets; 11, 12, 14, 15, 27 — beach seines; 22, 23, 24, 25, 26 — gill nets; 30, electrofishing; 98, fishermen; 99, intake screens.

**Species 30 indicates striped bass; 35 indicates white perch.

Table C-1 (Contd)

No.	River Mile* (km)	Date: Month	Date: Day	Date: Year	Gear†	Species**	Length (mm)
0902556	069	11	08	72	01	35	0000
	040	04	12	73	98	↑	
0902951	069	11	15	72	12		0152
	067	03	26	73	99		0154
0903002	064	05	22	↑	12	↓	0146
	062	06	06		05	35	
0903014	054	03	14		25	30	0552
	↑	03	14		98	↑	0584
0903018		01	03		25		0567
	↓	04	23		98		0000
0903019	054	01	03		25		0588
	000	03	31		98		0572
0903058	053	03	09		25		0570
	062	04	27		25		0000
0903059	053	03	09		25	↓	0645
	054	04	23		98	30	0000
0903141	062	04	20		05	35	0172
	104	05	16		98	35	
0903177	054	03	26		24	30	0575
		06	07		98	↑	
0903196	053	04	03	↓	24		0492
	049	04	13	73	98		0489
0903218	054	12	28	72	24		0605
	000	05	25	73	98		0584
0903219	054	12	28	72	24	↓	0555
		05	01	73	98	30	
0903275	064	05	10	↑	12	35	0180
	064	05	18		05	↑	
0903279	064	05	04		12		0161
	067	05	14		12		0157
0903296	064	05	10		05		0171
	064	06	26		05		0173
0903316	064	04	10		14		0211
	062	05	25		14		0210
0903320	064	04	10		14		0182
	062	04	11		05		0185
0903379	064	06	14		14		0172
	064	06	26		05		0169
0903411	054	05	25	↓	12	↓	
	054	06	30	73	12	35	0145

Table C-1 (Contd)

No.	River Mile* (km)	Date Month	Day	Year	Gear†	Species**	Length (mm)
0903502	051	03	13	73	25	30	0610
	062	05	01	↕	98	30	0617
0903557	064	06	01	↕	12	35	0170
	↕	↕	07	↕	12	↕	0165
0903666	↕	↕	14	↕	05	↕	0186
	064	06	22	↕	05	↕	0176
0903688	061	05	25	↕	14	↕	0170
	053	06	30	↕	12	↕	0169
0903729	053	05	25	↕	12	↕	0155
	054	06	29	↕	98	↕	
0903761	069	05	09	↕	06	↕	0158
	062	↕	24	↕	05	↕	0159
0903871	064	↕	22	↕	12	↕	0197
	062	↕	25	↕	14	↕	0195
0905001	062	05	08	↕	05	↕	0154
	062	06	21	↕	05	↕	
0905009	065	05	07	↕	00	↕	0194
	064	↕	18	↕	05	↕	
0905035	↕	↕	07	↕	12	↕	0138
	↕	05	30	↕	05	↕	0137
	↕	06	29	↕	12	↕	0126
0905040	↕	05	07	↕	12	↕	0180
	064	05	15	↕	12	↕	0179
0905184	062	05	11	↕	05	↕	0163
	062	06	29	↕	05	↕	0160
0905254	065	05	11	↕	00	↕	0129
	064	06	08	↕	15	↕	0125
0905265	065	05	11	↕	00	↕	0168
	040	↕	19	↕	98	↕	
0905319	065	↕	08	↕	00	↕	0136
	077	↕	09	↕	01	↕	0131
0905326	062	05	08	↕	15	↕	0187
	062	06	01	↕	12	↕	0188
0905414	064	↕	05	↕	30	↕	0184
	↕	↕	14	↕	05	↕	0181
0905418	↕	↕	05	↕	30	↕	0196
	↕	06	22	↕	05	↕	0195
0906002	↕	05	30	↕	05	↕	0151
	064	07	05	73	12	35	

Table C-1 (Contd)

No.	River Mile* (km)	Date Month	Date Day	Date Year	Gear†	Species**	Length (mm)
0906047	062	05	04	73	05	35	0161
	062	06	13	↑	↑	↑	0170
0906213	067	↑	07				0177
	↑		21				0176
0906221	↓	↓	07		↓		0161
	067	06	29		05		0161
0906237	061	05	25		14		0162
	054	06	05		98		
0910774	064	06	26		05		0184
	067	06	27		12		0180
0911722	067	07	03	↓	05		0180
	038	07	07	73	98		
09A0099	067	05	10	72	01		0178
	019	07	08	↑	98		0000
09A0948	065	09	21	↓	05		0000
	067	11	01	72	99		0180
09C0013	102	05	02	73	12		0162
	062	05	13	↑	98		
09C0026	102	05	02		12		0176
	102	06	10		98		
09C0071	037	05	03		12		0178
	035	05	22		↑		0175
09C0291	128	05	01				0180
	128	06	08		↓		0178
09C0324	043	04	20		12		0187
	091	05	26		98		
09C0432	083	04	24		12		0110
	067	05	01		99		0115
09C0681	091	↑	09		12		0167
	086		09		01		0160
09C0683	091		09		12		0178
	091	↓	26		98		
09C0863	101	05	25		12		0183
	102	06	10		98		
09C1694	157	05	31		12		0166
	064	06	26		05		0166
09C2087	093	05	29		12		0154
	094	06	05		↑		
09C2321	123	05	11		↓		0158
	093	05	16	↓	12	↓	0176
	093	06	01	73	15	35	0178

Table C-1 (Contd)

No.	River Mile* (km)	Date Month	Date Day	Date Year	Gear†	Species**	Length (mm)
09C2330	053	05	14	73	12	35	0166
	051	05	25		12		0165
09C2341	053	05	14		12		0165
	054	06	03		98		
09C2353	093	05	16		12		0162
	093	06	09		98		
09C2367	093	05	16		12		0152
	094	06	02		98		
09C2383	086	05	16		12		0182
	012	07	09		98		
09C2385	083	05	18		12		0176
	083		25		98		
09C2460	094		14		12		0186
	057	05	22		12		0186
09C2577	091	06	05		10		0188
	048		13		98		
09C3073	093		07		12		0188
	065		11				0185
09C3273	091		19		10		0173
	094		26		98		
09C3357	091		19		10		0226
	086		20		98		
09C3828	093		06		12		0173
	065		09		98		
09C3969	093		01		15		0215
			07		12		0214
09C4048			01		15		0164
			06		12		0160
09C4140			04		12		0152
	093		07		12		0153
09C4389	091		07		10		0196
	069	06	14		14		
51A0026	064	05	22		12		0121
	062	06	13		05		0125
51A0362	094	05	16		12		0122
	094		29				0124
51A0380	093		16				0133
	091		21				0125
51A0392	093		16				0121
	093	05	31	73	12	35	0120

Table C-1 (Contd)

No.	River Mile* (km)	Date			Gear†	Species**	Length (mm)
		Month	Day	Year			
51A0507	091	05	21	73	12	35	0108
	093	05	31	↑	27	↑	0107
	093	06	08		15		0107
51A0851	091	05	21		12		0109
	091	05	24		12		0106
51C0787	093	06	01		15		0122
	093	06	04		12		0119
51C0871	093	05	31		12		0117
	091	06	06		12		0109
51G0003	070	06	14		14		0135
	070	07	11		98		0135
51J0060	093	06	18		12		0120
	067	06	23		99		0113
51K0585	064	05	31	↓	05	↓	0135
	064	06	14	73	05	35	0135

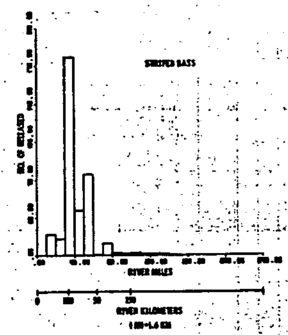

Figure C-1. Tagged Striped-Bass Releases Summarized by River Mile

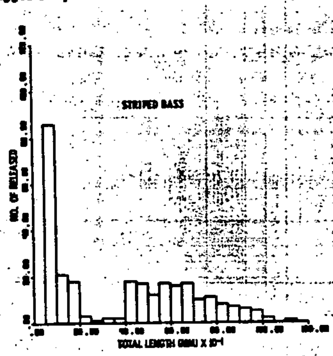

Figure C-2. Tagged Striped-Bass Releases Summarized by Total Length

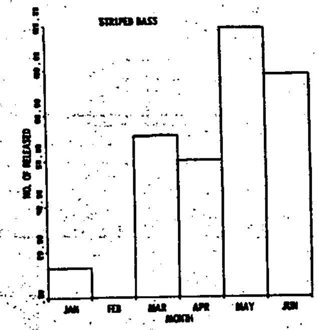

Figure C-3. Tagged Striped-Bass Releases Summarized by Month

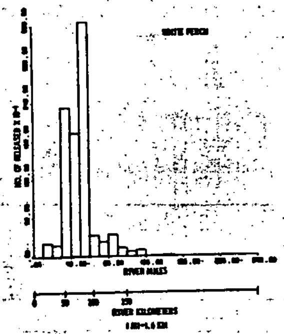

Figure C-4. Tagged White-Perch Releases Summarized by River Mile

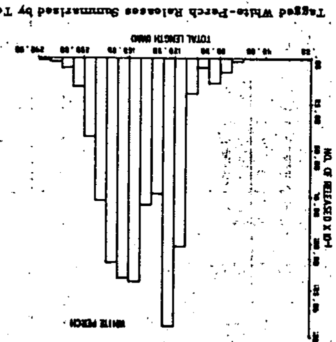

Figure C-5. Tagged White-Perch Releases Summarized by Total Length

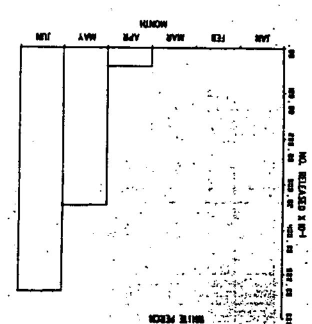

Figure C-6. Tagged White-Perch Releases Summarized by Month

APPENDIX D

MEAN VALUES AND SAMPLE SIZES OF MERISTIC AND MORPHOMETRIC CHARACTERISTICS (VARIABLES) DETERMINED FOR NINE GROUPINGS OF WHITE PERCH AND SEVEN GROUPINGS OF STRIPED BASS, REGIONS I, II, AND III, HUDSON RIVER, 1972

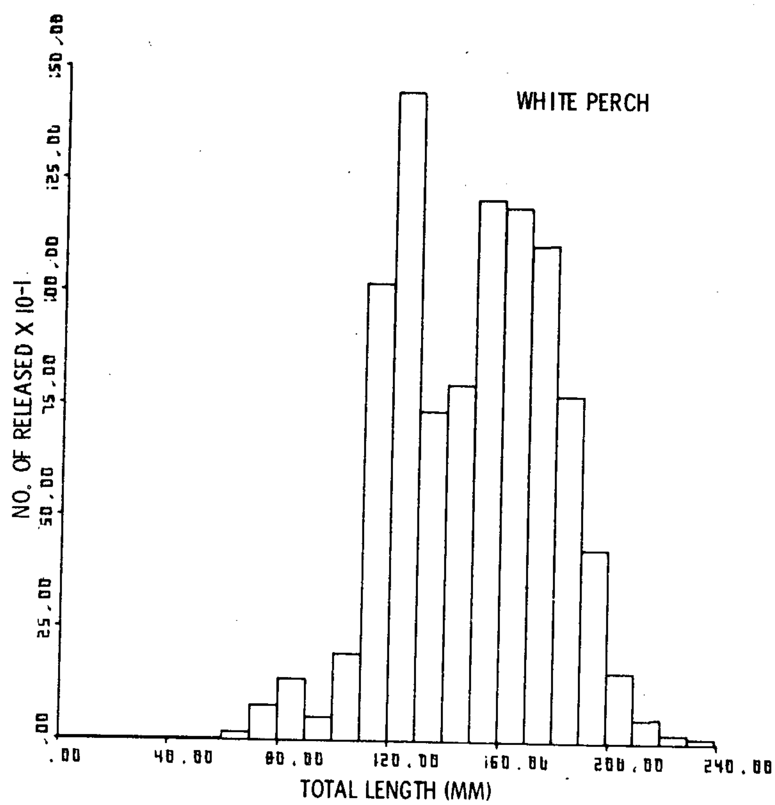

Figure C-5. Tagged White-Perch Releases Summarized by Total Length

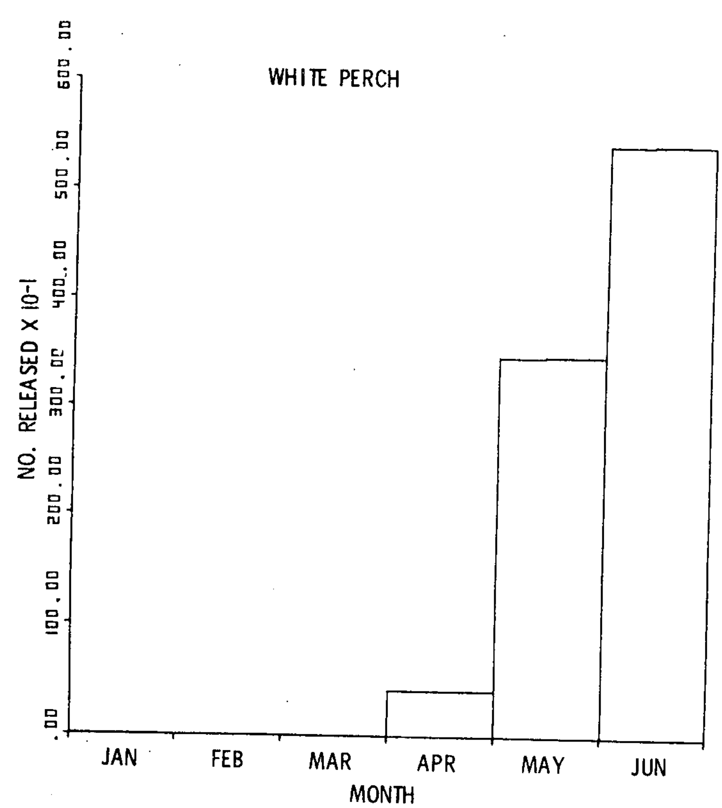

Figure C-6. Tagged White-Perch Releases Summarized by Month

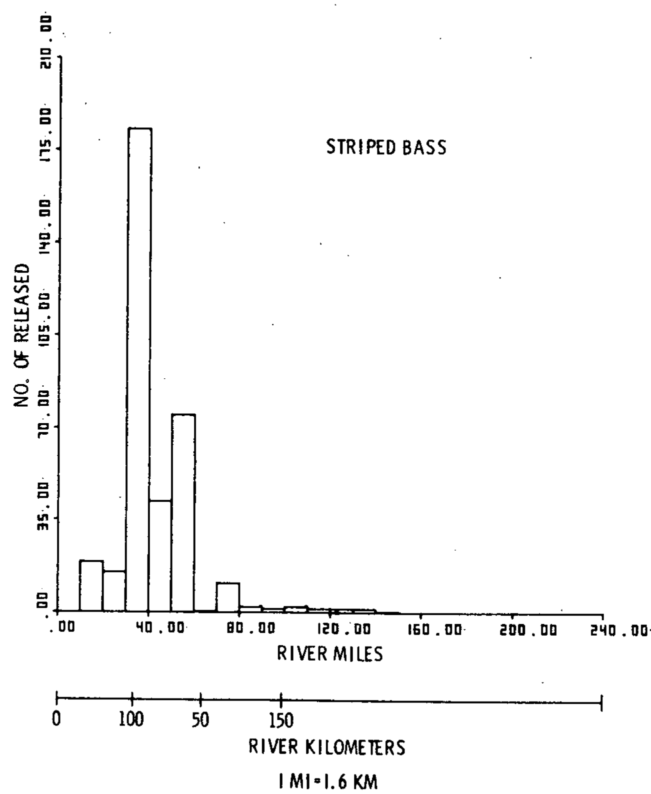

Figure C-1. Tagged Striped-Bass Releases Summarized by River Mile

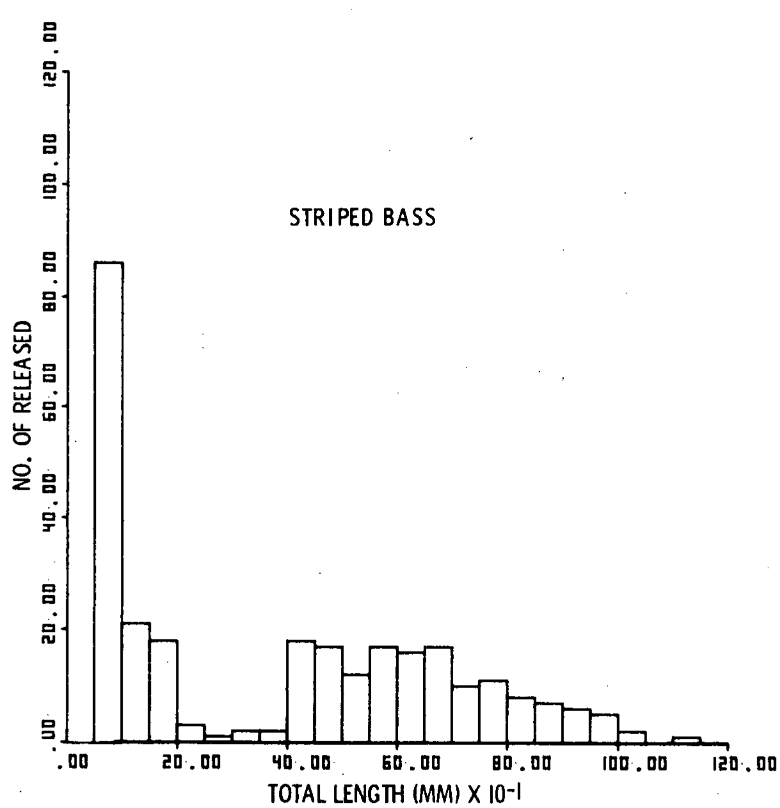

Figure C-2. Tagged Striped-Bass Releases Summarized by Total Length

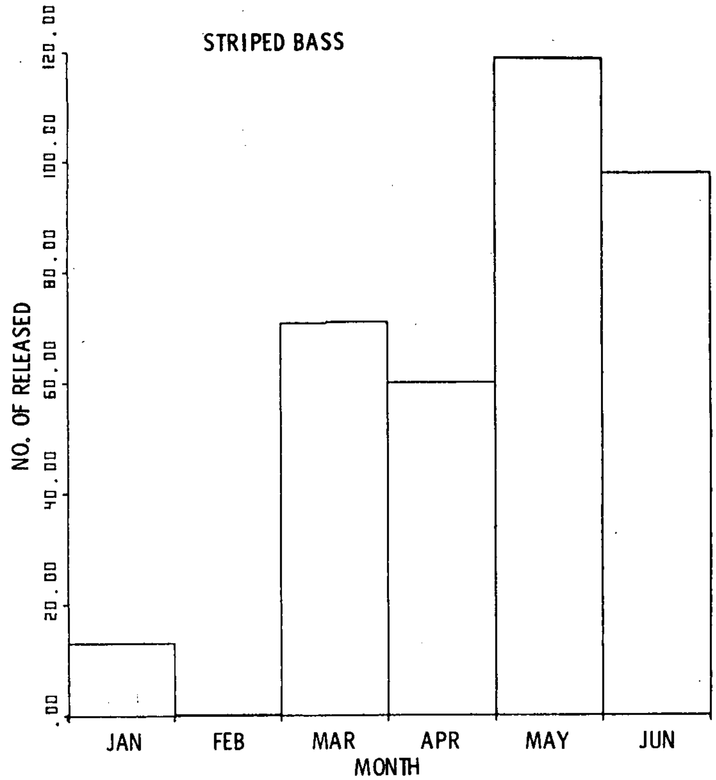

Figure C-3. Tagged Striped-Bass Releases Summarized by Month

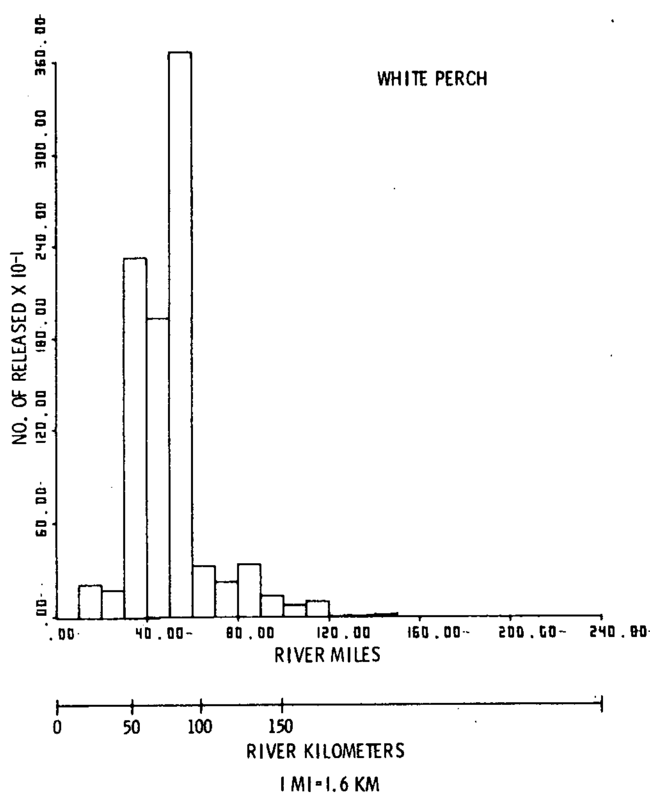

Figure C-4. Tagged White-Perch Releases Summarized by River Mile

APPENDIX D

MEAN VALUES AND SAMPLE SIZES OF MERISTIC AND MORPHOMETRIC CHARACTERISTICS (VARIABLES) DETERMINED FOR NINE GROUPINGS OF WHITE PERCH AND SEVEN GROUPINGS OF STRIPED BASS, REGIONS I, II, AND III, HUDSON RIVER, 1972

Table D-1

MEAN VALUES AND SAMPLE SIZES OF MERISTIC AND MORPHOMETRIC CHARACTERISTICS (VARIABLES) DETERMINED FOR NINE GROUPINGS OF WHITE PERCH COLLECTED IN REGIONS I, II, AND III, HUDSON RIVER, 1972

Variable*	Region I			Region II			Region III		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
1	0.81	0.81	0.86	0.80	0.73	0.85	0.78	0.75	0.81
2	2.58	2.59	2.71	2.63	2.33	2.62	2.45	2.34	2.44
3	1.23	1.25	1.26	1.21	1.25	1.26	1.25	1.26	1.27
4	0.31	0.31	0.32	0.30	0.31	0.32	0.31	0.31	0.33
5	1.55	1.57	1.50	1.57	1.57	1.52	1.52	1.54	1.57
6	0.20	0.19	0.21	0.19	0.20	0.21	0.21	0.20	0.21
7	0.07	0.07	0.08	0.07	0.07	0.08	0.07	0.07	0.08
8	0.24	0.25	0.25	0.22	0.23	0.25	0.22	0.23	0.24
9	0.07	0.07	0.08	0.07	0.08	0.08	0.08	0.08	0.08
10	0.16	0.16	0.17	0.16	0.16	0.17	0.16	0.16	0.16
11	0.53	0.52	0.53	0.54	0.52	0.52	0.52	0.51	0.49
12	0.10	0.10	0.11	0.10	0.11	0.11	0.11	0.11	0.11
13	0.40	0.42	0.40	0.38	0.39	0.40	0.40	0.39	0.40
14	1.24	1.46	1.16	1.12	1.17	1.18	1.17	1.18	1.18
15	0.38	0.34	0.35	0.34	0.33	0.35	0.34	0.34	0.34
16	0.18	0.19	0.18	0.18	0.19	0.19	0.19	0.20	0.20
17	0.12	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12
18	0.73	0.70	0.72	0.69	0.63	0.68	0.64	0.62	0.62
19	48.56	47.86	48.70	48.47	48.55	48.37	48.67	48.18	47.52
20	7.98	9.61	8.22	8.03	8.04	8.04	8.06	8.02	8.10
21	11.61	10.92	11.10	11.62	11.26	10.95	11.16	11.32	11.18
22	0.27	0.28	0.28	0.27	0.26	0.28	0.27	0.27	0.27
23	0.17	0.17	0.17	0.16	0.17	0.17	0.17	0.18	0.17
24	1.60	1.65	1.60	1.64	1.53	1.57	1.56	1.51	1.60
25	0.14	0.15	0.15	0.14	0.14	0.15	0.14	0.14	0.15
26	9.59	9.40	10.02	9.66	9.66	9.72	9.69	9.64	9.50
27	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
28	0.14	0.14	0.15	0.13	0.14	0.16	0.14	0.14	0.15
29	0.96	0.97	0.98	0.93	0.97	1.02	0.96	0.97	1.04
30	9.24	9.05	9.12	9.13	9.28	9.18	9.14	9.26	9.10
31	1.00	1.00	1.00	1.00	1.02	1.02	1.02	1.02	1.00
32	0.17	0.17	0.18	0.16	0.17	0.19	0.17	0.17	0.18
33	0.63	0.63	0.66	0.61	0.64	0.71	0.66	0.64	0.68
34	0.12	0.12	0.12	0.11	0.12	0.13	0.12	0.12	0.13
35	0.69	0.70	0.70	0.70	0.70	0.75	0.70	0.70	0.76
36	12.27	12.44	12.56	12.52	12.77	12.50	12.85	12.88	12.80
37	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
38	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	0.81
39	0.13	0.14	0.14	0.13	0.13	0.14	0.13	0.13	0.14
40	0.20	0.20	0.22	0.20	0.20	0.22	0.21	0.20	0.22
41	0.66	0.67	0.65	0.65	0.67	0.64	0.65	0.66	0.65
42	14.12	14.25	14.26	14.37	14.44	14.20	14.28	14.50	14.14
43	15.00	15.00	15.00	14.97	14.93	14.95	15.00	15.00	15.00
44	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
45	11.86	12.23	12.16	12.10	11.95	11.64	11.89	11.98	11.82
46	0.22	0.23	0.23	0.22	0.21	0.26	0.22	0.22	0.22
47	1.62	1.73	1.52	1.73	1.80	1.93	1.69	1.78	1.88
48	20.80	20.67	20.86	20.69	20.62	20.56	20.57	20.20	21.32
Sample Size	(102)	(52)	(50)	(115)	(45)	(48)	(49)	(50)	(50)

*Variable numbers coincide with meristic and morphometric characteristics listed on page V-39 of text.

Table D-2

STANDARD DEVIATIONS AND SAMPLE SIZES OF MERISTIC AND MORPHOMETRIC CHARACTERISTICS (VARIABLES) DETERMINED FOR NINE GROUPINGS OF WHITE PERCH COLLECTED IN REGIONS I, II, AND III, HUDSON RIVER, 1972

Variable*	Region I			Region II			Region III		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
1	0.06	0.07	0.08	0.08	0.05	0.10	0.08	0.08	0.09
2	0.23	0.22	0.36	0.20	0.19	0.38	0.22	0.20	0.27
3	0.02	0.01	0.01	0.12	0.01	0.02	0.09	0.06	0.07
4	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.02	0.02
5	0.14	0.10	0.16	0.10	0.10	0.14	0.12	0.11	0.14
6	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.02
7	0.005	0.006	0.007	0.009	0.004	0.006	0.006	0.006	0.008
8	0.02	0.01	0.04	0.02	0.01	0.02	0.01	0.01	0.01
9	0.01	0.009	0.009	0.01	0.01	0.008	0.01	0.006	0.008
10	0.01	0.006	0.01	0.02	0.02	0.01	0.01	0.01	0.01
11	0.03	0.02	0.07	0.03	0.07	0.04	0.03	0.02	0.02
12	0.01	0.01	0.009	0.01	0.008	0.01	0.01	0.008	0.008
13	0.02	0.13	0.02	0.05	0.02	0.02	0.03	0.03	0.03
14	1.06	2.67	0.05	0.11	0.02	0.04	0.05	0.06	0.07
15	0.35	0.04	0.03	0.03	0.01	0.01	0.02	0.02	0.02
16	0.18	0.07	0.02	0.02	0.01	0.02	0.02	0.01	0.02
17	0.01	0.06	0.01	0.01	0.008	0.007	0.008	0.01	0.008
18	0.13	0.07	0.11	0.08	0.09	0.10	0.09	0.07	0.06
19	3.39	4.89	0.90	1.05	1.40	1.12	1.32	1.15	1.23
20	0.42	11.09	0.41	0.26	0.29	0.20	0.51	0.31	0.30
21	0.67	0.68	0.54	0.78	0.61	0.50	0.55	0.51	0.52
22	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.02
23	0.01	0.01	0.01	0.01	0.009	0.01	0.01	0.01	0.01
24	0.13	0.13	0.18	0.17	0.08	0.14	0.15	0.14	0.14
25	0.01	0.01	0.01	0.01	0.009	0.01	0.01	0.01	0.01
26	0.49	0.53	0.62	0.52	0.52	0.53	0.50	0.48	0.50
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
29	0.09	0.10	0.11	0.12	0.07	0.13	0.09	0.09	0.11
30	0.43	0.36	0.38	0.40	0.45	0.39	0.35	0.44	0.36
31	0.09	0.00	0.00	0.00	0.14	0.14	0.14	0.14	0.00
32	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
33	0.06	0.05	0.07	0.06	0.04	0.06	0.08	0.05	0.05
34	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
35	0.06	0.08	0.08	0.09	0.06	0.07	0.06	0.06	0.08
36	0.58	0.50	0.57	0.62	0.42	0.54	0.35	0.32	0.45
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.01	0.01	0.01	0.01	0.008	0.01	0.01	0.01	0.01
40	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.02
41	0.04	0.06	0.05	0.04	0.07	0.06	0.03	0.04	0.05
42	0.65	0.55	0.59	0.59	0.62	0.74	0.79	0.58	0.72
43	0.19	0.00	0.00	0.16	0.25	0.20	0.00	0.00	0.00
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.70	0.80	0.68	0.61	0.56	0.78	0.82	0.91	0.59
46	0.01	0.01	0.01	0.02	0.01	0.29	0.01	0.02	0.02
47	0.65	0.52	0.54	0.53	0.66	0.66	0.50	0.58	0.65
48	1.05	0.83	0.92	0.92	0.64	0.64	0.79	0.94	1.05
Sample Size	(102)	(52)	(50)	(115)	(45)	(48)	(49)	(50)	(50)

*Variable numbers coincide with meristic and morphometric characteristics listed on page V-39 of text.

Table D-4

STANDARD DEVIATIONS AND SAMPLE SIZES OF MERISTIC AND MORPHOMETRIC CHARACTERISTICS (VARIABLES) DETERMINED FOR SEVEN GROUPINGS OF STRIPED BASS COLLECTED IN REGIONS I, II, AND III, HUDSON RIVER, 1972

Variable*	Region I			Region II		Region III	
	Spring	Summer	Fall	Spring	Summer	Spring	Summer
1	0.06	0.08	0.15	0.50	0.87	0.06	0.21
2	0.20	0.35	0.19	0.37	4.15	0.37	5.46
3	0.05	0.02	0.22	0.02	0.06	0.01	0.01
4	0.01	0.01	0.05	0.03	0.05	0.01	0.06
5	0.13	0.13	0.08	0.22	0.29	0.08	0.39
6	0.01	0.01	0.03	0.01	0.01	0.01	0.01
7	0.009	0.01	0.02	0.01	0.01	0.01	0.01
8	0.02	0.04	0.06	0.04	0.29	0.04	0.32
9	0.007	0.009	0.06	0.01	0.01	0.005	0.01
10	0.009	0.009	0.02	0.008	0.02	0.01	0.009
11	0.03	0.03	0.02	0.07	0.80	0.05	1.08
12	0.01	0.01	0.02	0.01	0.009	0.01	0.009
13	0.02	0.01	0.09	0.02	0.02	0.01	0.01
14	0.06	0.03	0.20	0.02	0.03	0.32	0.24
15	0.01	0.02	0.06	0.01	0.02	0.01	0.01
16	0.02	0.02	0.04	0.02	0.01	0.01	0.02
17	0.007	0.01	0.01	0.004	0.02	0.01	0.008
18	0.07	0.06	0.07	0.06	0.09	0.07	0.04
19	2.51	2.96	2.02	2.20	2.89	1.64	1.94
20	0.48	0.57	0.34	0.39	0.51	0.42	0.60
21	0.80	0.71	0.66	0.64	0.84	0.52	0.57
22	0.02	0.01	0.04	0.01	0.02	0.01	0.01
23	0.01	0.01	0.03	0.01	0.01	0.005	0.01
24	0.18	0.11	0.09	0.01	0.11	0.06	0.10
25	0.01	0.01	0.02	0.00	0.01	0.01	0.01
26	0.00	0.00	0.00	0.17	0.00	0.00	0.00
27	0.47	0.55	0.57	0.50	0.52	0.31	0.32
28	0.01	0.01	0.01	0.01	0.01	0.01	0.02
29	0.08	0.13	0.08	0.07	0.08	0.07	0.15
30	0.28	0.21	0.19	0.29	0.28	0.42	0.00
31	0.13	0.00	0.00	0.00	0.00	0.00	0.00
32	0.01	0.01	0.02	0.01	0.01	0.01	0.009
33	0.69	0.08	0.04	0.04	0.04	0.06	0.06
34	0.01	0.01	0.01	0.006	0.01	0.01	0.01
35	0.06	0.11	0.06	0.04	0.06	0.06	0.07
36	0.81	0.58	0.46	0.58	0.57	0.52	0.42
37	1.00	1.00	1.00	1.00	1.00	1.00	1.00
38	5.00	5.00	5.00	5.00	5.00	5.00	5.00
39	0.01	0.008	0.02	0.008	0.009	0.008	0.008
40	0.01	0.01	0.003	0.01	0.01	0.009	0.01
41	0.07	0.03	0.06	0.04	0.08	0.03	0.04
42	0.29	0.66	0.56	0.61	0.71	0.56	0.41
43	0.13	0.00	0.19	0.17	0.28	0.00	0.00
44	4.00	4.00	4.00	4.00	4.00	4.00	4.00
45	0.83	0.94	0.76	0.75	0.95	1.03	0.98
46	0.01	0.01	0.03	0.01	0.01	0.01	0.01
47	0.58	0.44	0.46	0.95	0.23	0.84	0.59
48	2.11	1.94	1.17	1.57	1.84	1.17	1.45
Sample Size	(59)	(43)	(26)	(32)	(34)	(10)	(18)

*Variable numbers coincide with meristic and morphometric characters listed on page V-39 of text.

Table D-3

MEAN VALUES AND SAMPLE SIZES OF MERISTIC AND MORPHOMETRIC CHARACTERISTICS (VARIABLES) DETERMINED FOR SEVEN GROUPINGS OF STRIPED BASS COLLECTED IN REGIONS I, II, AND III, HUDSON RIVER, 1972

Variable*	Region I			Region II		Region III	
	Spring	Summer	Fall	Spring	Summer	Spring	Summer
1	0.78	0.80	0.77	0.76	0.80	0.80	0.85
2	2.66	2.62	2.58	2.64	3.29	2.80	4.04
3	1.21	1.22	1.20	1.21	1.21	1.20	1.21
4	0.29	0.30	0.29	0.29	0.30	0.28	0.29
5	1.72	1.67	1.73	1.73	1.67	1.72	1.67
6	0.17	0.18	0.17	0.16	0.18	0.16	0.17
7	0.07	0.07	0.07	0.06	0.07	0.05	0.06
8	0.23	0.24	0.25	0.22	0.28	0.19	0.28
9	0.07	0.08	0.08	0.08	0.08	0.07	0.09
10	0.15	0.15	0.14	0.15	0.15	0.15	0.16
11	0.52	0.51	0.49	0.54	0.64	0.55	0.77
12	0.11	0.11	0.11	0.11	0.11	0.12	0.11
13	0.36	0.36	0.34	0.36	0.37	0.35	0.38
14	1.12	1.14	1.12	1.13	1.13	1.02	1.05
15	0.23	0.23	0.24	0.24	0.24	0.24	0.24
16	0.20	0.20	0.19	0.19	0.20	0.20	0.17
17	0.10	0.10	0.10	0.10	0.11	0.10	0.10
18	0.51	0.52	0.54	0.53	0.55	0.53	0.58
19	61.59	61.46	61.03	62.65	61.00	63.40	61.16
20	10.37	10.62	11.03	10.81	10.73	10.80	10.61
21	13.20	13.23	14.03	13.90	13.32	13.50	12.72
22	0.20	0.21	0.21	0.21	0.20	0.22	0.21
23	0.17	0.18	0.17	0.17	0.17	0.17	0.17
24	1.19	1.17	1.23	1.22	1.18	1.27	1.24
25	0.14	0.15	0.14	0.14	0.14	0.14	0.14
26	3.00	3.00	3.00	2.96	3.00	3.00	3.00
27	10.66	10.69	10.42	10.43	10.82	11.10	10.88
28	0.07	0.08	0.07	0.06	0.07	0.05	0.06
29	0.52	0.52	0.52	0.49	0.50	0.38	0.40
30	9.05	9.04	8.96	9.09	9.08	9.20	9.00
31	1.01	1.00	1.00	1.00	1.00	1.00	1.00
32	0.13	0.13	0.13	0.13	0.13	0.12	0.13
33	0.75	0.66	0.63	0.64	0.63	0.57	0.64
34	0.07	0.08	0.08	0.07	0.07	0.07	0.08
35	0.46	0.48	0.46	0.45	0.44	0.43	0.46
36	12.08	12.25	12.15	12.28	12.08	12.50	12.22
37	1.00	1.00	1.00	1.00	1.00	1.00	1.00
38	5.00	5.00	5.00	5.00	5.00	5.00	5.00
39	0.09	0.09	0.10	0.09	0.09	0.09	0.09
40	0.15	0.15	0.16	0.15	0.15	0.14	0.14
41	0.63	0.61	0.62	0.64	0.63	0.63	0.63
42	14.98	15.11	15.34	15.43	15.08	15.10	15.05
43	14.98	15.00	14.96	14.96	14.91	15.00	15.00
44	4.00	4.00	4.00	4.00	4.00	4.00	4.00
45	13.49	13.13	13.76	13.59	13.44	12.80	12.55
46	0.15	0.14	0.15	0.14	0.14	0.14	0.14
47	2.79	2.88	2.84	2.15	2.94	2.40	2.66
48	23.55	25.60	26.53	25.96	25.14	25.50	24.00
Sample Size	(59)	(43)	(26)	(32)	(34)	(10)	(18)

*Variable numbers coincide with meristic and morphometric characters listed on page V-39 of text.

Table D-1

MEAN VALUES AND SAMPLE SIZES OF MERISTIC AND MORPHOMETRIC CHARACTERISTICS (VARIABLES) DETERMINED FOR NINE GROUPINGS OF WHITE PERCH COLLECTED IN REGIONS I, II, AND III, HUDSON RIVER, 1972

Variable*	Region I			Region II			Region III		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
1	0.81	0.81	0.86	0.80	0.73	0.85	0.78	0.75	0.81
2	2.58	2.59	2.71	2.63	2.33	2.62	2.45	2.34	2.44
3	1.23	1.25	1.26	1.21	1.25	1.26	1.25	1.26	1.27
4	0.31	0.31	0.32	0.30	0.31	0.32	0.31	0.31	0.33
5	1.55	1.57	1.50	1.57	1.57	1.52	1.52	1.54	1.57
6	0.20	0.19	0.21	0.19	0.20	0.21	0.21	0.20	0.21
7	0.07	0.07	0.08	0.07	0.07	0.08	0.07	0.07	0.08
8	0.24	0.25	0.25	0.22	0.23	0.25	0.22	0.23	0.24
9	0.07	0.07	0.08	0.07	0.08	0.08	0.08	0.08	0.08
10	0.16	0.16	0.17	0.16	0.16	0.17	0.16	0.16	0.16
11	0.53	0.52	0.53	0.54	0.52	0.52	0.52	0.51	0.49
12	0.10	0.10	0.11	0.10	0.11	0.11	0.11	0.11	0.11
13	0.40	0.42	0.40	0.38	0.39	0.40	0.40	0.39	0.40
14	1.24	1.46	1.16	1.12	1.17	1.18	1.17	1.18	1.18
15	0.38	0.34	0.35	0.34	0.33	0.35	0.34	0.34	0.34
16	0.18	0.19	0.18	0.18	0.19	0.19	0.19	0.20	0.20
17	0.12	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12
18	0.73	0.70	0.72	0.69	0.63	0.68	0.64	0.62	0.62
19	48.56	47.86	48.70	48.47	48.55	48.37	48.67	48.18	47.52
20	7.98	9.61	8.22	8.03	8.04	8.04	8.06	8.02	8.10
21	11.61	10.92	11.10	11.62	11.26	10.95	11.16	11.32	11.18
22	0.27	0.28	0.28	0.27	0.26	0.28	0.27	0.27	0.27
23	0.17	0.17	0.17	0.16	0.17	0,17	0.17	0.18	0.17
24	1.60	1.65	1.60	1.64	1.53	1.57	1.56	1.51	1.60
25	0.14	0.15	0.15	0.14	0.14	0.15	0.14	0.14	0.15
26	9.59	9.40	10.02	9.66	9.66	9.72	9.69	9.64	9.50
27	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
28	0.14	0.14	0.15	0.13	0.14	0.16	0.14	0.14	0.15
29	0.96	0.97	0.98	0.93	0.97	1.02	0.96	0.97	1.04
30	9.24	9.05	9.12	9.13	9.28	9.18	9.14	9.26	9.10
31	1.00	1.00	1.00	1.00	1.02	1.02	1.02	1.02	1.00
32	0.17	0.17	0.18	0.16	0.17	0.19	0.17	0.17	0.18
33	0.63	0.63	0.66	0.61	0.64	0.71	0.66	0.64	0.68
34	0.12	0.12	0.12	0.11	0.12	0.13	0.12	0.12	0.13
35	0.69	0.70	0.70	0.70	0.70	0.75	0.70	0.70	0.76
36	12.27	12.44	12.56	12.52	12.77	12.50	12.85	12.88	12.80
37	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
38	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	0.81
39	0.13	0.14	0.14	0.13	0.13	0.14	0.13	0.13	0.14
40	0.20	0.20	0.22	0.20	0.20	0.22	0.21	0.20	0.22
41	0.66	0.67	0.65	0.65	0.67	0.64	0.65	0.66	0.65
42	14.12	14.25	14.26	14.37	14.44	14.20	14.28	14.50	14.14
43	15.00	15.00	15.00	14.97	14.93	14.95	15.00	15.00	15.00
44	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
45	11.86	12.23	12.16	12.10	11.95	11.64	11.89	11.98	11.82
46	0.22	0.23	0.23	0.22	0.21	0.26	0.22	0.22	0.22
47	1.62	1.73	1.52	1.73	1.80	1.93	1.69	1.78	1.88
48	20.80	20.67	20.86	20.69	20.62	20.56	20.57	20.20	21.32
Sample Size	(102)	(52)	(50)	(115)	(45)	(48)	(49)	(50)	(50)

*Variable numbers coincide with meristic and morphometric characteristics listed on page V-39 of text.

Table D-2

STANDARD DEVIATIONS AND SAMPLE SIZES OF MERISTIC AND MORPHOMETRIC CHARACTERISTICS (VARIABLES) DETERMINED FOR NINE GROUPINGS OF WHITE PERCH COLLECTED IN REGIONS I, II, AND III, HUDSON RIVER, 1972

Variable*	Region I			Region II			Region III		
	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall
1	0.06	0.07	0.08	0.08	0.05	0.10	0.08	0.08	0.09
2	0.23	0.22	0.36	0.20	0.19	0.38	0.22	0.20	0.27
3	0.02	0.01	0.01	0.12	0.01	0.02	0.09	0.06	0.07
4	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.02	0.02
5	0.14	0.10	0.16	0.10	0.10	0.14	0.12	0.11	0.14
6	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.02
7	0.005	0.006	0.007	0.009	0.004	0.006	0.006	0.006	0.008
8	0.02	0.01	0.04	0.02	0.01	0.02	0.01	0.01	0.01
9	0.01	0.009	0.009	0.01	0.01	0.008	0.01	0.006	0.008
10	0.01	0.006	0.01	0.02	0.02	0.01	0.01	0.01	0.01
11	0.03	0.02	0.07	0.03	0.07	0.04	0.03	0.02	0.02
12	0.01	0.01	0.009	0.01	0.008	0.01	0.01	0.008	0.008
13	0.02	0.13	0.02	0.05	0.02	0.02	0.03	0.03	0.03
14	1.06	2.67	0.05	0.11	0.02	0.04	0.05	0.06	0.07
15	0.35	0.04	0.03	0.03	0.01	0.01	0.02	0.02	0.02
16	0.18	0.07	0.02	0.02	0.01	0.02	0.02	0.01	0.02
17	0.01	0.06	0.01	0.01	0.008	0.007	0.008	0.01	0.008
18	0.13	0.07	0.11	0.08	0.09	0.10	0.09	0.07	0.06
19	3.39	4.89	0.90	1.05	1.40	1.12	1.32	1.15	1.23
20	0.42	11.09	0.41	0.26	0.29	0.20	0.51	0.31	0.30
21	0.67	0.68	0.54	0.78	0.61	0.50	0.55	0.51	0.52
22	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.02
23	0.01	0.01	0.01	0.01	0.009	0.01	0.01	0.01	0.01
24	0.13	0.13	0.18	0.17	0.08	0.14	0.15	0.14	0.14
25	0.01	0.01	0.01	0.01	0.009	0.01	0.01	0.01	0.01
26	0.49	0.53	0.62	0.52	0.52	0.53	0.50	0.48	0.50
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
29	0.09	0.10	0.11	0.12	0.07	0.13	0.09	0.09	0.11
30	0.43	0.36	0.38	0.40	0.45	0.39	0.35	0.44	0.36
31	0.09	0.00	0.00	0.00	0.14	0.14	0.14	0.14	0.00
32	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
33	0.06	0.05	0.07	0.06	0.04	0.06	0.08	0.05	0.05
34	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
35	0.06	0.08	0.08	0.09	0.06	0.07	0.06	0.06	0.08
36	0.58	0.50	0.57	0.62	0.42	0.54	0.35	0.32	0.45
37	0.00	0.00	0.00	0.00	0.00	0.00	0,00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.01	0.01	0.01	0.01	0.008	0.01	0.01	0.01	0.01
40	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.02
41	0.04	0.06	0.05	0.04	0.07	0.06	0.03	0.04	0.05
42	0.65	0.55	0.59	0.59	0.62	0.74	0.79	0.58	0.72
43	0.19	0.00	0.00	0.16	0.25	0.20	0.00	0.00	0.00
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.70	0.80	0.68	0.61	0.56	0.78	0.82	0.91	0.59
46	0.01	0.01	0.01	0.02	0.01	0.29	0.01	0.02	0.02
47	0.65	0.52	0.54	0.53	0.66	0.66	0.50	0.58	0.65
48	1.05	0.83	0.92	0.92	0.64	0.64	0.79	0.94	1.05
Sample Size	(102)	(52)	(50)	(115)	(45)	(48)	(49)	(50)	(50)

*Variable numbers coincide with meristic and morphometric characteristics listed on page V-39 of text.

Table D-3

MEAN VALUES AND SAMPLE SIZES OF MERISTIC AND MORPHOMETRIC CHARACTERISTICS (VARIABLES) DETERMINED FOR SEVEN GROUPINGS OF STRIPED BASS COLLECTED IN REGIONS I, II, AND III, HUDSON RIVER, 1972

Variable*	Region I			Region II		Region III	
	Spring	Summer	Fall	Spring	Summer	Spring	Summer
1	0.78	0.80	0.77	0.76	0.80	0.80	0.85
2	2.66	2.62	2.58	2.64	3.29	2.80	4.04
3	1.21	1.22	1.20	1.21	1.21	1.20	1.21
4	0.29	0.30	0.29	0.29	0.30	0.28	0.29
5	1.72	1.67	1.73	1.73	1.67	1.72	1.67
6	0.17	0.18	0.17	0.16	0.18	0.16	0.17
7	0.07	0.07	0.07	0.06	0.07	0.05	0.06
8	0.23	0.24	0.25	0.22	0.28	0.19	0.28
9	0.07	0.08	0.08	0.08	0.08	0.07	0.09
10	0.15	0.15	0.14	0.15	0.15	0.15	0.16
11	0.52	0.51	0.49	0.54	0.64	0.55	0.77
12	0.11	0.11	0.11	0.11	0.11	0.12	0.11
13	0.36	0.36	0.34	0.36	0.37	0.35	0.38
14	1.12	1.14	1.12	1.13	1.13	1.02	1.05
15	0.23	0.23	0.24	0.24	0.24	0.24	0.24
16	0.20	0.20	0.19	0.19	0.20	0.20	0.17
17	0.10	0.10	0.10	0.10	0.11	0.10	0.10
18	0.51	0.52	0.54	0.53	0.55	0.53	0.58
19	61.59	61.46	61.03	62.65	61.00	63.40	61.16
20	10.37	10.62	11.03	10.81	10.73	10.80	10.61
21	13.20	13.23	14.03	13.90	13.32	13.50	12.72
22	0.20	0.21	0.21	0.21	0.20	0.22	0.21
23	0.17	0.18	0.17	0.17	0.17	0.17	0.17
24	1.19	1.17	1.23	1.22	1.18	1.27	1.24
25	0.14	0.15	0.14	0.14	0.14	0.14	0.14
26	3.00	3.00	3.00	2.96	3.00	3.00	3.00
27	10.66	10.69	10.42	10.43	10.82	11.10	10.88
28	0.07	0.08	0.07	0.06	0.07	0.05	0.06
29	0.52	0.52	0.52	0.49	0.50	0.38	0.40
30	9.05	9.04	8.96	9.09	9.08	9.20	9.00
31	1.01	1.00	1.00	1.00	1.00	1.00	1.00
32	0.13	0.13	0.13	0.13	0.13	0.12	0.13
33	0.75	0.66	0.63	0.64	0.63	0.57	0.64
34	0.07	0.08	0.08	0.07	0.07	0.07	0.08
35	0.46	0.48	0.46	0.45	0.44	0.43	0.46
36	12.08	12.25	12.15	12.28	12.08	12.50	12.22
37	1.00	1.00	1.00	1.00	1.00	1.00	1.00
38	5.00	5.00	5.00	5.00	5.00	5.00	5.00
39	0.09	0.09	0.10	0.09	0.09	0.09	0.09
40	0.15	0.15	0.16	0.15	0.15	0.14	0.14
41	0.63	0.61	0.62	0.64	0.63	0.63	0.63
42	14.98	15.11	15.34	15.43	15.08	15.10	15.05
43	14.98	15.00	14.96	14.96	14.91	15.00	15.00
44	4.00	4.00	4.00	4.00	4.00	4.00	4.00
45	13.49	13.13	13.76	13.59	13.44	12.80	12.55
46	0.15	0.14	0.15	0.14	0.14	0.14	0.14
47	2.79	2.88	2.84	2.15	2.94	2.40	2.66
48	23.55	25.60	26.53	25.96	25.14	25.50	24.00
Sample Size	(59)	(43)	(26)	(32)	(34)	(10)	(18)

*Variable numbers coincide with meristic and morphometric characters listed on page V-39 of text.

Table D-4

STANDARD DEVIATIONS AND SAMPLE SIZES OF MERISTIC AND MORPHOMETRIC CHARACTERISTICS (VARIABLES) DETERMINED FOR SEVEN GROUPINGS OF STRIPED BASS COLLECTED IN REGIONS I, II, AND III, HUDSON RIVER, 1972

Variable*	Region I			Region II		Region III	
	Spring	Summer	Fall	Spring	Summer	Spring	Summer
1	0.06	0.08	0.15	0.50	0.87	0.06	0.21
2	0.20	0.35	0.19	0.37	4.15	0.37	5.46
3	0.05	0.02	0.22	0.02	0.06	0.01	0.01
4	0.01	0.01	0.05	0.03	0.05	0.01	0.06
5	0.13	0.13	0.08	0.22	0.29	0.08	0.39
6	0.01	0.01	0.03	0.01	0.01	0.01	0.01
7	0.009	0.01	0.02	0.01	0.01	0.01	0.01
8	0.02	0.04	0.06	0.04	0.29	0.04	0.32
9	0.007	0.009	0.06	0.01	0.01	0.005	0.01
10	0.009	0.009	0.02	0.008	0.02	0.01	0.009
11	0.03	0.03	0.02	0.07	0.80	0.05	1.08
12	0.01	0.01	0.02	0.01	0.009	0.01	0.009
13	0.02	0.01	0.09	0.02	0.02	0.01	0.01
14	0.06	0.03	0.20	0.02	0.03	0.32	0.24
15	0.01	0.02	0.06	0.01	0.02	0.01	0.01
16	0.02	0.02	0.04	0.02	0.01	0.01	0.02
17	0.007	0.01	0.01	0.004	0.02	0.01	0.008
18	0.07	0.06	0.07	0.06	0.09	0.07	0.04
19	2.51	2.96	2.02	2.20	2.89	1.64	1.94
20	0.48	0.57	0.34	0.39	0.51	0.42	0.60
21	0.80	0.71	0.66	0.64	0.84	0.52	0.57
22	0.02	0.01	0.04	0.01	0.02	0.01	0.01
23	0.01	0.01	0.03	0.01	0.01	0.005	0.01
24	0.18	0.11	0.09	0.01	0.11	0.06	0.10
25	0.01	0.01	0.02	0.00	0.01	0.01	0.01
26	0.00	0.00	0.00	0.17	0.00	0.00	0.00
27	0.47	0.55	0.57	0.50	0.52	0.31	0.32
28	0.01	0.01	0.01	0.01	0.01	0.01	0.02
29	0.08	0.13	0.08	0.07	0.08	0.07	0.15
30	0.28	0.21	0.19	0.29	0.28	0.42	0.00
31	0.13	0.00	0.00	0.00	0.00	0.00	0.00
32	0.01	0.01	0.02	0.01	0.01	0.01	0.009
33	0.69	0.08	0.04	0.04	0.04	0.06	0.06
34	0.01	0.01	0.01	0.006	0.01	0.01	0.01
35	0.06	0.11	0.06	0.04	0.06	0.06	0.07
36	0.81	0.58	0.46	0.58	0.57	0.52	0.42
37	1.00	1.00	1.00	1.00	1.00	1.00	1.00
38	5.00	5.00	5.00	5.00	5.00	5.00	5.00
39	0.01	0.008	0.02	0.008	0.009	0.008	0.008
40	0.01	0.01	0.003	0.01	0.01	0.009	0.01
41	0.07	0.03	0.06	0.04	0.08	0.03	0.04
42	0.29	0.66	0.56	0.61	0.71	0.56	0.41
43	0.13	0.00	0.19	0.17	0.28	0.00	0.00
44	4.00	4.00	4.00	4.00	4.00	4.00	4.00
45	0.83	0.94	0.76	0.75	0.95	1.03	0.98
46	0.01	0.01	0.03	0.01	0.01	0.01	0.01
47	0.58	0.44	0.46	0.95	0.23	0.84	0.59
48	2.11	1.94	1.17	1.57	1.84	1.17	1.45
Sample Size	(59)	(43)	(26)	(32)	(34)	(10)	(18)

*Variable numbers coincide with meristic and morphometric characters listed on page V-39 of text.