SIZE SELECTIVITY AND RELATIVE CATCH EFFICIENCY OF A 3 m BEAM TRAWL AND A 1.0 m^2 EPIBENTHIC SLED FOR SAMPLING YOUNG OF THE YEAR STRIPED BASS AND OTHER FISHES IN THE HUDSON RIVER ESTUARY

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TABLE OF CONTENTS

	PAGE
1.0 EXECUTIVE SUMMARY.	1
2.0 INTRODUCTION	3
3.0 METHODS.	7
3.1 FIELD SAMPLING.	7
3.2 SIZE SELECTIVITY.	9
3.3 SAMPLE UNITS AND DENSITY CALCULATIONS	10
3.4 EXPERIMENTAL DESIGN FOR COMPARING RELATIVE CATCH EFFICIENCY.	12
3.5 COMBINED STANDING CROP ESTIMATES.	15
4.0 RESULTS AND DISCUSSION	19
4.1 SIZE SELECTIVITY.	19
4.2 RELATIVE CATCH EFFICIENCY	26
4.2.1 Areal and Volumetric Density	26
4.2.2 Frequency and Percent of Zero-Catch Samples.	29
4.2.3 Two-Factor Analysis of Variance Comparing Catch Efficiency of the 3 m Beam Trawl and 1.0 m^2 Epibenthic Sled	31
4.2.4 Relative Catch Efficiency.	38
4.3 COMBINED STANDING CROP.	38
5.0 GENERAL DISCUSSION	45
6.0 LITERATURE CITED	50
APPENDIX	

LIST OF FIGURES

		PAGE
Figure 1	Tappan Zee, Croton-Haverstraw, and Indian Point sampling regions in the lower Hudson River estuary	8
Figure 2	Length-Frequency distribution for striped bass collected by a 3 m Beam Trawl and a 1.0 m^2 Epibenthic Sled in the lower Hudson River estuary (River Kilometers 39-76) during the week of 13-19 August 1984	21
Figure 3	Length-Frequency distribution for striped bass collected by a 3 m Beam Trawl and a 1.0 m^2 Epibenthic Sled in the lower Hudson River estuary (River Kilometers 39-76) during the week of 27 August - 2 September 1984	22
Figure 4	Length-Frequency distribution for striped bass collected by a 3 m Beam Trawl and a 1.0 m^2 Epibenthic Sled in the lower Hudson River estuary (River Kilometers 39-76) during the week of 10-16 September 1984.	23
Figure 5	Length-Frequency distribution for striped bass collected by a 3 m Beam Trawl and a 1.0 m^2 Epibenthic Sled in the lower Hudson River estuary (River Kilometers 39-76) during the week of 24-30 September 1984.	24
Figure 6	Interaction between gear type (Trawl = 3 m Beam Trawl, Sled = 1.0 m Epibenthic Sled) and sampling week (13-19 August, 27 August-2 September, 10-16 September, and 24-30 September 1984) for young of the year striped bass volumetric density.	33
Figure 7	Interaction between gear type (Trawl = 3 m Beam Trawl, Sled = 1.0 m Epibenthic Sled) and sampling week (13-19 August, 27 August-2 September, 10-16 September, and 24-30 September 1984) for young of the year bay anchovy volumetric density.	34
Figure 8	Interaction between gear type (Trawl = 3 m Beam Trawl, Sled = 1.0 m Epibenthic Sled) and sampling week (13-19 August, 27 August-2 September, 10-16 September, and 24-30 September 1984) for young of the year American shad volumetric density	35
Figure 9	Interaction between gear type (Trawl = 3 m Beam Trawl, Sled = 1.0 m Epibenthic Sled) and sampling week (13-19 August, 27 August-2 September, 10-16 September, and 24-30 September 1984) for young of the year weakfish volumetric density.	36

LIST OF TABLES

PAGE

TABLE 1. SAMPLE UNIT CHARACTERISTICS FOR THE 3 m BEAM TRAWL AND 1.0 m^2 EPIBENTHIC SLED WHEN TOWED AGAINST RIVER CURRENTS AT 1.5 m • sec^{-1} DURING THE AUGUST-SEPTEMBER 1984 GEAR COMPARISON STUDY IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76) 11

TABLE 2. THE NUMBER OF TOWS COLLECTED IN EACH WEEK AND RIVER REGION BY A 3 m BEAM TRAWL AND A 1.0 m^2 EPIBENTHIC SLED IN THE LOWER HUDSON RIVER ESTUARY, AUGUST - SEPTEMBER 1984 14

TABLE 3. SAMPLING GEAR AND ABSOLUTE COLLECTION EFFICIENCY VALUES USED TO EVALUATE THE RELATIVE CONTRIBUTION OF A 1.0 m^2 EPIBENTHIC SLED OR 3 m BEAM TRAWL TO THE REGIONAL STANDING CROP OF YOUNG OF THE YEAR STRIPED BASS IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), OCTOBER 1983 AND AUGUST - SEPTEMBER 1984 18

TABLE 4. DESCRIPTIVE STATISTICS FOR STRIPED BASS LENGTH FREQUENCY DISTRIBUTIONS OBTAINED FROM 3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED SAMPLES FROM THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), 13 AUGUST - 30 SEPTEMBER 1984. 20

TABLE 5. χ^2 CONTINGENCY ANALYSIS COMPARING WEEKLY LENGTH FREQUENCY DISTRIBUTIONS OF STRIPED BASS OBTAINED FROM 3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED SAMPLES FROM THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), 13 AUGUST - 30 SEPTEMBER 1984 . . 25

TABLE 6. MEAN AREAL DENSITY (individuals per 1000 m^2) AND STANDARD ERROR OF MEAN AREAL DENSITY (S.E.) FOR YOUNG OF THE YEAR, AND YEARLING AND OLDER LIFE STAGES OF ABUNDANT FISH SPECIES CAUGHT DURING NIGHT SAMPLING WITH A 3 m BEAM TRAWL AND A 1.0 m^2 EPIBENTHIC SLED IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), AUGUST - SEPTEMBER 1984 27

TABLE 7. MEAN VOLUMETRIC DENSITY (individuals per 1000 m^3) AND STANDARD ERROR OF MEAN VOLUMETRIC DENSITY (S.E.) FOR YOUNG OF THE YEAR, AND YEARLING AND OLDER LIFE STAGES OF ABUNDANT FISH SPECIES CAUGHT DURING NIGHT SAMPLING WITH A 3 m BEAM TRAWL AND A 1.0 m^2 EPIBENTHIC SLED IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), AUGUST - SEPTEMBER 1984. 28

PAGE

TABLE 8. FREQUENCY AND PERCENT OF ZERO SAMPLES FOR YOUNG OF THE YEAR AND YEARLING AND OLDER LIFE STAGES OF ABUNDANT FISH SPECIES CAUGHT DURING NIGHT SAMPLING WITH A 1.0 m^2 EPIBENTHIC SLED AND A 3 m BEAM TRAWL IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), AUGUST - SEPTEMBER 1984 30

TABLE 9. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN DENSITY OF YOUNG OF THE YEAR STRIPED BASS AND SELECTED, ABUNDANT FISH SPECIES CAUGHT BY GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED) AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER AND 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76). . . . 32

TABLE 10. RELATIVE CATCH EFFICIENCY AND RELATIVE PRECISION OF YOUNG OF THE YEAR STRIPED BASS MEAN DENSITY ESTIMATES FROM A 3 m BEAM TRAWL COMPARED WITH A 1.0 m^2 EPIBENTHIC SLED, LOWER HUDSON RIVER ESTUARY, SEPTEMBER 1980, OCTOBER 1983, AND AUGUST-SEPTEMBER 1984. 39

TABLE 11. CONTRIBUTION OF 1.0 m^2 EPIBENTHIC SLED OR 3 m BEAM TRAWL SHOAL SAMPLES TO COMBINED STANDING CROP ESTIMATES (IN THOUSANDS) OF YOUNG OF THE YEAR STRIPED BASS IN THE TAPPAN ZEE (TZ) OR CROTON-HAVERSTRAW (CH) REGIONS OF THE HUDSON RIVER ESTUARY, OCTOBER 1983. 40

TABLE 12. CONTRIBUTION OF 1.0 m^2 EPIBENTHIC SLED OR 3 m BEAM TRAWL SHOAL SAMPLES TO COMBINED STANDING CROP ESTIMATES (IN THOUSANDS) OF YOUNG OF THE YEAR STRIPED BASS IN THE CROTON-HAVERSTRAW (CH) REGION OF THE HUDSON RIVER ESTUARY, AUGUST-SEPTEMBER 1984 41

TABLE 13. RELATIVE CONTRIBUTION OF 3 m BEAM TRAWL SHOAL SAMPLES (COMPARED TO 1.0 m^2 EPIBENTHIC SLED SAMPLES) TO THE ACCURACY AND PRECISION OF YOUNG OF THE YEAR STRIPED BASS STANDING CROP ESTIMATES FROM REGIONS OF THE LOWER HUDSON RIVER ESTUARY (TAPPAN ZEE, RIVER KILOMETERS 39-54; CROTON-HAVERSTRAW, RIVER KILOMETERS 55-62), OCTOBER 1983 AND AUGUST-SEPTEMBER 1984 43

TABLE 14. WEEKLY VARIATION IN YOUNG OF THE YEAR STRIPED BASS DENSITY ESTIMATES AND OCCURRENCE OF ZERO-CATCH SAMPLES FOR 1.0 m^2 EPIBENTHIC SLED AND 3 m BEAM TRAWL SAMPLES FROM THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76) DURING AUGUST-SEPTEMBER 1984. 47

1.0 EXECUTIVE SUMMARY

Size selectivity and relative catch efficiency of a 3 m beam trawl was compared with a 1.0 m^2 epibenthic sled in nocturnal sampling for young of the year striped bass and other fishes in the lower Hudson River estuary (River Kilometers 39-76) during August-September 1984. All samples were collected while towing against river currents, over a hard mud substrate, in water depths between 3 m and 6 m, and at a towing speed of 1.5 m • sec^{-1} (measured alongside the boat). Paired 5 minute samples were collected for each gear in regions of suspected high striped bass abundance. The effects of size selectivity and relative catch efficiency differences between gear was also evaluated with respect to combined standing crop estimates for young of the year striped bass using data from this study and from a previous study in October 1983.

Significant size selectivity was observed between striped bass captured in the epibenthic sled and beam trawl during the first week of sampling (13-19 August 1984) but not during the remaining three sampling weeks (27 August-2 September, 10-16 September, and 24-30 September 1984). The epibenthic sled caught a significantly higher proportion of striped bass less than 51 mm TL and significantly fewer striped bass greater than 71 mm TL during the first sampling week. However, the beam trawl caught striped bass over a greater size range and provides a more accurate description of length frequency distributions than the epibenthic sled. The beam trawl also consistently and significantly estimated higher striped bass densities than the epibenthic sled in all sampling weeks and for all size classes, including fish less than 51 mm TL. Adjustment of the beam trawl catch for the observed size selectivity below 51 mm TL would result in only a 14.2% increase in density over unadjusted values.

If the objective of a sampling program is to estimate the abundance of young of the year striped bass (approximately 50 to 150 mm TL), the beam trawl is the most efficient sampling gear. The beam trawl

catch efficiency for young of the year striped bass was approximately 4 times greater than the epibenthic sled, and density estimates were approximately two times more precise. These observed increases in catch efficiency and precision were smaller than in previous years and probably the result of the field sampling design which emphasized regions of high striped bass density (for size selectively studies) rather than a randomly allocated effort. The epibenthic sled estimated significantly higher densities of young of the year bay anchovy, American shad and weakfish, probably due to mesh size selectively by the beam trawl cod end which apparently extruded these small, relatively fragile species.

Combined standing crop estimates were generally greater for the beam trawl than for the epibenthic sled. Shoal standing crops based on beam trawl samples were between 0.7 and 77.4 times higher than estimates based on epibenthic sled samples, and were 1.4 to 5.8 times more precise. Regional standing crop estimates based on beam trawl samples were between 0.9 and 4.7 times higher than values based on epibenthic sled samples and were between 1.0 and 2.4 times more precise. The greatest variation in relative standing crop and precision was observed between weeks and regions in 1983. This variation is probably more representative than the variation observed in 1984 due to the aforementioned non-random sampling design.

2.0 INTRODUCTION

The Long River Fall Juvenile Survey is an annual stratified random sampling program designed to estimate the standing crop of young of the year (YOY) striped bass in the Hudson River estuary between New York City (River Kilometer 19) and Albany (River Kilometer 246) during late July through late October (Texas Instruments, TI, 1981; Normandeau Associates, Inc., NAI 1985a, 1985b). A standardized beach seine sample is used to estimate the density of YOY striped bass in the shore zone (<3 m deep), a 1.0 m^2 epibenthic sled samples along the river bottom in shoal (3 to 6 m deep) and bottom (>6 m deep) areas, and a 1.0 m^2 Tucker trawl is used to sample the water column in mid-water, shoal and channel areas. Standing crop estimates for YOY striped bass are used to examine variation in year class strength and evaluate the effects of cooling water withdrawal at several electric generating stations. It is therefore of interest to improve the precision and accuracy of YOY striped bass abundance estimates. Collection efficiency values are available for beach seine samples in the present Fall Juvenile Survey and provide relatively accurate and precise standing crop estimates from the shore zone (TI, 1981). The present study, and studies by TI (1980) and NAI (1982; 1985c) were designed to determine the relative collection efficiency of the 1.0 m^2 epibenthic sled as it is deployed in the Fall Juvenile Survey and identify possible improved sampling gear or deployment methods which could increase the accuracy and precision of the annual YOY striped bass standing crop estimate. This task is particularly important since the shoal and bottom strata are a substantial part of the Hudson River habitat relative to the shore zone and samples from these strata may contribute greatly to the standing crop estimate (TI, 1981).

Development of a fall juvenile striped bass abundance index and long-river combined standing crop estimate has led to several Hudson River studies which evaluated the effectiveness and efficiency of sampling gear for young of the year (YOY) fishes. The 1.0 m^2 epibenthic sled may be more appropriate for sampling ichthyoplankton than YOY fishes due to gear detection/avoidance (TI, 1980). The efficiency of the 1.0 m^2 epibenthic sled for YOY fishes (approximately 50-150 mm TL) is probably less than 10% (TI, 1980) and use of this gear yielded significantly ($p<0.05$) lower density estimates for YOY fish than a 3 m beam trawl (NAI, 1982; NAI 1985c). Mean YOY striped bass densities (fish per 1000 m^3) were approximately nine times higher based on beam trawl samples than based on epibenthic sled samples from the lower Hudson River during September 1980 (NAI, 1982) and densities were approximately 6 times higher during sampling in October 1983 (NAI, 1985c). Additionally, the aforementioned estimates of YOY striped bass density were at least three times more precise based on beam trawl samples than densities based on epibenthic sled samples.

Observed differences in precision of striped bass mean density estimates may be explained by a high frequency of occurrence of zero-catch samples from the epibenthic sled compared with the beam trawl. In September 1980, more than 88% of the epibenthic sled samples did not catch YOY striped bass, while only 15% of a comparable set of beam trawl samples did not catch YOY striped bass (NAI, 1982). Similarly, in October 1983, 88% of the epibenthic sled samples did not catch YOY striped bass while only 18% of comparable beam trawl samples did not catch YOY striped bass (NAI 1985c). The high frequency of zero-catch samples in the epibenthic sled was apparently related to avoidance of the gear by YOY fishes and not due to a smaller sample unit size (smaller volume of water sampled) compared with the beam trawl (NAI 1985c). An abundance index or standing crop estimate based on beam trawl sampling may be several times larger and more precise than one based on the epibenthic sled and provide greater resolution for comparing yearly variation in abundance estimates for YOY fishes.

In both the September 1980 and October 1983 gear comparison studies, samples from the 3 m beam trawl estimated higher mean areal (number of fish per 1000 m^2) and volumetric (number of fish per

1000 m^3) densities of YOY fishes, except for YOY bay anchovy. Size selectivity by extrusion of the small, relatively fragile YOY bay anchovies through the 13 mm mesh (stretch) of the beam trawl cod end probably accounted for higher density estimates in the epibenthic sled (which has 3 mm mesh netting). Size selectively was also observed for striped bass in 1983 (NAI 1985c) however an extremely small sample of fish limited statistical reliability of any comparison between the epibenthic sled length frequency distribution (based on only 36 fish) and the beam trawl (based on 693 fish). The beam trawl may have caught more large fish, fewer small fish or both.

Comparison of the epibenthic sled and 3 m beam trawl was undertaken in 1984 primarily to evaluate size selectivity differences between the two gear for YOY striped bass. Sampling was scheduled during August and September 1984 to collect the smallest, juvenile striped bass which would be sampled by the Long River Fall Juvenile Survey (NAI 1985a; 1985b), thus maximizing the possibility of observing selectivity differences between the two gear. Paired sampling was conducted at night in shoal regions (< 6 m deep) of suspected high YOY striped bass densities (Tappan Zee, Croton-Haverstraw, and Indian Point) to maximize the number of fish collected and measured by each gear.

Although the primary objective of the 1984 gear comparison study was to compare size selectivity of the beam trawl and the epibenthic sled, two secondary objectives of this study were to 1) determine the significance of any observed size selectivity with respect to catch efficiency and 2) evaluate the relationship between observed catch efficiency differences between gear and combined standing crop estimates. Relative catch efficiency of the beam trawl with respect to the epibenthic sled was evaluated in 1984 and compared with the 1980 and 1983 studies (NAI, 1982; 1985c). Beam trawl or epibenthic sled samples were also used to provide shoal density and standing crop estimates of

YOY striped bass and to compare the relative contribution of each gear to the precision and accuracy of the regional combined standing crop estimate for October 1983 and August-September 1984.

3.0 METHODS

3.1 FIELD SAMPLING

Recommended modifications to the beam trawl gear and deployment procedures (NAI 1985c) were implemented in the present study. Modifications to the gear (Appendix Figure 1) included:

1) attaching a hood between the beam and headrope,

2) use of a small cookie sweep instead of a chain sweep,

3) counter-weighing the beam trawl frame with 15 kg steel skids, and

4) flowmeter installation using a cable on a diagonal between the upper corner of the beam and the lower, front corner of the opposite runner.

Modifications to deployment procedures included:

1) five minute tows against river currents at 1.5 $m \bullet sec^{-1}$, and

2) measuring both tow distance and volume; previous studies (NAI 1982, 1985c) did not consistently measure both parameters for each gear.

Descriptions of the sampling gear and vessels are presented in the Appendix (Appendix Figures 1-2; Appendix Tables 1-2).

Sampling was conducted at night in the Tappan Zee, Croton-Haverstraw and Indian Point regions of the lower Hudson River estuary (Figure 1) during the weeks of 13-19 August, 27 August-2 September, 10-16 September and 24-30 September 1984. In each week and river region, the same shoal sites were sampled by the 1.0 m^2 epibenthic sled and the 3 m beam trawl. Shoal sampling depths varied between 3 to 6 m and the predominant bottom type in these regions was smooth, hard mud. Sampling sites were selected in regions of suspected high density of young of the year (YOY) striped bass since the primary objective of this study was to compare size selectivity of each gear.

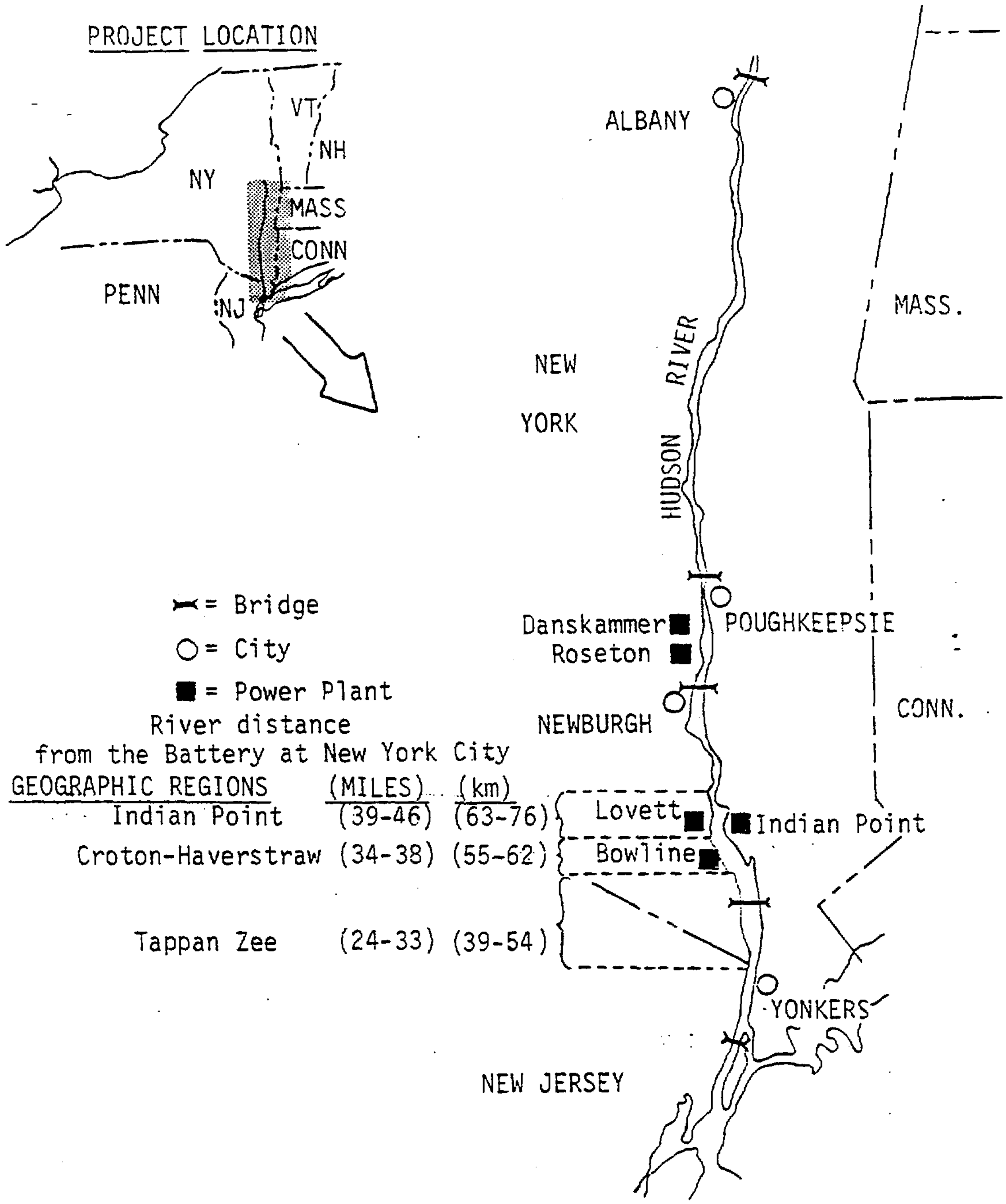


Figure 1. Tappan Zee, Croton-Haverstraw, and Indian Point sampling regions in the lower Hudson River estuary.

Tows were matched in both time and location. These "paired" tows were conducted with both boats setting and retrieving the gear at the same time while towing against river currents at 1.5 m • sec^{-1}. This tow speed and orientation against river currents was determined to be optimum for the beam trawl in previous studies (NAI 1982; 1985c) and is the deployment procedure used for the epibenthic sled in the Long River Fall Juvenile Survey (NAI 1985a, 1985b). Tow paths were parallel, identical in tow duration (5 minutes) and length, and approximately 50 m apart. Towing speed for each gear was measured alongside each boat using a calibrated General Oceanics, Inc. (GO) electronic flowmeter (Model 2031).

Tow distance across the river bottom was measured to the nearest 10 m using the difference between LORAN-C coordinates from the beginning and end of each beam trawl or epibenthic sled tow. Sample volume was measured using calibrated GO flowmeters (Model 2031) placed in the center of the mouth opening of each net. A sample was considered void if either tow distance or volume was not measured and if sampling problems occurred during the tow which would affect the relationship between the measured sample area or volume and the catch (e.g., the net was snagged and a hole was torn in the cod end).

3.2 SIZE SELECTIVITY

Size selectivity of the beam trawl and epibenthic sled was investigated by measuring the total length in mm of the first 1500 striped bass caught by each gear in successive samples from each sampling week. For each gear, sampling ended when 1500 striped bass were caught or 50 hours of sampling effort was expended. The one exception was early during the week of 10-16 September 1984 when field crews observed low striped bass catches and extra fishing effort was expended beyond 50 hours to provide 38 supplemental epibenthic sled samples; otherwise sampling efforts were paired as described in Section

3.1. Subsampling for size selectivity measurements was not permitted within a sample. Size selectivity data was presented graphically by gear and week, parametric statistics were summarized using the Statistical Analysis System (SAS) UNIVARIATE procedure, and frequency distributions were compared using a χ^2 technique (SAS PROC FREQ) for two-sample frequency distributions (SAS, 1982; Sokal and Rohlf, 1981).

3.3 SAMPLE UNITS AND DENSITY CALCULATIONS

Fish collected in each sample were identified and enumerated by length classes. Seasonally adjusted YOY cut-off lengths (Appendix Table 3) were empirically determined during 1984 and used to differentiate among YOY, yearling and older fish. Since the emphasis in this study was on YOY fishes, particularly striped bass, densities were calculated for two groups of fish: YOY and yearling and older. Densities were expressed as number of fish (N) per 1000 m^2 (areal density) and as N per 1000 m^3 (volumetric density) for each gear.

Area estimates of sample unit size (m^2) for the beam trawl and epibenthic sled were obtained from the product of measured tow distance (m) times net mouth width (m). Width of the 3 m beam trawl (Appendix Figure 1) and 1.0 m^2 epibenthic sled (Appendix Figure 2) was fixed by the rigid construction of the gear at 3 m and 1 m respectively. Sample volumes (m^3) for the beam trawl and epibenthic sled were obtained by direct measurement from calibrated flowmeters as described above. A summary of sample unit characteristics for the 1984 study is presented for each gear in Table 1.

As objectives changed in previous programs, density data for each gear were not consistently based on empirical measurement of both volumetric and areal sample units. In the 1980 study (NAI 1982), both tow volume and tow area were empirically measured for the beam trawl while only volume was measured for the epibenthic sled. In the 1983

TABLE 1. SAMPLE UNIT CHARACTERISTICS FOR THE 3 m BEAM TRAWL AND 1.0 m^2 EPIBENTHIC SLED WHEN TOWED AGAINST RIVER CURRENTS AT 1.5 $m \bullet sec^{-1}$ DURING THE AUGUST-SEPTEMBER 1984 GEAR COMPARISON STUDY IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SAMPLING GEARS	TOW DURATION (minutes)	SAMPLE UNIT	N (number of tows)	MEAN SAMPLE UNIT	STANDARD ERROR
Beam Trawl	5	AREA (m^2)	257	1289	12
	5	VOLUME (m^3)	257	1327	10
Epibenthic Sled	5	AREA (m^2)	322	423	3
	5	VOLUME (m^3)	322	437	3

study (NAI 1985c), tow volume was empirically measured for the epibenthic sled while tow area was measured for the beam trawl. Cross-year comparisons using density data based on the same sample unit (Sections 4.3 and 5.0) required estimation of the unmeasured sample unit. In the 1980 data, tow area for the epibenthic sled was estimated using a constant derived from the ratio of the mean measured sample volume (378 m^3) divided by the mean tow distance as measured by the beam trawl in paired tows (391 m^3) times the filtration efficiency (0.96675, TI 1981). Tow volume for the beam trawl in the 1983 data (NAI 1985c) was estimated using the measured tow distance for each tow times the mouth dimensions (3.0 m x 0.9 m) times the observed mean filtration efficiency of the beam trawl (0.73, NAI 1982).

3.4 EXPERIMENTAL DESIGN FOR COMPARING RELATIVE CATCH EFFICIENCY

The experimental design for comparing relative catch efficiencies between the beam trawl and epibenthic sled was a two-factor analysis of variance (ANOVA) model. Sampling gear was the test factor and sampling week was a blocking factor in the design. The complete, two-factor ANOVA model is described in regression terms using in the following equation (Neter and Wasserman, 1974):

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1 X_2 + \text{error} \qquad \text{(Equation 1)}$$

where β is the intercept, β_1 through β_3 are regression coefficients for the main effects (β_1 and β_2), and two-way interaction (β_3), error is the amount of variation not explained by the model,

Y = density of YOY striped bass and other selected, abundant YOY fish expressed as N per 1000 m^2 or N per 1000 m^3,

X_1 = sampling gear, and

X_2 = sampling week.

Since concentrations of fish were sampled weekly as a first priority in this study to obtain striped bass for length frequency analysis (Section 3.2), the experimental design was not balanced with respect to Hudson River region (Table 2). Therefore, samples were pooled and region was not used as a blocking factor in the ANOVA model as in past studies (NAI 1982, 1985c). Sampling effort also differed among weeks in this study (Table 2), thus requiring a multiple regression model (Equation 1) to analyze data from the unbalanced design.

Analysis of variance was an appropriate analytical method because it allowed simultaneous comparison of fish density estimates between gear and among sampling weeks. ANOVA is a particularly useful technique because several hypotheses can be simultaneously tested while the overall statistical error rate is held within prespecified limits (Sokal and Rohlf, 1981); in this study, an error rate of less than 5% was used. ANOVA models require data to be from random samples with respect to the test factor (i.e. gear). Additionally, the error term (error, Equation 1) must be independent of variation in the model factors and normally distributed with essentially equal variance among factors (Sokal and Rohlf, 1981). These assumptions are generally satisfied by transforming the data (Sokal and Rohlf, 1981); a common logarithm transformation ($\log_{10}$) is often appropriate for fisheries density data (Green 1979; NAI 1985c).

Data summaries and analyses were conducted using the Statistical Analysis System (SAS version 82.3, SAS Institute 1982). The SAS general linear models procedure (PROC GLM) was used to analyze the unbalanced, ANOVA models described above. The response variable for this model was the areal or volumetric density of YOY striped bass and other selected, abundant YOY fish species. Fish densities were transformed using Log_{10} (X+1) to eliminate variance heterogeneity as indicated by examination of regression residual plots. Treatment contrasts for factors from significant ($p<0.05$) ANOVA models were compared using the SAS Least Square Means Procedure (LSMEANS).

TABLE 2. THE NUMBER OF TOWS COLLECTED IN EACH WEEK AND RIVER REGION BY A 3 m BEAM TRAWL AND A 1.0 m^2 EPIBENTHIC SLED IN THE LOWER HUDSON RIVER ESTUARY, AUGUST-SEPTEMBER 1984.

WEEK (1984)	HUDSON RIVER REGION (a)	NUMBER OF SAMPLES	
		TRAWL	SLED
13-19 August	Tappan Zee	0	0
	Croton-Haverstraw	49	54
	Indian Point	6	7
27 August - 2 September	Tappan Zee	4	0
	Croton-Haverstraw	66	70
	Indian Point	0	4
10-16 September	Tappan Zee	1	24
	Croton-Haverstraw	72	96
	Indian Point	1	1
24-30 September	Tappan Zee	0	0
	Croton-Haverstraw	58	66
	Indian Point	0	0

(a)Hudson River Region
- Tappan Zee is 39-54 km upriver from the Battery at New York City
- Croton-Haverstraw is 55-62 km upriver from the Battery at New York City
- Indian Point is 63-76 km upriver from the Battery at New York City

3.5 COMBINED STANDING CROP ESTIMATES

Catch data from the 1983 and 1984 gear comparison studies were used in conjunction with the complementary Long River Fall Juvenile and Beach Seine Survey samples to estimate the relative contribution of the beam trawl or epibenthic sled to the regional combined standing crop of YOY striped bass. In 1983, regional combined standing crop was calculated for the Tappan Zee and Croton-Haverstraw river regions for the weeks of 3-9 October and 17-23 October. In 1984, combined standing crops were calculated for the Croton-Haverstraw region only (because of the unbalanced sampling effort, Table 2), during the weeks of 13-19 August, 27 August - 2 September, 10-16 September and 24-30 September.

Shoal stratum standing crop estimates were calculated using density data derived from the epibenthic sled or beam trawl samples in the appropriate weeks and river regions using assumed absolute collection efficiency values of 50%, 10% or 1% for each gear. The same three collection efficiency values were also used for 1.0 m^2 epibenthic sled samples from the bottom stratum and 1.0 m^2 Tucker trawl samples from the channel stratum in each river region and week. An actual collection efficiency of 0.255 (variance = 0.002) and a night/day scaling factor of 2.136 (variance = 0.081) were used to estimate absolute abundance of striped bass sampled by a 30.5 m beach seine in the shore zone (< 3 m deep) of each river region and week (TI 1981; NAI 1985a, 1985b). The following equations, also used in previously reported combined standing crop calculations (TI 1981; NAI 1985a, 1985b), were used to compute the standing crop of YOY striped bass in this study:

Standing crop estimate and its standard error for stratum k within region r during week w:

$$N_{krw} = V_{kr}\, d_{krw} \qquad \text{(Equation 2)}$$

and

$$SE_{N_{krw}} = (V_{kr})\,(SE_{d_{krw}}) \qquad \text{(Equation 3)}$$

where

V_{kr} = river volume (1000 m^3) of stratum k within region r

d_{krw} and $SE_{d_{krw}}$ = Volumetric (fish per 1000 m^3) density and standard error of volumetric density for stratum k within region r during week w.

Standing crop ~~estimate~~ and its standard error for all strata of region r during week w (= regional standing crop):

$$N_{rw} = \sum_{k=1}^{3} N_{krw} \qquad \text{(Equation 4)}$$

and

$$SE_{N_{rw}} = \sqrt{\sum_{k=1}^{3} \left(SE_{N_{krw}}\right)^2} \qquad \text{(Equation 5)}$$

where

N_{krw} and $SE_{N_{krw}}$ = as in Equations 2 and 3.

Three absolute collection efficiency values were selected to encompass a range of efficiency values which may apply to either the beam trawl or epibenthic sled (NAI 1982; 1985c). The collection efficiency of the beach seine (0.255) was previously determined and lies within the selected range. Table 3 summarizes the combinations of gear and collection efficiencies used to evaluate the sensitivity of the regional combined standing crop estimates to shoal stratum densities based on the epibenthic sled or beam trawl for the aforementioned weeks and regions in 1983 and 1984.

TABLE 3. SAMPLING GEAR AND ABSOLUTE COLLECTION EFFICIENCY VALUES USED TO EVALUATE THE RELATIVE CONTRIBUTION OF A 1.0 m^2 EPIBENTHIC SLED OR 3 m BEAM TRAWL TO THE REGIONAL STANDING CROP OF YOY STRIPED BASS IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), OCTOBER 1983 AND AUGUST-SEPTEMBER 1984.

STRATUM	GEAR	ABSOLUTE EFFICIENCY
Shore	Beach Seine	Mean = 0.255 (variance = 0.002) Night/Day Ratio = 2.136 (variance = 0.081)
Shoal	Epibenthic Sled or Beam Trawl	0.50 0.10 0.01
Bottom	Epibenthic Sled	0.50 0.10 0.01
Channel	Tucker Trawl	0.50 0.10 0.01

4.0 RESULTS AND DISCUSSION

4.1 SIZE SELECTIVITY

Descriptive statistics for weekly length frequency distributions of striped bass caught by the 3 m beam trawl and 1.0 m^2 epibenthic sled demonstrate rapid growth in the population between the first and last week of the study (Table 4; Appendix Tables 4 and 5, Appendix Figure 3). For the beam trawl, mean length of striped bass increased by more than 22 mm from 62.8 mm TL during the week of 13-19 August to 85.5 mm TL during the week of 24-30 August 1984. For the epibenthic sled, mean length of striped bass increased by at least 28 mm from 58.0 mm TL to 86.7 mm TL between the weeks of 13-19 August and 24-30 September 1984. During the week of 13-19 August 1984, striped bass mean length was nearly 5 mm smaller based on samples from the epibenthic sled than based on beam trawl samples. In each of the remaining three sampling weeks, mean lengths were within approximately 1 mm for both gear.

Lower mean length of striped bass caught by the epibenthic sled compared to the beam trawl during the first week of sampling suggested cod end size selectivity similar to that observed for bay anchovies (NAI 1982, 1985c) may have occurred for small striped bass in 1984. The beam trawl cod end has a mesh size approximately 4 times greater than the epibenthic sled (1.3 cm stretch vs 0.3 cm, Appendix Figures 1 and 2). Examination of weekly length frequency histograms (Figures 2, 3, 4 and 5) and χ^2 contingency analyses (Table 5) confirms the existence of significant size selectivity differences between gear during the first sampling week. The epibenthic sled caught a significantly higher proportion of striped bass in the 31-40 mm TL and 41-50 mm TL length groups, and significantly fewer striped bass in the 71-80 mm TL length group (Table 5; Figure 2). The combination of catching proportionally more small striped bass and less large striped bass in the epibenthic sled resulted in a highly significant ($p = 0.0001$) overall difference between gear during the week of 13-19 August 1984. In subsequent sampling weeks, length frequency

TABLE 4. DESCRIPTIVE STATISTICS FOR STRIPED BASS LENGTH FREQUENCY DISTRIBUTIONS OBTAINED FROM 3 m BEAM TRAWL OR 1.0 m² EPIBENTHIC SLED SAMPLES FROM 39-76), 13 AUGUST - 30 SEPTEMBER 1984.

GEAR	WEEK (1984)	N	MEAN (mm TL)	S.D.	SKEWNESS	KURTOSIS	MAX-IMUM	MIN-IMUM	DESCRIPTION
3 m BEAM TRAWL	13-19 Aug	1470	62.8	9.3	0.17 ± 0.12	1.95 ± 0.25	110	34	Slight right skewness leptokurtosis
	27 Aug-2 Sep	1120	68.9	9.4	0.03 ± 0.14	-0.31 ± 0.29	104	41	Normal skewness slight platykurtosis
	10-16 Sep	489	77.4	9.4	0.19 ± 0.22	-0.02 ± 0.44	107	49	Normal skewness Normal kurtosis
	24-30 Sep	1182	85.5	10.3	0.51 ± 0.14	0.48 ± 0.28	129	60	Right skewness slight leptokurtosis
	13 Aug-30 Sep	4261	72.4	13.3	0.32 ± 0.07	0.13 ± 0.15	129	34	Right skewness normal kurtosis
1.0 m² EPI-BENTHIC SLED	13-19 Aug	132	58.0	10.1	-0.34 ± 0.42	-0.58 ± 0.83	79	32	Normal skewness Normal kurtosis
	27 Aug-2 Sep	153	67.7	9.5	0.30 ± 0.39	-0.22 ± 0.78	97	48	Normal skewness Normal kurtosis
	10-16 Sep	64	77.8	12.0	0.16 ± 0.60	1.17 ± 1.18	113	41	Normal skewness Normal kurtosis
	24-30 Sep	113	86.7	12.7	2.01 ± 0.45	7.86 ± 0.90	154	68	Right skewness Leptokurtosis
	13 Aug-30 Sep	462	70.9	15.4	0.61 ± 0.22	2.01 ± 0.45	154	32	Right skewness Leptokurtosis

N = Number caught
TL = Total length
S.D. = Standard Deviation
± 95% C.I. = 95% confidence interval
Normal skewness = Skewness not significantly different from 0, which is the value obtained from a normal distribution.
Normal kurtosis = Kurtosis not significantly different from 0, which is the value obtained from a normal distribution.
Right skewness = Significant positive skewness indicating more striped bass were larger than the mean length than would be expected from a normal distribution.
Left skewness = Significant negative skewness indicating more striped bass were smaller than the mean length than would be expected from a normal distribution.
Leptokurtosis = Significant positive kurtosis indicating more striped bass were close to the mean length than would be expected from a normal distribution.
Platykurtosis = Significant negative kurtosis indicating more striped bass were both higher and lower than the mean length than would be expected from a normal distribution.

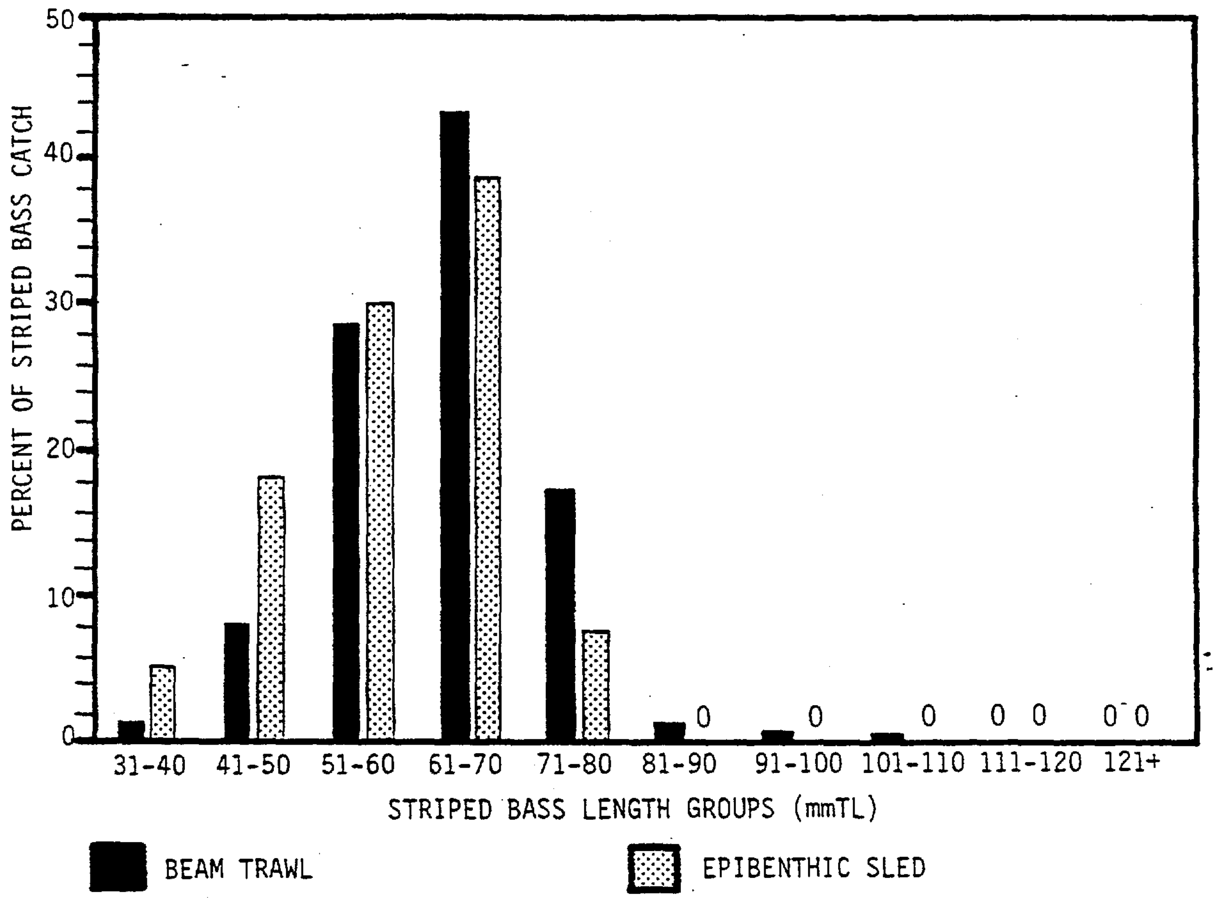


Figure 2. Length-Frequency distribution for striped bass collected by a 3 m Beam Trawl and a 1.0 m^2 Epibenthic Sled in the lower Hudson River estuary (River Kilometers 39-76) during the week of 13-19 August 1984. The number of striped bass measured for each gear were: 1470 for the Beam Trawl and 132 for the Epibenthic Sled.

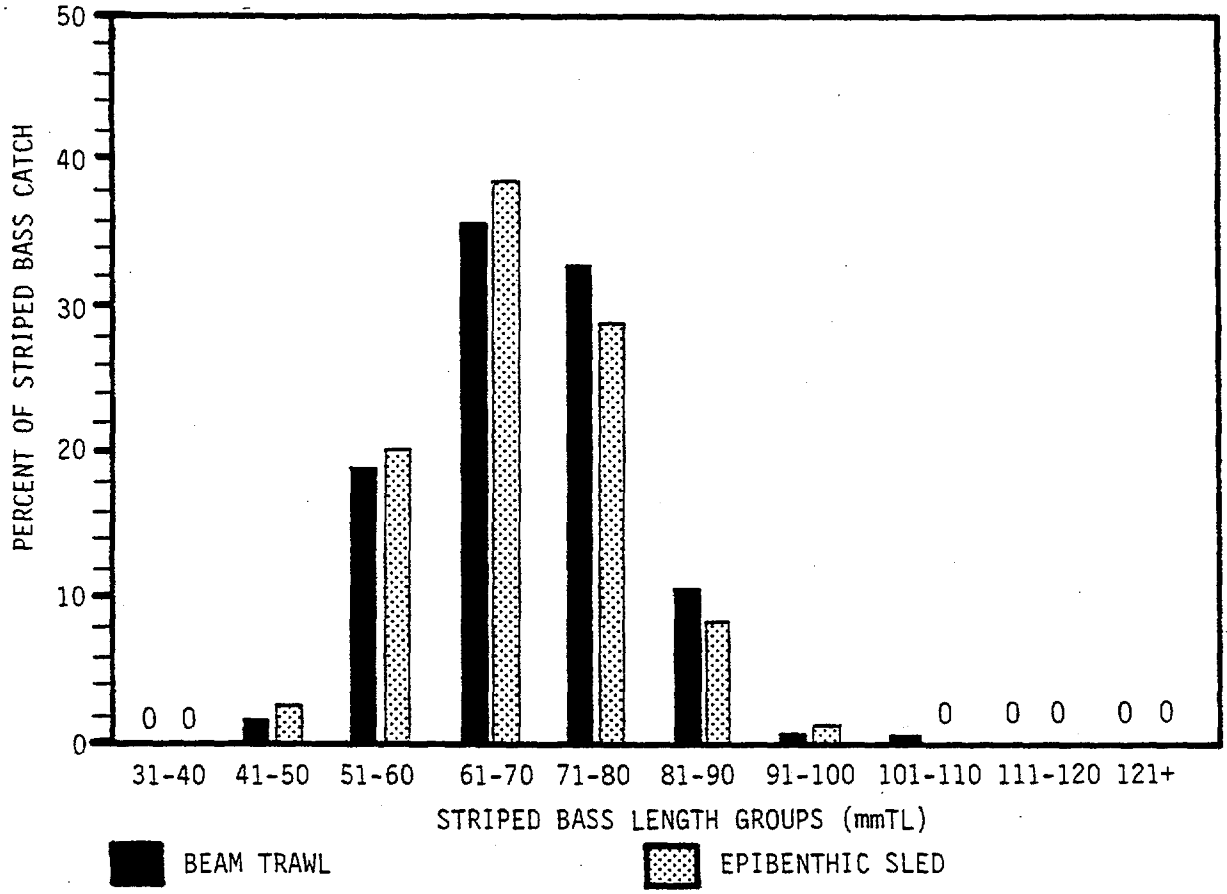


Figure 3. Length-Frequency distribution for striped bass collected by a 3 m Beam Trawl and a 1.0 m^2 Epibenthic Sled in the lower Hudson River estuary (River Kilometers 39-76) during the week of 27 August - 2 September 1984. The number of striped bass measured for each gear were: 1120 for the Beam Trawl and 153 for the Epibenthic Sled.

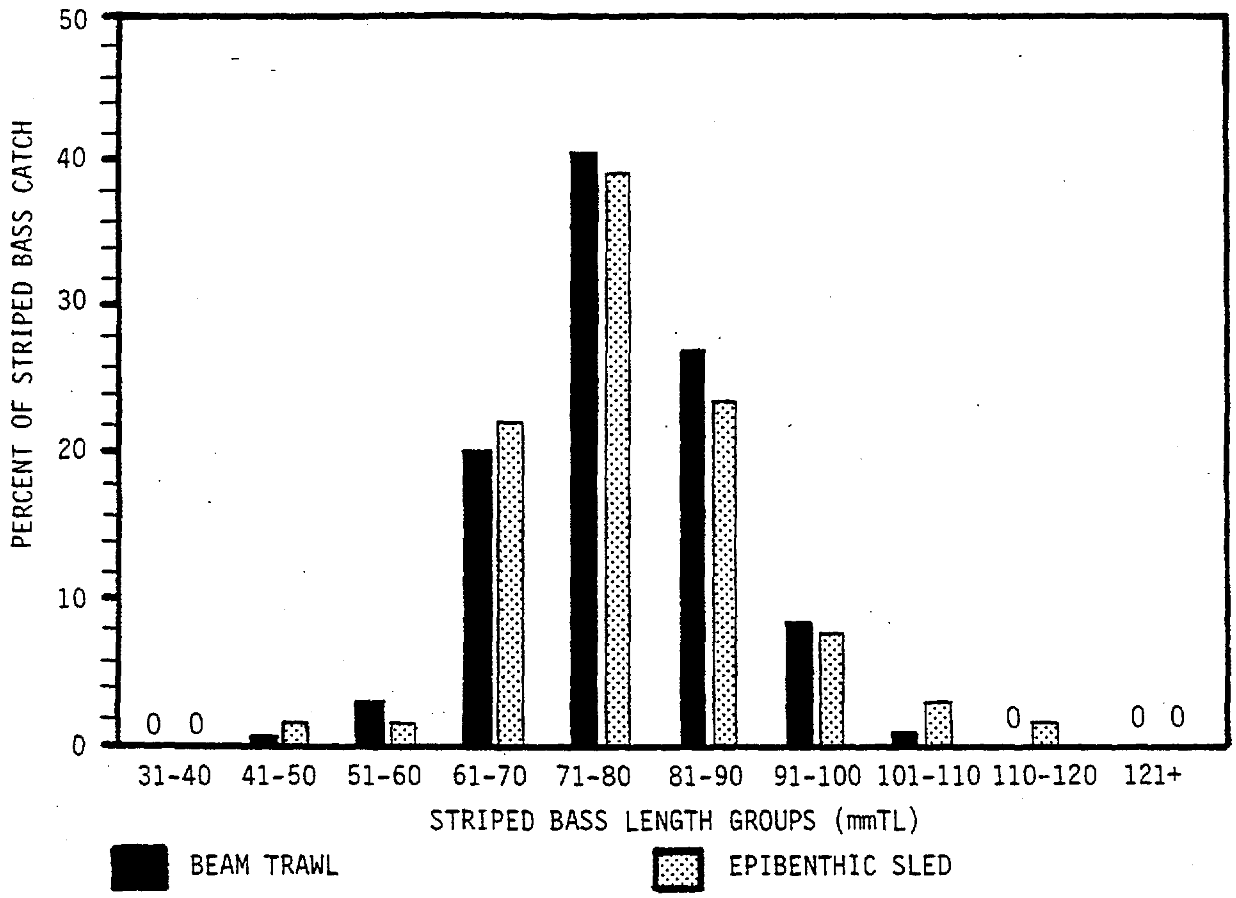


Figure 4. Length-Frequency distribution for striped bass collected by a 3 m Beam Trawl and a 1.0 m^2 Epibenthic Sled in the lower Hudson River estuary (River Kilometers 39-76) during the week of 10-16 September 1984. The number of striped bass measured for each gear were: 489 for the Beam Trawl and 64 for the Epibenthic Sled.

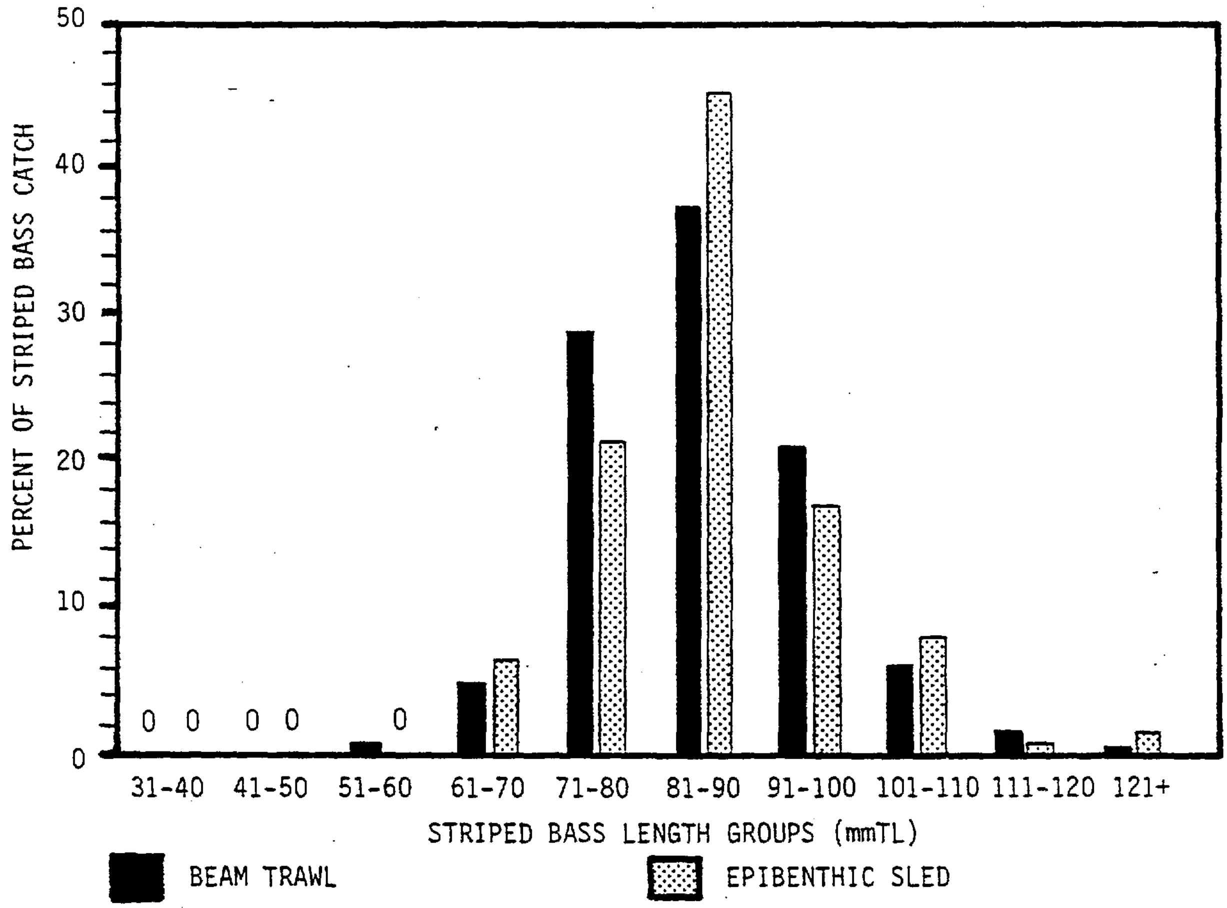


Figure 5. Length-Frequency distribution for striped bass collected by a 3 m Beam Trawl and a 1.0 m^2 Epibenthic Sled in the lower Hudson River estuary (River Kilometers 39-76) during the week of 24-30 September 1984. The number of striped bass measured for each gear were: 1182 for the Beam Trawl and 113 for the Epibenthic Sled.

TABLE 5. χ^2 CONTINGENCY ANALYSIS COMPARING WEEKLY LENGTH FREQUENCY DISTRIBUTIONS OF STRIPED BASS OBTAINED FROM 3 m BEAM TRAWL OR 1.0 m² EPIBENTHIC SLED SAMPLES FROM THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), 13 AUGUST-30 SEPTEMBER 1984.

SAMPLING WEEK (1984)	GEAR	STATISTIC	LENGTH GROUP (mm TL) 31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-110	>111	χ^2	df	$p>\chi^2$
13-19 August	Beam Trawl	observed	18	118	420	634	256	24				36.92	5	0.0001
		expected	23	130	422	629	244	22						
		cell χ^2	1.1	1.2	0.0	0.0	0.6	0.2						
	Epibenthic Sled	observed	7	24	40	51	10	0						
		expected	2	12	38	56	22	2						
		cell χ^2	11.8	12.9	0.1	0.5	6.5	2.0						
27 August-2 September	Beam Trawl	observed		19	209	398	366	119	9			2.78	5	0.7339
		expected		20	211	402	361	116	10					
		cell χ^2		0.1	0.0	0.0	0.1	0.1	0.0					
	Epibenthic Sled	observed		4	31	59	44	13	2					
		expected		3	29	55	49	16	1					
		cell χ^2		0.6	0.2	0.3	0.6	0.5	0.3					
10-16 September	Beam Trawl	observed			15	99	198	131	41	5		5.62	5	0.3449
		expected			15	100	197	129	41	7				
		cell χ^2			0.0	0.0	0.0	0.0	0.0	0.6				
	Epibenthic Sled	observed			2	14	25	15	5	3				
		expected			2	13	26	17	5	1				
		cell χ^2			0.0	0.1	0.0	0.2	0.0	4.6				
24-30 September	Beam Trawl	observed				59	339	442	249	69	24	6.27	5	0.2089
		expected				62	331	450	244	71	25			
		cell χ^2				0.1	0.2	0.1	0.1	0.1	0.0			
	Epibenthic Sled	observed				7	24	51	19	9	3			
		expected				6	32	43	24	7	2			
		cell χ^2				0.2	2.0	1.4	0.9	0.7	0.2			

LEGEND:
observed = number of striped bass collected in the length group.
expected = calculated number of striped bass in the length group based on the hypothesis that no difference exists between length frequency distributions for each gear.
cell χ^2 = χ^2 value comparing the significance of differences between observed and expected values for each gear in each length group. A cell χ^2 of 3.84 or larger was significant at $p<0.05$.
df = degrees of freedom for the overall χ^2.
$p>\chi^2$ = probability of obtaining the overall χ^2 by chance. a $p > \chi^2$ of less than 0.05 was considered significant.

NOTE: Length groups were combined at the upper or lower end of each distribution to insure that more than 80% of the cells in each weekly contingency table had at least 5 fish.

distributions were not significantly different between the beam trawl and epibenthic sled (Table 5; Figure 3, 4, and 5).

Skewness and kurtosis statistics for the weekly length frequency distributions (Table 4) support the observed significant differences by the χ^2 analysis and provide additional insight into the fishing characteristics of each gear. During the week of 13-19 August 1984, slight right skewness of the striped bass length frequency distribution from the beam trawl indicated proportionally more fish larger than the mean length were caught, (fewer small fish) and significant leptokurtosis indicated a relatively limited size range of fish was caught. During the same week, the epibenthic sled length frequency distribution was normal. By the second sampling week, right skewness of the beam trawl length frequency distribution was not observed, and a slight playkurtosis indicated a slightly greater size range of striped bass was caught compared with the previous week. By the last sampling week in the study, striped bass length frequency distributions for both gear were identical and had shifted to right skewness and platykurtosis indicating a relatively narrow size range of fish were caught with proportionally more fish greater than the mean length. The shift towards right skewness in the frequency distributions from both gear may represent a natural growth phenomenon related to a high proportion of early cohort fish in the shoal areas (NAI 1985a, 1985b).

4.2 RELATIVE CATCH EFFICIENCY

4.2.1 Areal and Volumetric Density

Mean areal densities (Table 6) were approximately the same as mean volumetric densities (Table 7) for the most abundant YOY fish species collected by both the 3 meter beam trawl and 1.0 m^2 epibenthic sled. Slightly higher volumetric densities observed in previous studies (NAI 1985c) may be attributed to methods of estimating sample unit size (Section 3.3) since differences between areal and volumetric densities

TABLE 6. MEAN AREAL DENSITY (individuals per 1000 m^2) AND STANDARD ERROR OF MEAN AREAL DENSITY (S.E.) FOR YOUNG OF THE YEAR, AND YEARLING AND OLDER LIFE STAGES OF ABUNDANT FISH SPECIES CAUGHT DURING NIGHT SAMPLING WITH A 3 m BEAM TRAWL AND A 1.0 m^2 EPIBENTHIC SLED IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), AUGUST - SEPTEMBER 1984.

	YOUNG OF THE YEAR				YEARLING AND OLDER			
	3 m BEAM TRAWL (N=257)		1.0 m^2 EPI-BENTHIC SLED (N=322)		3 m BEAM TRAWL (N=257)		1.0 m^2 EPI-BENTHIC SLED (N=322)	
COMMON NAME	MEAN	S.E.	MEAN	S.E.	MEAN	S.E.	MEAN	S.E.
Striped bass	13.3	0.8	3.4	0.4	0.2	<0.1	0.1	<0.1
Bay anchovy	29.0	3.0	1261.2	61.9	0.6	0.1	11.2	1.2
American shad	0.4	0.1	4.4	3.0	0.0	0.0	0.0	0.0
Weakfish	0.7	0.1	1.9	0.3	0.0	0.0	0.0	0.0
White perch	1.3	0.2	0.1	<0.1	22.1	1.6	6.4	1.3
All Species[(a)]	45.1	3.1	1272.9	61.8	30.5	1.9	20.9	2.0

(a) Appendix Table 6 presents a complete listing of mean areal density for each fish species caught in this study.

TABLE 7. MEAN VOLUMETRIC DENSITY (individuals per 1000 m^3) AND STANDARD ERROR OF MEAN VOLUMETRIC DENSITY (S.E.) FOR YOUNG OF THE YEAR, AND YEARLING AND OLDER LIFE STAGES OF ABUNDANT FISH SPECIES CAUGHT DURING NIGHT SAMPLING WITH A 3 m BEAM TRAWL AND A 1.0 m^2 EPIBENTHIC SLED IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), AUGUST - SEPTEMBER 1984.

	YOUNG OF THE YEAR				YEARLING AND OLDER			
	3 m BEAM TRAWL		1.0 m^2 EPI-BENTHIC SLED		3 m BEAM TRAWL		1.0 m^2 EPI-BENTHIC SLED	
COMMON NAME	MEAN (N=257)	S.E.	MEAN (N=322)	S.E.	MEAN (N=257)	S.E.	MEAN (N=322)	S.E.
Striped bass	12.9	0.8	3.2	0.4	0.2	<0.1	0.1	<0.1
Bay anchovy	26.5	2.7	1233.2	58.3	0.6	0.1	10.8	1.1
American shad	0.4	<0.1	4.7	3.4	0.0	0.0	0.0	0.0
Weakfish	0.7	0.1	1.8	0.3	0.0	0.0	0.0	0.0
White perch	1.3	0.2	0.1	<0.1	21.7	1.7	6.5	1.7
All Species [a]	42.2	2.8	1244.8	58.1	30.0	1.9	20.5	2.2

[a] Appendix Table 7 presents a complete listing of mean volumetric density for each fish species caught in this study.

were not observed when both sample volume and area were measured for both gear. Striped bass and bay anchovy were the most abundant YOY fish species sampled by both gear. Striped bass accounted for approximately 30% of the beam trawl YOY catch and 0.3% of the epibenthic sled catch, while YOY bay anchovies accounted for approximately 64% of the beam trawl YOY catch and 99% of the epibenthic sled YOY catch. Other relatively abundant YOY species were American shad, weakfish and white perch (Tables 6 and 7). White perch were the most abundant yearling and older fish species caught by the beam trawl, while yearling and older bay anchovies were most abundant in the epibenthic sled. Hogchoker and white catfish were other relatively abundant yearling and older fishes caught by both gear (Appendix Tables 6 and 7).

4.2.2 Frequency and Percent of Zero-Catch Samples

A relatively high percent of epibenthic sled samples caught YOY striped bass during 1984 (Table 8) compared with previous studies (NAI 1982; 1985b), which probably reflects the fact that sampling was conducted with both gear in regions of relatively high striped bass abundance. YOY bay anchovy occurred most frequently in samples from both the epibenthic sled and beam trawl (Table 8). YOY bay anchovies were present in all but 2 of the 322 epibenthic sled samples and in all but 18 out of the 257 beam trawl samples.

Yearling and older white perch were present in all but 15 out of 257 beam trawl samples, and were found in 157 out of 322 epibenthic sled samples (Table 8). Yearling and older bay anchovies were present in 66% of the epibenthic sled samples, and in 36% of the beam trawl samples. Yearling and older hogchokers were found in 82% of the beam trawl samples and 37% of the epibenthic sled samples (Appendix Table 8). Finally, yearling and older white catfish were present in 56% of the beam trawl samples and in 28% of the epibenthic sled samples (Appendix Table 8).

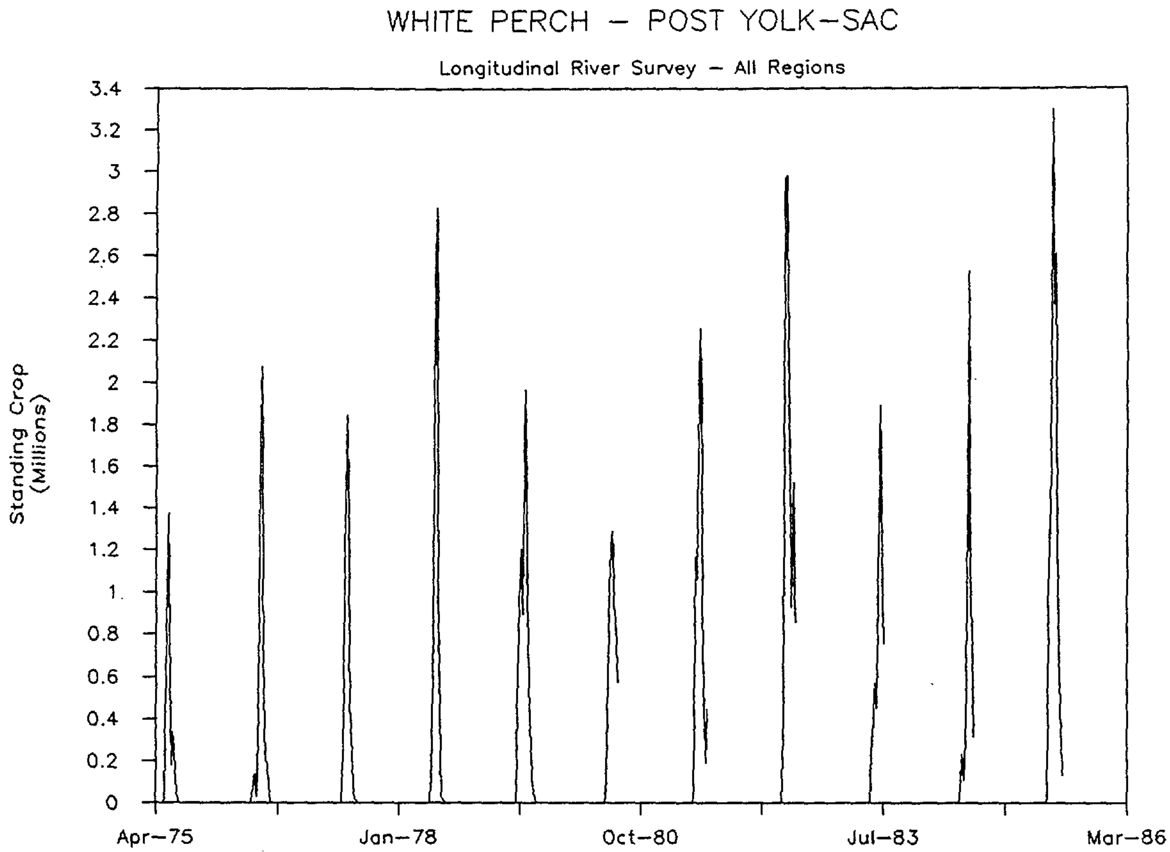

WHITE PERCH – POST YOLK-SAC
Longitudinal River Survey – All Regions
Standing Crop (Millions)
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Apr-75
Jan-78
Oct-80
Jul-83
Mar-86

TABLE 8. FREQUENCY AND PERCENT OF ZERO SAMPLES FOR YOUNG OF THE YEAR AND YEARLING AND OLDER LIFE STAGES OF FISH CAUGHT DURING NIGHT SAMPLING WITH A 1.0 m^2 EPIBENTHIC SLED AND A 3 m BEAM TRAWL IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), AUGUST-SEPTEMBER 1984.

	YOUNG OF THE YEAR LIFE STAGE				YEARLING AND OLDER LIFE STAGES			
	3 m BEAM TRAWL		1.0 m^2 EPIBENTHIC SLED		3 m BEAM TRAWL		1.0 m^2 EPIBENTHIC SLED	
COMMON NAME	FREQUENCY(a) (N=257)	%(b)	FREQUENCY (N=322)	%	FREQUENCY (N=257)	%	FREQUENCY (N=322)	%
Striped bass	26	10.1	186	57.8	216	84.0	314	97.5
Bay anchovy	18	7.0	2	0.6	165	64.2	111	34.5
American shad	173	67.3	229	71.1	257	100.0	322	100.0
Weakfish	184	71.6	252	78.3	257	100.0	322	100.0
White perch	145	56.4	304	94.4	15	5.8	165	51.2
ALL SPECIES COMBINED(c)	3	1.2	0	0.0	9	3.5	36	11.2

(a) N = number of samples which did not catch species, lifestage; Total N at top of each column.

(b) % = percent of samples which did not catch species, lifestage.

(c) Appendix Table 8 presents a complete listing of frequency and percent zero samples for each fish species caught in this study.

4.2.3 Two-Factor Analysis of Variance Comparing Catch Efficiency of the 3 m Beam Trawl and 1.0 m^2 Epibenthic Sled

YOY of four species were selected for catch efficiency analysis: striped bass, bay anchovy, American shad and weakfish. Highly significant ($p<0.0001$) two-factor ANOVA models for comparing the catch efficiency of the beam trawl and epibenthic sled in relation to sampling week were obtained for all four YOY species (Table 9; Appendix Tables 6-23). Models using either areal or volumetric density for the response variable explained approximately 41% of the sampling variation for striped bass, 79% for bay anchovy, 14% for American shad, and 44% of the variation for weakfish (Table 9; Appendix Tables 9-26). Sampling gear, week, and the two-way ($p<0.05$) interaction between gear and week were significant factors for each YOY species compared. The presence of a significant interaction for each species indicates that weekly changes in distribution may have influenced the gear comparison study in 1984; differences between gear are therefore best interpreted by examining the interaction between gear and sampling week for each species (Figures 6-9; Appendix Table 27).

YOY Striped Bass

The beam trawl estimated significantly ($p<0.05$) greater mean YOY striped bass densities than the epibenthic sled during all sampling weeks (Figure 6; Appendix Table 27). In spite of the observed size selectivity by the beam trawl for large striped bass during the first sampling week (Section 4.1), the highest mean density was observed for beam trawl samples during week 1 (13-19 August 1984). During week 3, beam trawl mean density was significantly ($p<0.05$) lower than mean densities from weeks 1, 2 and 4. However, beam trawl density during week 3 was still significantly ($p<0.05$) greater than the epibenthic sled mean density. Epibenthic sled mean density was lowest during week 3 (10-16 September 1984).

TABLE 9. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN DENSITY OF YOUNG OF THE YEAR STRIPED BASS AND SELECTED, ABUNDANT FISH SPECIES CAUGHT BY GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED) AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST-2 SEPTEMBER, 10-16 SEPTEMBER AND 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

YOY FISH SPECIES	RESPONSE VARIABLE (DENSITY) (a)	MODEL (b)			SIGNIFICANT FACTORS ($p<0.05$) (c)	
		F	p>F	R^2	MAIN	TWO-WAY
Striped bass	Areal	56.39	0.0001	0.41	Gear, Week	GearxWeek
	Volumetric	56.72	0.0001	0.41	Gear, Week	GearxWeek
Bay anchovy	Areal	313.35	0.0001	0.79	Gear, Week	GearxWeek
	Volumetric	306.63	0.0001	0.79	Gear, Week	GearxWeek
American shad	Areal	13.82	0.0001	0.15	Gear, Week	GearxWeek
	Volumetric	13.07	0.0001	0.14	Gear, Week	GearxWeek
Weakfish	Areal	65.19	0.0001	0.44	Gear, Week	GearxWeek
	Volumetric	66.87	0.0001	0.45	Gear, Week	GearxWeek

(a) Areal Density as $\log_{10}$ (N per 1000 m^2 + 1)

Volumetric density as $\log_{10}$ (N per 1000 m^3 + 1)

(b) *Evaluation of model significance:*

F = calculated F-ratio
p = probability of obtaining a larger F-ratio;
a p>F of less than 0.05 was considered significant
R^2 = coefficient of determination

(c) Factors are listed for significant ANOVA models under the appropriate column for main factors and interactions.

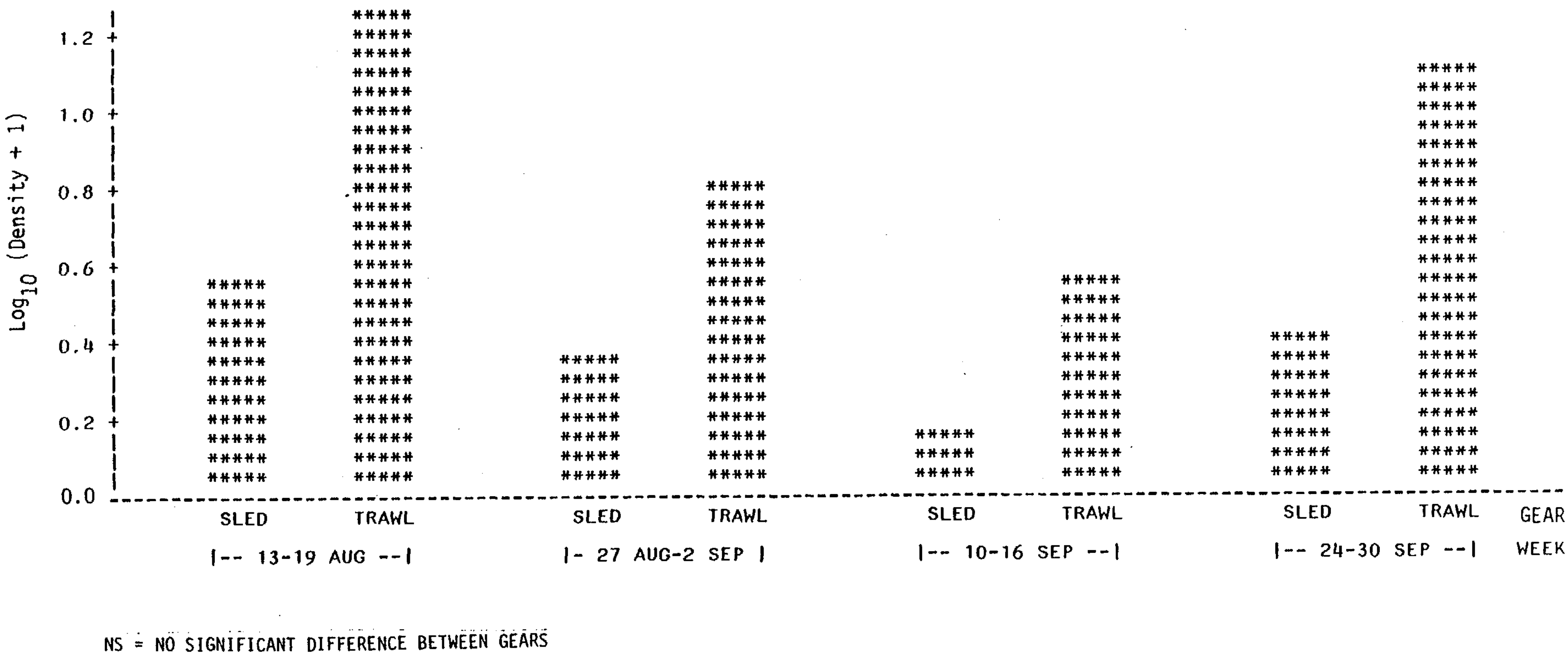
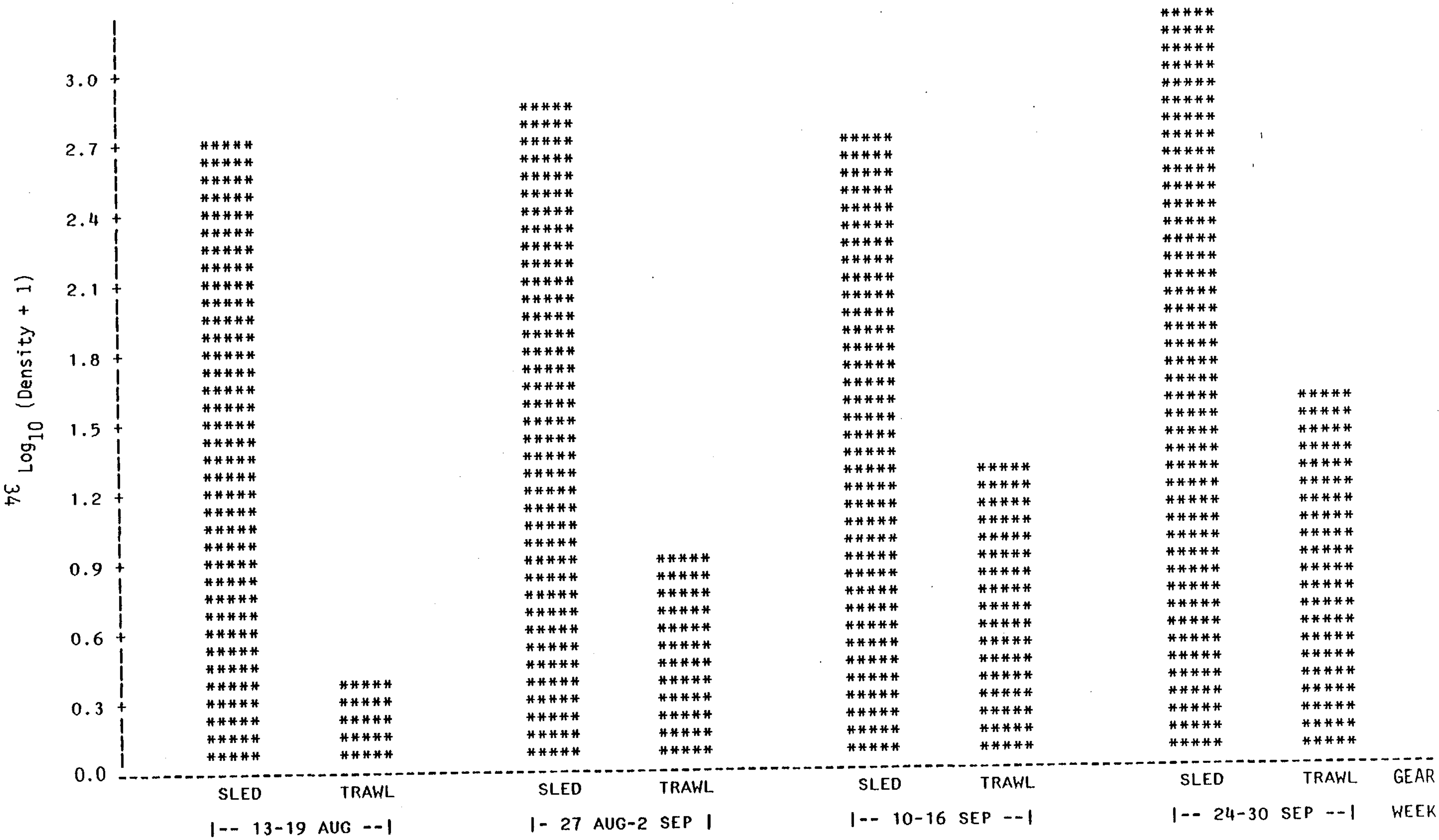
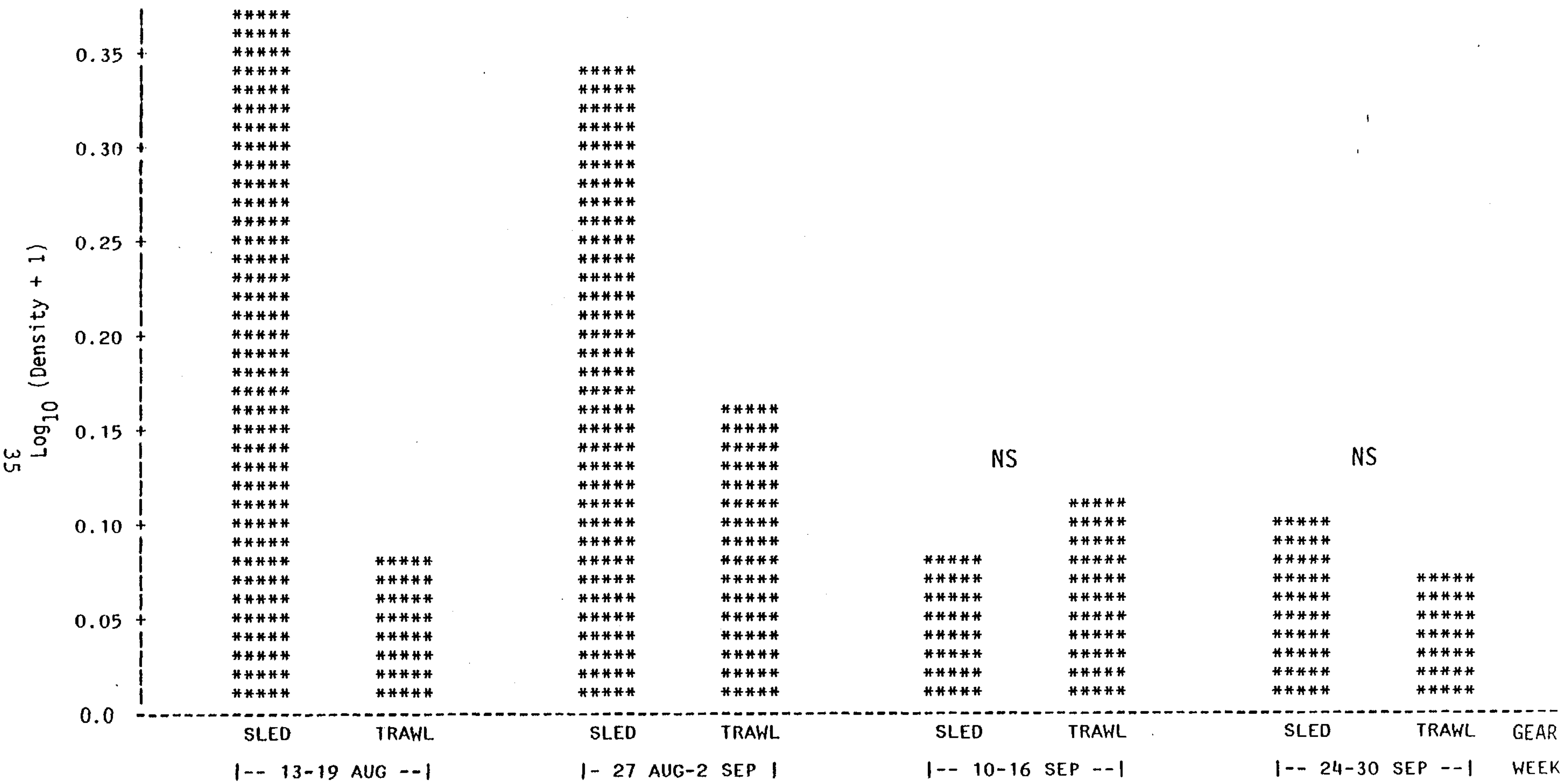


Figure 6. Interaction between gear type (Trawl = 3 m Beam Trawl, Sled = 1.0 m^2 Epibenthic Sled) and sampling week (13-19 August, 27 August-2 September, 10-16 September, and 24-30 September 1984) for young young of the year striped bass, volumetric density.



NS = NO SIGNIFICANT DIFFERENCE BETWEEN GEARS

Figure 7. Interaction between gear type (Trawl = 3 m Beam Trawl, sled = 1.0 m^2 Epibenthic Sled) and sampling week (13-19 August, 27 August-2 September, 10-16 September, and 24-30 September 1984) for young of the year bay anchovy, volumetric density.



NS = NO SIGNIFIGANT DIFFERENCE BETWEEN GEAR

Figure 8. Interaction between gear type (Trawl = 3 m Beam Trawl, Sled = 1.0 m^2 Epibenthic Sled) and sampling week (13-19 August, 27 August-2 September, 10-16 September, and 24-30 September 1984) for young of the year American shad, volumetric density.

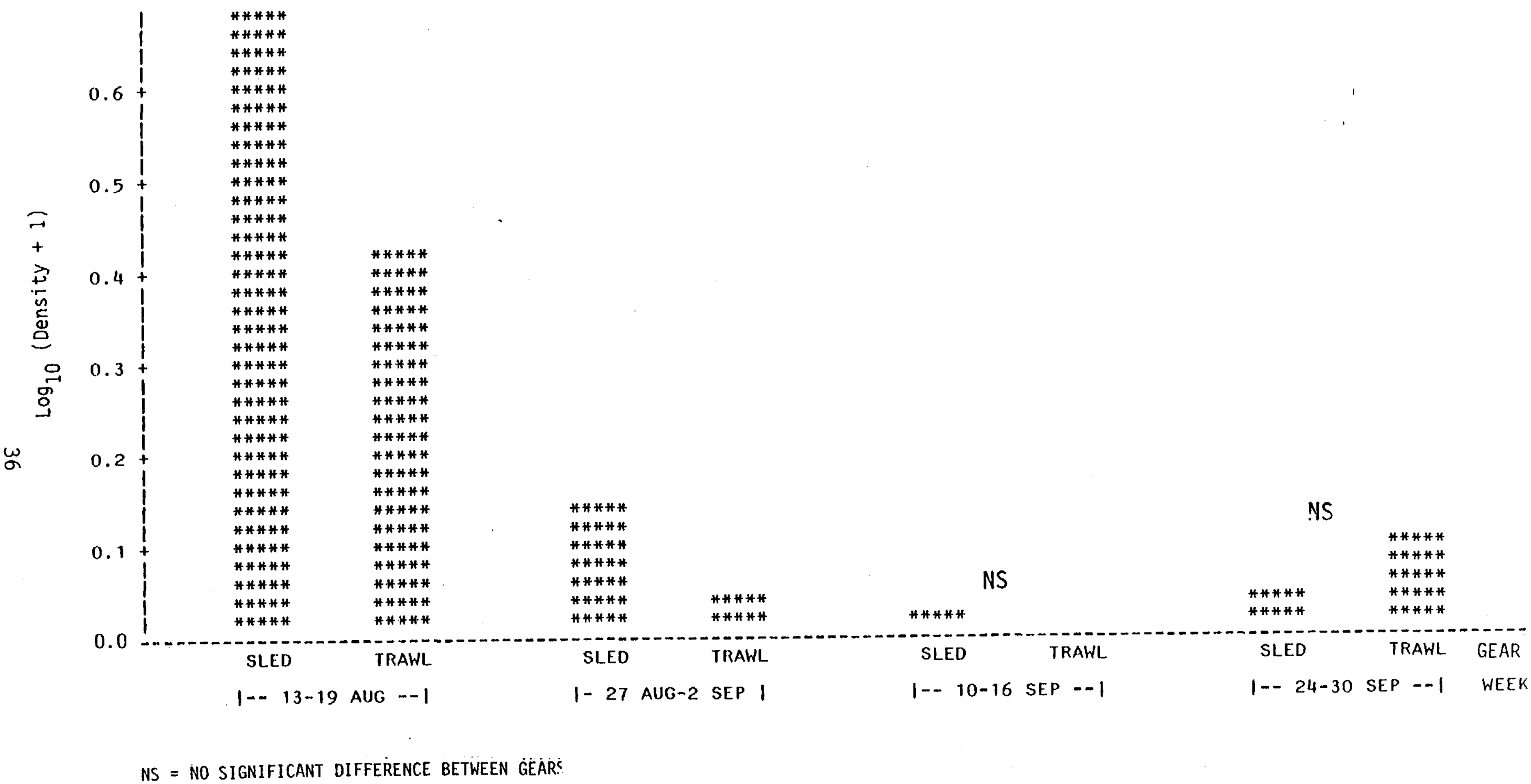


Figure 9. Interaction between gear type (Trawl = 3 m Beam Trawl, Sled = 1.0 m^2 Epibenthic Sled) and sampling week (13-19 August, 27 August-2 September, 10-16 September, and 24-30 September 1984) for young of the year weakfish, volumetric density.

YOY Bay Anchovy

The epibenthic sled estimated significantly ($p<0.05$) higher mean YOY bay anchovy densities than the beam trawl during all sampling weeks (Figure 7; Appendix Table 27). The highest YOY bay anchovy mean density estimate was observed in the epibenthic sled during week 4 (24-30 September 1984), and the lowest mean density was from the beam trawl during week 1 (13-19 August 1984). Beam trawl catches of bay anchovy increased significantly ($p<0.05$) between week 1 and week 4 suggesting size selectivity became less significant as the study progressed, perhaps due to seasonal growth of YOY bay anchovies.

YOY American Shad

Mean density for YOY American shad was significantly ($p<0.05$) greater based on epibenthic sled samples than from beam trawl samples during the first two sampling weeks (Figure 8; Appendix Table 27). Mean densities were not significantly different between gear during the last two weeks of sampling.

YOY Weakfish

YOY weakfish mean densities were highest during week 1 (13-19 August 1984), and significantly ($p<0.05$) higher based on the epibenthic sled than from the beam trawl during the first two sampling weeks (Figure 9; Appendix Table 27). During the last two sampling weeks, mean densities were not significantly different between gear and were significantly lower than from the first sampling week.

4.2.4 Relative Catch Efficiency

Overall mean density of YOY striped bass based on beam trawl samples was approximately 4 times larger and 2 times more precise than mean density based on epibenthic sled samples (Table 10) for both areal and volumetric density estimates. The 1984 relative catch efficiency for the beam trawl was similar to the 1983 value but less than relative catch efficiency for 1980. The 1984 relative precision was approximately one-third less than in 1983 or 1980 (Table 10). Differences between 1984 and previous years may be related to the non-random sampling design in 1984 which selected sampling sites in regions of high striped bass density. Therefore, relative catch efficiency and precision for 1980 and 1983 likely reflect the expected efficiency and precision for a long river program based on random allocation of beam trawl samples.

4.3 COMBINED STANDING CROP

Beam trawl standing crop estimates were higher than those based on epibenthic sled samples for both shoal and regional estimates from lower Hudson River regions during October 1983 and August-September 1984 (Tables 11 and 12). One exception occurred; during the week of 3-9 October 1983 in Croton-Haverstraw, the epibenthic sled shoal and regional combined standing crop estimates were slightly higher than estimates based on the beam trawl. This anomaly may have resulted from a miss match in the timing of sampling since the epibenthic sled sampled in the Croton-Haverstraw region during the first part of the sampling week (5 October 1983) while the beam trawl sampled this region during the last part of the week (9 October 1983) and may not have been exposed to the same striped bass population. This phenomenon may also be the result of the method for estimating beam trawl sample unit size in 1983 (NAI 1985c) which produced slightly higher volumetric densities (lower sample volume estimates) than when sample volume was empirically measured in 1984 (Sections 3.3 and 4.2.1).

TABLE 10. RELATIVE CATCH EFFICIENCY AND RELATIVE PRECISION OF YOUNG OF THE YEAR STRIPED BASS MEAN DENSITY ESTIMATES FROM A 3 m BEAM TRAWL COMPARED WITH A 1.0 m^2 EPIBENTHIC SLED, LOWER HUDSON RIVER ESTUARY, SEPTEMBER 1980, OCTOBER 1983, AND AUGUST-SEPTEMBER 1984.

GEAR	YEAR [a]	N [b]	DENSITY MEAN ± S.E. (c)	RELATIVE CATCH EFFICIENCY (d)	PRECISION C.V. (%) (e)	RELATIVE PRECISION (f)
DENSITY AS N per 1000 m^2						
1.0 m^2 Epibenthic Sled	1980	45	0.8 ± 0.4	1.0	50.0	1.0
	1983	107	1.2 ± 0.4	1.0	33.3	1.0
	1984	322	3.4 ± 0.4	1.0	11.8	1.0
3 m Beam Trawl	1980	40	4.3 ± 0.7	5.4	16.3	3.1
	1983	80	4.6 ± 0.5	3.8	10.9	3.1
	1984	257	13.3 ± 0.8	3.9	6.0	2.0
DENSITY AS N per 1000 m^3						
1.0 m^2 Epibenthic Sled	1980	45	0.8 ± 0.4	1.0	50.0	1.0
	1983	107	1.2 ± 0.4	1.0	33.3	1.0
	1984	322	3.2 ± 0.4	1.0	12.5	1.0
3 m Beam Trawl	1980	40	7.5 ± 1.3	9.4	16.3	3.1
	1983	80	7.0 ± 0.8	5.8	10.9	3.1
	1984	257	12.9 ± 0.8	4.0	6.2	2.0

(a) 1980 data from NAI, 1982
1983 data from NAI, 1985b
1984 data from the present study

(b) N = number of samples

(c) Mean ± S.E. - mean density ± standard error of mean density

(d) Relative catch efficiency = within year trawl mean sled mean

(e) C.V. = coefficient of variation = S.E. mean × 100.

(f) Relative precision = sled C.V. within year sled or trawl C.V.

TABLE 11. CONTRIBUTION OF 1.0 m^2 EPIBENTHIC SLED OR 3 m BEAM TRAWL SHOAL SAMPLES TO COMBINED STANDING CROP ESTIMATES (IN THOUSANDS) OF YOUNG OF THE YEAR STRIPED BASS IN THE TAPPAN ZEE (TZ) OR CROTON-HAVERSTRAW (CH) REGIONS OF THE HUDSON RIVER ESTUARY, OCTOBER 1983.

		ASSUMED GEAR COLLECTION EFFICIENCY		SHOAL STANDING CROP				REGIONAL COMBINED STANDING CROP			
				EPIBENTHIC SLED		BEAM TRAWL		EPIBENTHIC SLED		BEAM TRAWL	
WEEK	RIVER REGION	EPIBENTHIC SLED OR BEAM TRAWL	TUCKER TRAWL	TOTAL	S.E.	TOTAL	S.E.	TOTAL	S.E.	TOTAL	S.E.
3-9 OCT 1983	TZ	0.5	*	59	47	1552	313	4134	1766	5628	1793
		0.1	*	295	234	7761	1564	8049	4407	15515	4670
		0.01	*	2945	2336	77611	15642	52085	41237	126751	44042
	CH	0.5	*	522	193	351	80	3163	934	2992	917
		0.1	*	2612	964	1757	400	7319	1733	6464	1495
		0.01	*	26116	9642	17569	3996	54076	14929	45530	12077
17-23 OCT 1983	TZ	0.5	*	16	16	1238	290	334	178	1555	340
		0.1	*	82	82	6190	1448	400	196	6508	1459
		0.01	*	824	824	61904	14483	1141	843	62221	14484
	CH	0.5	*	13	13	725	126	1349	535	2061	549
		0.1	*	65	65	3626	629	1401	539	4962	826
		0.01	*	654	654	36261	6294	1989	844	37597	6317

LEGEND:

* = No fish were caught by the Tucker trawl
Total = Standing crop in thousands of fish
S.E. = Standard Error of standing crop.

TABLE 12. CONTRIBUTION OF 1.0 m^2 EPIBENTHIC SLED OR 3 m BEAM TRAWL SHOAL SAMPLES TO COMBINED STANDING CROP ESTIMATES (IN THOUSANDS) OF YOUNG OF THE YEAR STRIPED BASS IN THE CROTON-HAVERSTRAW (CH) REGION OF THE HUDSON RIVER ESTUARY, AUGUST-SEPTEMBER 1984.

		ASSUMED GEAR COLLECTION EFFICIENCY		SHOAL STANDING CROP				REGIONAL COMBINED STANDING CROP			
				EPIBENTHIC SLED		BEAM TRAWL		EPIBENTHIC SLED		BEAM TRAWL	
WEEK	RIVER REGION	EPIBENTHIC SLED OR BEAM TRAWL	TUCKER TRAWL	TOTAL	S.E.	TOTAL	S.E.	TOTAL	S.E.	TOTAL	S.E.
13-19 AUG 1984	CH	0.5	*	425	62	1762	128	2268	637	3605	647
		0.1	*	2126	308	8808	639	4132	717	10815	910
		0.01	*	21256	3080	88083	6392	25104	3424	91931	6564
27 AUG-2 SEP 1984	CH	0.5	0.5	366	96	960	153	3828	1434	4422	1439
			0.1	366	96	960	153	4262	1529	4856	1534
			0.01	366	96	960	153	9140	5606	9734	5607
	CH	0.1	0.5	1831	478	4800	764	5835	1559	8804	1669
			0.1	1831	478	4800	764	6269	1647	9238	1752
			0.01	1831	478	4800	764	11147	5639	14116	5670
	CH	0.01	0.5	18310	4781	48000	7638	28418	6406	58108	8747
			0.1	18310	4781	48000	7638	28852	6428	58542	8764
			0.01	18310	4781	48000	7638	33730	8391	63420	10290
10-16 SEP 1984	CH	0.5	*	94	22	440	73	4240	1171	4585	1173
		0.1	*	471	111	2200	367	7296	1475	9026	1516
		0.01	*	4705	1114	21999	3671	41687	9225	58980	9866
24-30 SEP 1984	CH	0.5	*	326	87	1264	114	13569	6763	14507	6763
		0.1	*	1632	437	6320	571	16553	6906	21241	6916
		0.01	*	16324	4372	63203	5711	50118	15795	96998	16217

LEGEND:

* = No fish were caught by the Tucker trawl
Total = Standing crop in thousands of fish
S.E. = Standard Error of standing crop.

Standing crops also varied substantially depending on the assumed gear collection efficiency. As a result of direct scaling, shoal standing crops increased by five times if an assumed collection efficiency of 0.1 was used instead of 0.5, by ten times if 0.01 was used instead of 0.1, and by fifty times if an assumed collection efficiency of 0.01 was used instead of 0.5.

However, direct scaling did not predict the magnitude of change for shoal or regional combined standing crop based on the three assumed collection efficiency values because: 1) the shoal stratum standing crop involves two strata (shore and shoal) and is dependent on density estimates from both beach seine (shore) and epibenthic sled or beam trawl samples (shoal), and 2) regional estimates are based on the contribution of four strata (shore, shoal, bottom and channel) in various combinations. Since the shoal represents a smaller proportion of the regional standing crop, the effect of the beam trawl is less than its effect on the shoal standing crop. The contribution of either the epibenthic sled or beam trawl was therefore proportional to differences in distribution (density) of YOY striped bass among strata. Higher density of fish in the shoals would contribute proportionally more to the standing crop estimate and therefore differences in density estimates between gear would result in greater changes in shoal or regional standing crops.

Shoal standing crop estimates based on beam trawl samples were between 0.7 and 77.4 times higher than estimates based on epibenthic sled samples, and were between 1.4 and 5.8 times more precise (Table 13). Regional combined standing crop estimates based on beam trawl samples were between 0.9 and 4.7 times higher than values based on epibenthic sled samples, and were between 1.0 and 2.4 times more precise (Table 13). The greatest variation in relative standing crop and relative precision was observed between weeks and regions in 1983. This variation is probably more representative of differences between gear than the variation observed in 1984, because the 1983 shoal samples were

TABLE 13. RELATIVE CONTRIBUTION OF 3 m BEAM TRAWL SHOAL SAMPLES (COMPARED TO 1.0 m^2 EPIBENTHIC SLED SAMPLES) TO THE ACCURACY AND PRECISION OF YOUNG OF THE YEAR STRIPED BASS STANDING CROP ESTIMATES FROM REGIONS OF THE LOWER HUDSON RIVER ESTUARY (TAPPAN ZEE, RIVER KILOMETERS 39-54; CROTON-HAVERSTRAW, RIVER KILOMETERS 55-62), DURING OCTOBER 1983 AND AUGUST-SEPTEMBER 1984.

		RELATIVE STANDING CROP (a)		RELATIVE PRECISION (b)	
SAMPLING WEEK	RIVER REGION	SHOAL	REGION	SHOAL	REGION
3-9 Oct 1983	Tappan Zee	26.3	1.4	3.9	1.3
	Croton-Haverstraw	0.7	0.9	1.6	1.0
17-23 Oct 1983	Tappan Zee	77.4	4.7	4.3	2.4
	Croton-Haverstraw	55.8	1.5	5.8	1.5
13-19 Aug 1984	Croton-Haverstraw	4.1	1.6	2.0	1.5
27 Aug - 2 Sep 1984	Croton-Haverstraw	2.6	1.2	1.6	1.2
10-16 Sep 1984	Croton-Haverstraw	4.7	1.1	1.4	1.1
24-30 Sep 1984	Croton-Haverstraw	3.9	1.1	3.0	1.1

(a) Relative standing crop = Beam trawl standing crop ÷ epibenthic sled standing crop for shoal or regional standing crop within each sampling week, holding gear collection efficiency constant.

(b) Relative precision = Coefficient of variation (C.V.) for epibenthic standing crop ÷ C.V. for beam trawl standing crop.

C.V. = Standard error ÷ standing crop x 100 (Cochran 1977).

collected from randomly allocated sampling sites (NAI 1985c) while the 1984 program sampled continually in regions of high YOY striped bass abundance (Section 3.2).

5.0 GENERAL DISCUSSION

In the first sampling week of this study the 1.0 m^2 epibenthic sled was observed to catch a significantly higher proportion of striped bass less than 50 mm TL and a significantly lower proportion of striped bass greater than 70 mm TL compared with the 3 m beam trawl (Section 4.1). In the remaining three sampling weeks of the study, significant size selectivity differences were not observed between the two gear. The significantly higher proportion of small striped bass caught by the epibenthic sled in the first sampling week could be due to fewer fish caught and measured by the sled, the sled exhibiting size selectivity towards smaller fish and the beam trawl exhibiting size selectivity towards larger fish, or one of the two gear exhibiting size selectivity and the other not. The overall size range of striped bass caught by the epibenthic sled was only 32 mm TL to 79 mm TL during the first sampling week, while the beam trawl caught bass ranging between 34 mm TL and 110 mm TL during the same week (Table 4). The relatively higher proportion of small fish ($\leq$50 mm TL) caught by the epibenthic sled appears to result from a small sample size (only 132 fish were caught and measured from the sled while 1470 fish were caught and measured from the beam trawl) and from catching fish over a smaller size range than the beam trawl. Therefore, the beam trawl provides a more accurate description of YOY striped bass length frequency distribution than the epibenthic sled because of a larger sample size.

Although significant size selectivity differences were observed for striped bass between the 3 m beam trawl and 1.0 m^2 epibenthic sled during the first sampling week in 1984 (Table 5; Figure 2), the beam trawl mean YOY striped bass density was significantly higher than the epibenthic sled mean density during that week (Table 9, Figure 6; Appendix Table 27). Striped bass mean densities (areal or volumetric) were approximately 4 times higher based on the beam trawl than mean densities based on the epibenthic sled during the week of

13-19 August 1984, and the beam trawl estimates were approximately 2 times more precise (Table 14). Furthermore, the mean density of striped bass less than 51 mm TL was 2.1 fish per 1000 m^3 ($\pm$ 0.2 S.E.) from beam trawl samples and only 1.1 fish per 1000 m^3 ($\pm$ 0.3 S.E.) from the epibenthic sled. Therefore, although the epibenthic sled caught proportionally more small (<51 mm TL) striped bass compared to the beam trawl, the greater catch efficiency of the beam trawl resulted in higher density estimates for even the smallest fish.

Two possible explanations exist for observed differences in catch efficiency between the two trawls:

1) mesh size selectivity and extrusion of small fish (Clutter and Anraku 1968), and

2) gear avoidance related to net mouth dimensions, gear orientation, and detection distance (Barkley 1972).

Consistently higher YOY striped bass density estimates by the 3 m beam trawl compared with the 1.0 m^2 epibenthic sled cannot be explained by mesh size selectivity since the gear with the largest mesh also had the highest catch efficiency. Avoidance of the epibenthic sled by YOY striped bass can explain significant differences in catch efficiency between the gear. The epibenthic sled has a small mouth opening and relatively fine mesh netting which would increase the detection distance and reduce the escape distance of fish, thus maximizing the escape probability (Barkley 1972) relative to the beam trawl. Avoidance of the epibenthic sled may also be greater than the beam trawl because the sled net is rigidly mounted on a frame which positions the mouth opening approximately 0.3 m above the river bottom (Appendix Figure 2) and may permit fish escapement under the net, while the cookie sweep of the beam trawl maintains contact with the river bottom while fishing and would not permit escapement under the net.

TABLE 14. WEEKLY VARIATION IN YOUNG OF THE YEAR STRIPED BASS DENSITY ESTIMATES AND OCCURRENCE OF ZERO-CATCH SAMPLES FOR 1.0 m^2 EPIBENTHIC SLED AND 3 m BEAM TRAWL SAMPLES FROM THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76) DURING AUGUST-SEPTEMBER 1984.

			AREAL DENSITY			VOLUMETRIC DENSITY			ZERO SAMPLES	
1984 WEEK	GEAR	NUMBER OF TOWS	MEAN	S.E.	C.V.	MEAN	S.E.	C.V.	N	%
13-19 Aug	Epibenthic Sled	61	5.2	0.8	15.4	4.8	0.7	14.6	20	32.8
	Beam Trawl	55	22.1	1.5	6.8	22.5	1.5	6.7	1	1.8
27 Aug-2 Sep	Epibenthic Sled	74	4.2	1.1	26.2	4.3	1.1	25.6	41	55.4
	Beam Trawl	70	11.3	1.8	15.9	11.1	1.8	16.2	6	8.6
10-16 Sep	Epibenthic Sled	121	1.3	0.3	23.1	1.3	0.3	23.1	92	76.0
	Beam Trawl	74	5.5	0.9	16.4	5.4	0.9	16.7	19	25.7
24-30 Sep	Epibenthic Sled	66	4.4	1.3	29.5	4.0	1.1	27.5	33	50.0
	Beam Trawl	58	17.1	1.6	9.4	15.6	1.4	8.9	0	0.0
13 Aug-30 Sep	Epibenthic Sled	322	3.4	0.4	11.8	3.2	0.4	12.5	186	57.8
	Beam Trawl	257	13.3	0.8	6.0	12.9	0.8	6.2	26	10.1

LEGEND:

Areal density = Number of fish per 1000 m^2
Volumetric density = Number of fish per 1000 m^3
S.E. = Standard error of mean density
C.V. = Coefficient of variation = S.E. ÷ *mean* density × 100
N = Number of zero samples; % = percent of zero samples

Adjustment of the beam trawl catch based on the observed proportion of striped bass less than 51 mm TL in the epibenthic sled catch would result in an increase in mean density of approximately 14.2% during the week of 13-19 August 1984 (based on the differences in expected values calculated for the 31-40 and 41-50 mm length groups, Table 5). This adjustment is not recommended, however, because 1) the observed differences were based on a relatively small sample size of fish for the epibenthic sled (132 fish for the sled vs 1470 fish for the beam trawl) and 2) a 14.2% adjustment is more than one order of magnitude smaller than the percent difference between unadjusted mean densities and relatively insignificant with respect to weekly sampling variation (Table 14).

The overall accuracy and precision of regional and riverwide combined standing crop estimates may be strongly influenced by a high frequency of zero-catch samples. For example, the lowest standing crop values were observed in the week of 17-23 October 1983 in the Tappan Zee and Croton-Haverstraw river regions (Table 11) which resulted in the greatest relative standing crop and relative precision for the beam trawl (Table 13). In each of these river regions, the epibenthic sled only caught one YOY striped bass and no fish were present in the shore zone. One fish accounted for a standing crop of 16,000 fish in the Tappan Zee shoal stratum and 13,000 fish in the Croton-Haverstraw shoal stratum (Table 11). Yet clearly fish were present in greater density than estimated by the epibenthic sled, as observed by the increase in standing crop and precision of beam trawl samples (Tables 11, 13 and 14). If a similar situation occurred in other regions and strata, a substantial underestimate of striped bass combined standing crop could result. Strata and regions with low densities are particularly vulnerable to underestimate, and cannot always be scaled by a relative catch efficiency factor.

If the epibenthic sled data were adjusted by the relative catch efficiency of the beam trawl, standing crop for the week of 17-23 October 1983 in the shoal strata of the Tappan Zee and Croton-Haverstraw river regions, each standing crop would be multiplied by 5.8 (Table 10). However, if no YOY striped bass were caught instead of one fish in each region, the standing crop adjusted for collection efficiency would still be zero. The beam trawl has exhibited a substantially lower frequency of zero catches in 1983 (NAI, 1985c) and in the present study (Tables 8 and 14) and should minimize this source of inaccuracy in riverwide and regional standing crop estimates. Clearly, if the objective of a program is to accurately and precisely estimate the abundance of YOY striped bass (approximately 50 to 150 mm TL), the beam trawl is the most efficient sampling gear.

6.0 LITERATURE CITED

Barkley, R.A. 1972. Selectivity of towed-net samplers. Fishery Bull. 70(3):799-820.

Clutter, R.I. and M. Anraku. 1968. Avoidance of samplers. In: D.J. Tranter (Ed.), Part I, Reviews on zooplankton sampling methods, p. 57-76. UNESCO Monogr. Oceanogr. Methodol. 2, Zooplankton sampling.

Cochran, W.G. 1977. Sampling techniques, 3rd edition. John Wiley & Sons, NY. 428 p.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley & Sons, Inc., NY. 257 p.

Neter, J. and W. Wasserman. 1974. Applied Linear Statistical Models. Richard D. Irwin, Inc. Homewood. 842 p.

Normandeau Associates, Inc. 1982. Optimum deployment and relative catch efficiency of a 3 m beam trawl for quantitative fisheries sampling in the Hudson River estuary. Prepared for New York Power Authority.

__________. 1985a. 1982 Year Class Report for the Hudson River Estuary Monitoring Program. Prepared for Consolidated Edison Company of New York, Inc.

__________. 1985b. 1983 Year Class Report for the Hudson River Estuary Monitoring Program. Prepared for Consolidated Edison Company of New York, Inc.

__________. 1985c. Relative catch efficiency of a 3 m beam trawl, a 6.2 m high-rise trawl and a 1.0 m^2 epibenthic sled for sampling young of the year striped bass and other fishes in the Hudson River estuary. Prepared for New York Power Authority.

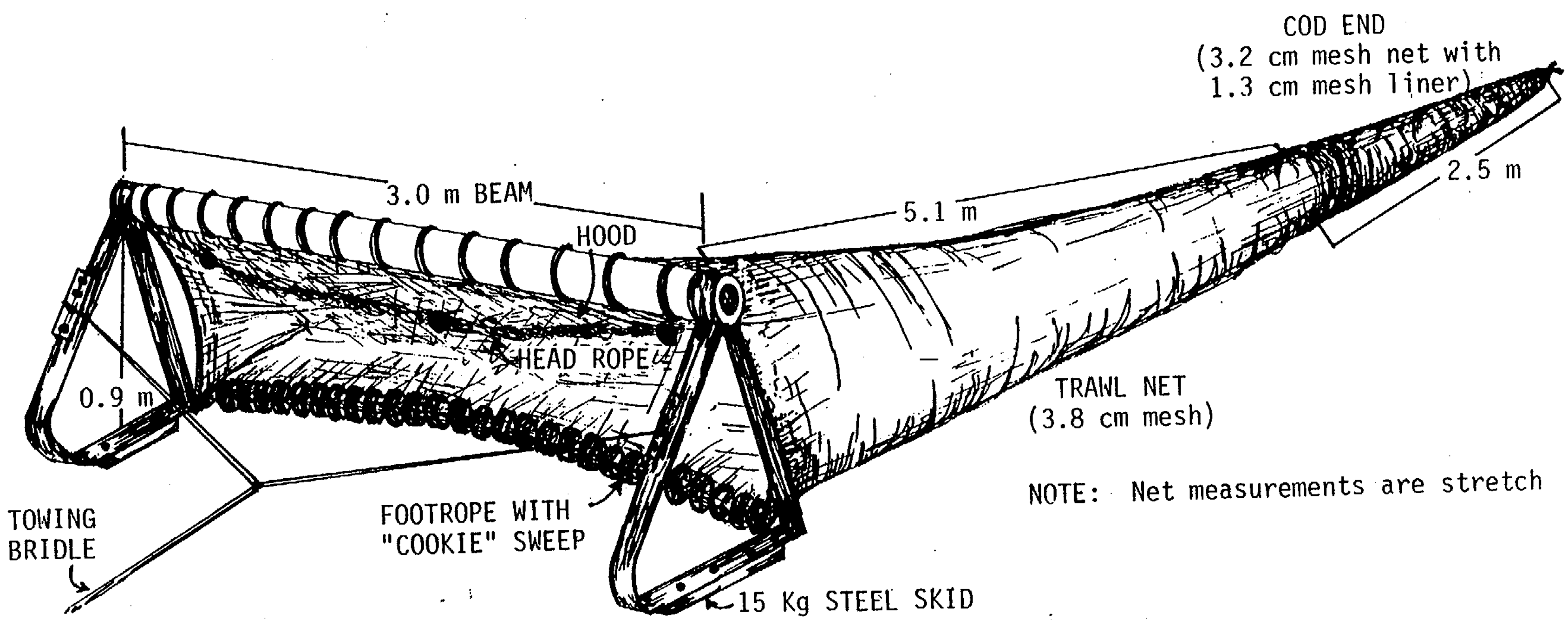
SAS Institute Inc. 1982. SAS User's Guide: Statistics, 1982 Edition/ SAS Institute, Cary, North Carolina. 584 pp.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. W.H. Freeman and Company, San Francisco. 859 pp.

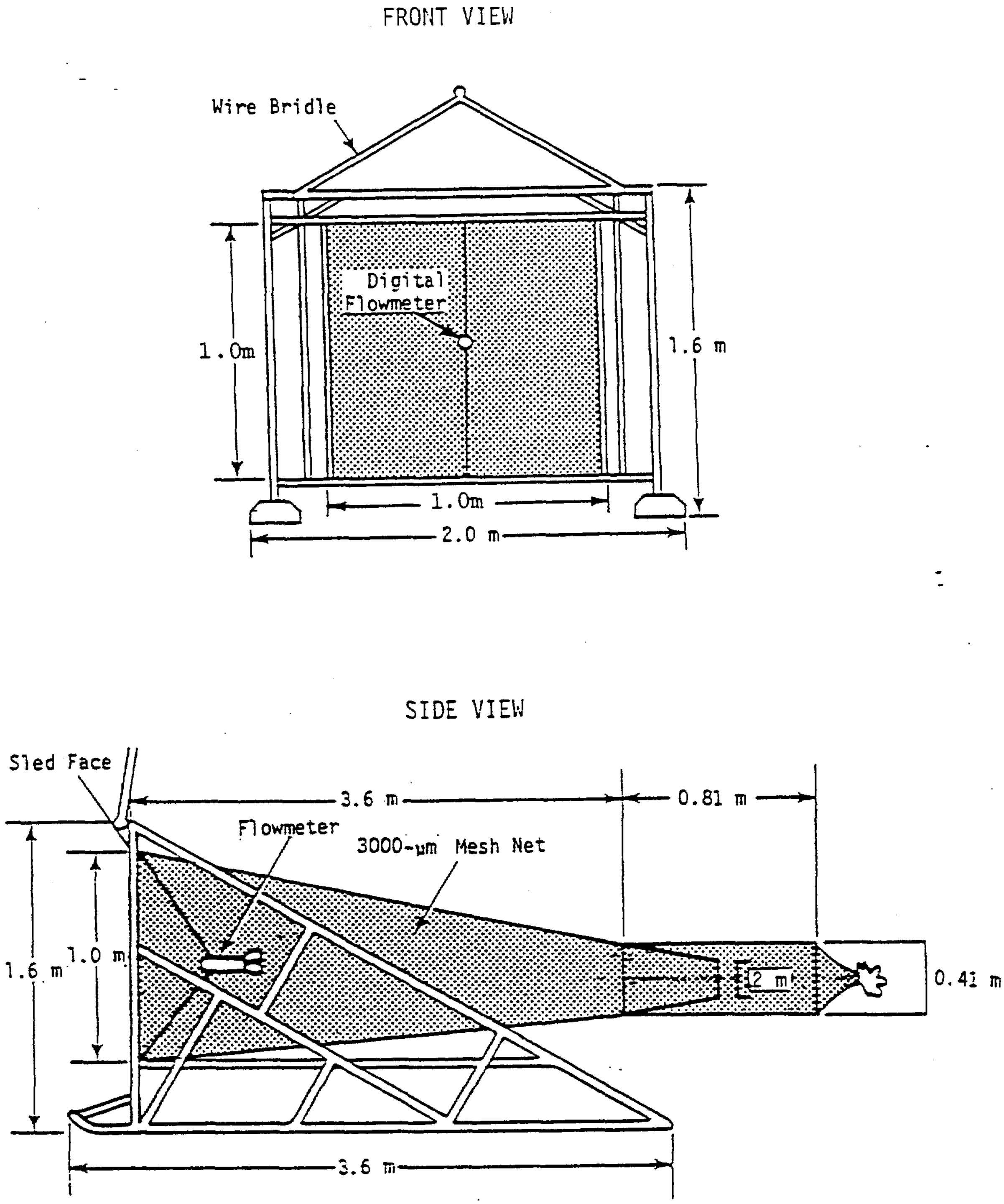
Texas Instruments Incorporated. 1980. Report on 1978-1979 studies to evaluate catch efficiency of the 1.0 m^2 epibenthic sled. Prepared for Consolidated Edison Company of New York, Inc.

__________. 1981. 1979 Year Class Report for the Multiplant Impact Study of the Hudson River Estuary. Prepared for Consolidated Edison Company of New York, Inc.

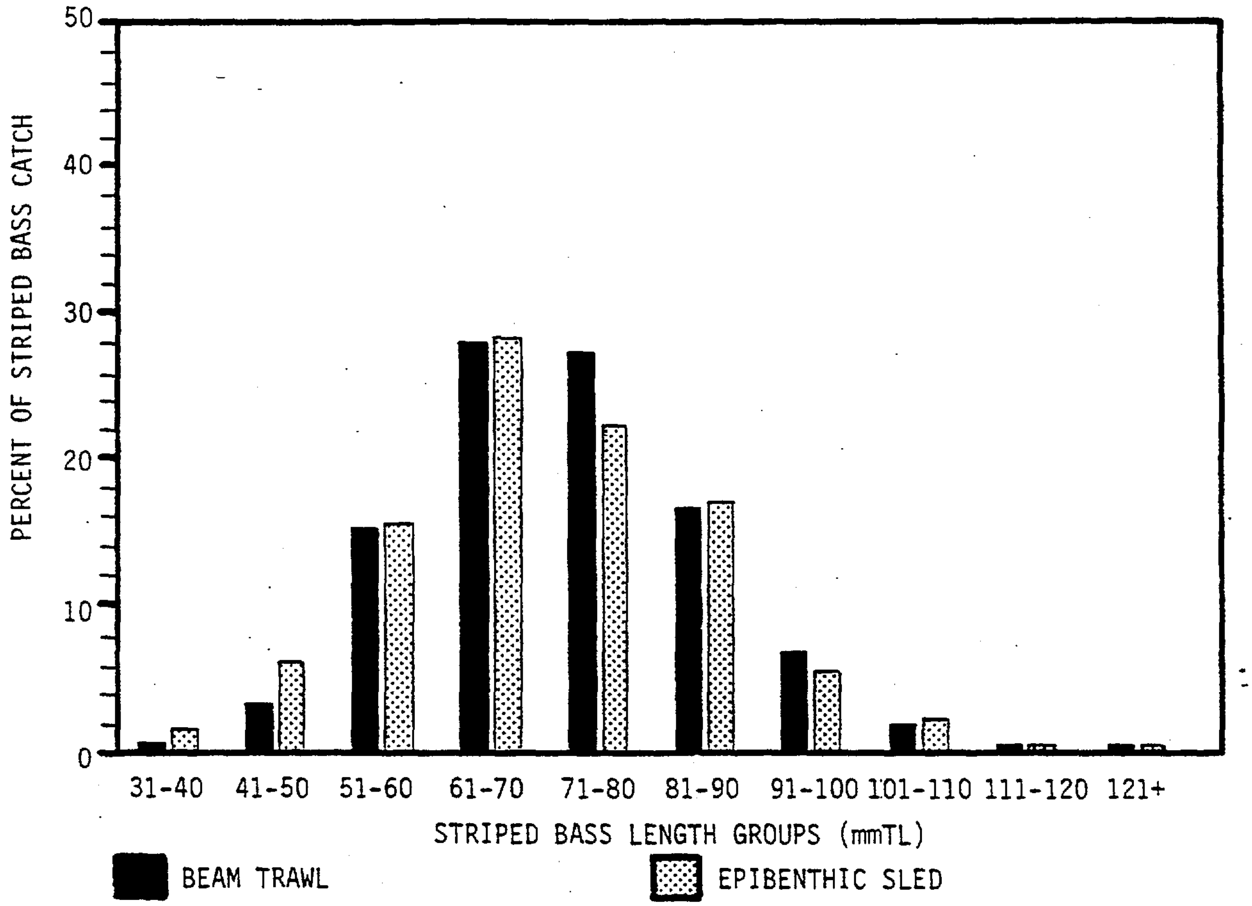
APPENDIX



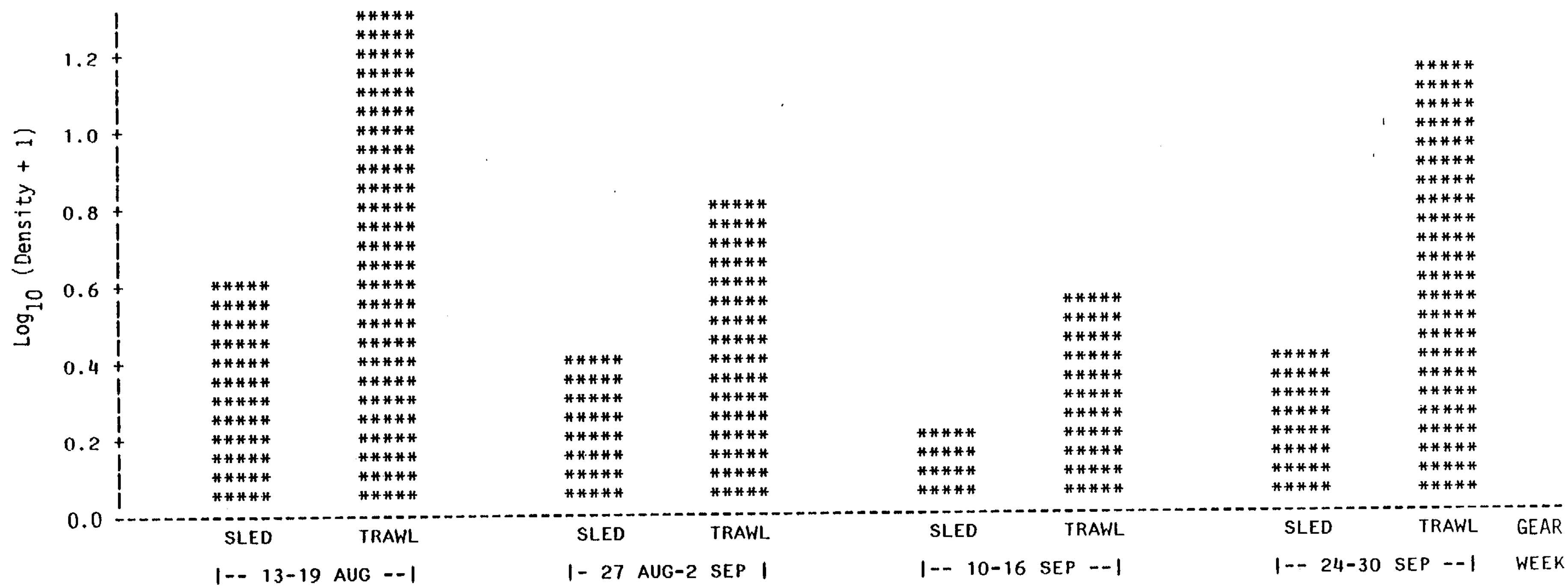
Appendix Figure 1. Schematic of the 3.0 meter beam trawl.



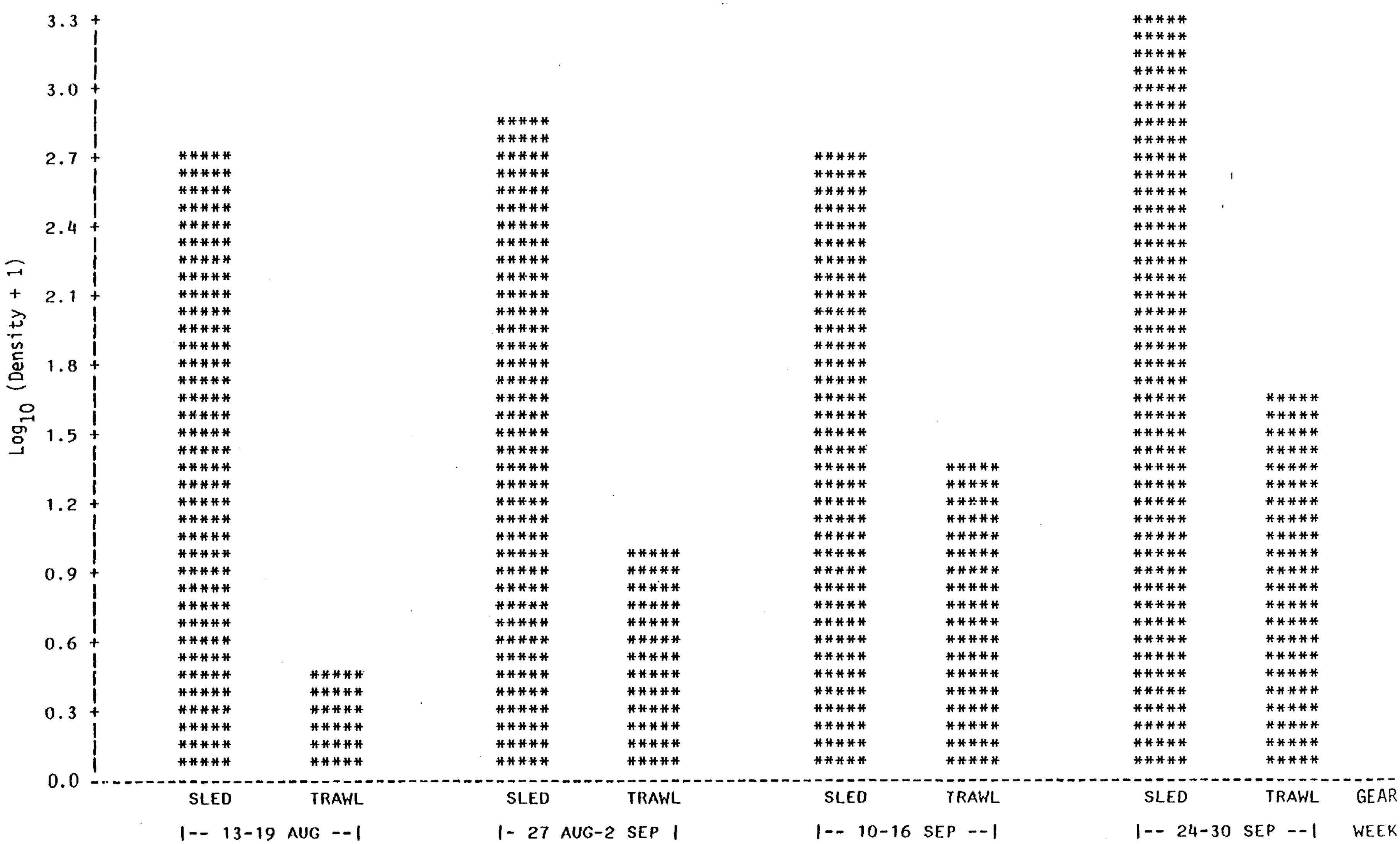
Appendix Figure 2. 1.0 m^2 Epibenthic Sled.



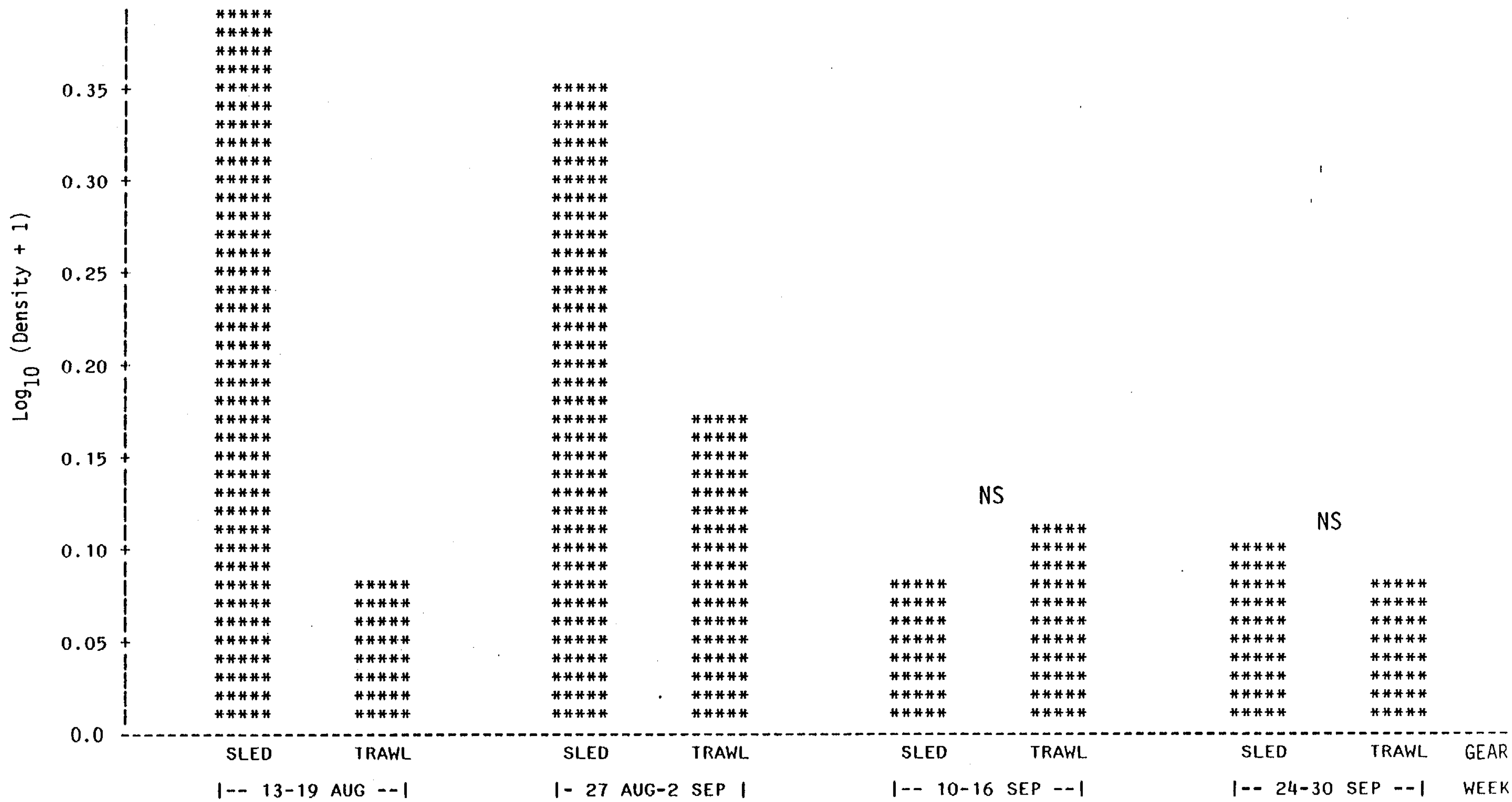
Appendix Figure 3. Composite Length-Frequency distribution for striped bass collected by a 3 m Beam Trawl and a 1.0 m^2 Epibenthic Sled in the lower Hudson River estuary (River Kilometers 39-76) during the weeks of 13 August - 30 September 1984. The Number of striped bass measured for each gear were: 4261 for the Beam Trawl and 462 for the Epibenthic Sled.



Appendix Figure 4. Interaction between gear type (Trawl = 3 m Beam Trawl, Sled = 1.0 m^2 Epibenthic Sled) and sampling week (13-19 August, 27 August-2 September, 10-16 September, and 24-30 September 1984) for young of the year striped bass, areal density.

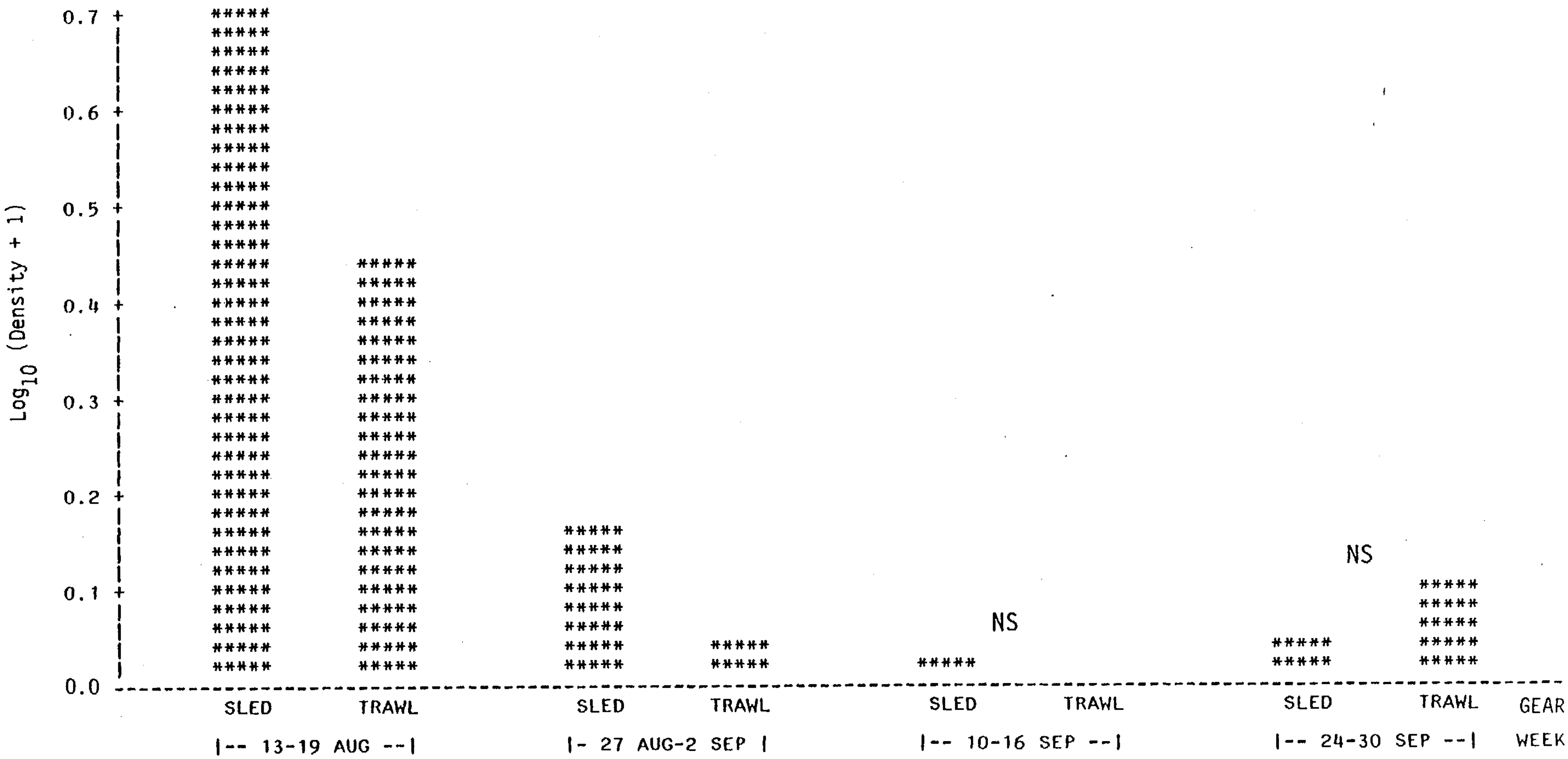


Appendix Figure 5. Interaction between gear type (Trawl = 3 m Beam Trawl, Sled = 1.0 m^2 Epibenthic Sled) and sampling week (13-19 August, 27 August-2 September, 10-16 September, and 24-30 September 1984) for young of the year bay anchovy, areal density.



NS = NO SIGNIFIGANT DIFFERENCE BETWEEN GEAR

Appendix Figure 6. Interaction between gear type (Trawl = 3 m Beam Trawl, Sled = 1.0 m^2 Epibenthic Sled) and sampling week (13-19 August, 27 August-2 September, 10-16 September, and 24-30 September 1984) for young of the year American shad areal density.



NS = NO SIGNIFIGANT DIFFERENCE BETWEEN GEAR

Appendix Figure 7. Interaction between gear tupe (Trawl = 3 m Beam Trawl, Sled = 1.0 m^2 Epibenthic Sled) and sampling week (13-19 August, 27 August-2 September, 10-16 September, and 24-30 September 1984) for young of the year weakfish, areal density.

APPENDIX TABLE 1. *R/V FRITCHER* SAMPLING VESSEL USED TO DEPLOY THE 3 m BEAM TRAWL.

R/V FRITCHER

Manufacturer:	Baldwinville Boat Yard, Baldwinville, New York
Year:	1977
LOA:	31 feet 10 inches
Weight:	8.5 tons
Beam:	11 feet 3 inches
Draft:	4 feet
Fuel Tanks:	2 - 100 gallon
Power:	GM 453 Diesel, 100 hp
Hull:	Steel

- Borg Warner Gear Box
- Hancock 18 inch Double Drum Hydro Winch w/Horizontal Capstan
- Mast is 15'4" high
- 2 Booms - each 10'4"
- A-Frame - Approx. each leg is 12.5 feet long positioned 5'2" from Stern
- Closed Cycle 20-gallon capacity-keel cooled

APPENDIX TABLE 2. *R/V WOODY I* SAMPLING VESSEL USED TO DEPLOY THE 1.0 m^2 EPIBENTHIC SLED.

R/V WOODY I

Manufacturer:	Bruno Stillman Inc., Newington, NH
Year:	1979
LOA:	42 feet
Weight:	9 tons
Beam:	12 feet 3 inches
Draft:	4 feet
Fuel Tanks:	Fore-200 gallon, Aft-100 gallon
Power:	3306 Turbo-charged Caterpillar Diesel

- Single Screw
- Twin disk reverse gear
- 2 single drum Down East Marine Engineering Hydro winches with horizontal capstans
- Mast with booms
- Open cooling system

APPENDIX TABLE 3. COMMON AND SCIENTIFIC NAMES, AND CUT-OFF LENGTHS USED TO SEPARATE YOUNG OF THE YEAR, YEARLING, AND OLDER FISH COLLECTED IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), AUGUST - SEPTEMBER 1984.

		WEEK 1 (13-19 AUG 84)		WEEK 2 (27 AUG-2 SEP 84)		WEEK 3 (10-16 SEP 84)		WEEK 4 (24-30 SEP 84)	
SCIENTIFIC NAME	COMMON NAME	DIV 1[a]	DIV 2[b]	DIV 1[a]	DIV 2[b]	DIV 1	DIV 2	DIV 1	DIV 2
Anchoa mitchilli	Bay anchovy	60	150	60	150	70	150	70	150
Alosa sapidissima	American shad	130	200	130	200	130	230	130	230
Pomatomus saltatrix	Bluefish	300	350	300	350	350	350	350	350
Ictalurus nebulosus	Brown bullhead	80	150	100	150	100	150	100	150
Lepomis gibbosus	Pumpkinseed	60	150	60	150	70	150	70	150
Cyprinus carpio	Carp	90	150	100	150	120	150	120	150
Anguilla rostrata	American eel	20	150	20	150	20	150	20	150
Trinectes maculatus	Hogchoker	35	150	40	150	50	150	50	150
Etheostoma olmstedi	Tessellated darter	65	150	70	150	70	150	75	150
Brevoortia tyrannus	Atlantic menhaden	180	180	180	180	180	180	180	180
Alosa aestivalis	Blueback herring	110	160	110	160	110	180	110	180
Osmerus mordax	Rainbow smelt	80	150	80	150	80	150	80	150
Acipencer oxyrhynchus	Atlantic sturgeon	100	200	125	200	125	200	125	200
Morone saxatilis	Striped bass	110	175	110	200	120	200	140	200
Microgadus tomcod	Atlantic tomcod	140	235	140	235	150	235	150	235
Ictalurus catus	White catfish	80	150	100	150	100	150	100	150
Morone americana	White perch	85	120	85	120	90	135	90	135
Perca flavescens	Yellow Perch	95	160	95	160	95	160	100	160
Syngnathus fuscus	Northern pipefish	120	150	120	150	120	150	150	150
Caranx hippos	Crevalle jack	100	150	120	150	120	150	120	150
Cynoscion regalis	Weakfish	120	225	175	225	175	225	200	225
Selene vomer	Lookdown	80	150	100	150	100	150	100	150
Menidia beryllina	Tidewater silverside	50	150	60	150	60	150	60	150
Peprilus triacanthus	Butterfish	60	150	100	150	100	150	100	150
Membras martinica	Rough silverside	60	150	75	150	75	150	75	150
Paralichthys dentatus	Summer flounder	100	150	125	150	125	150	125	150
Prionotus evolans	Striped searobin	80	150	120	150	120	150	150	150

a,b DIV 1 and DIV 2 represent Division 1 and Division 2 maximum total length (*in mm*). These divisions were empirically determined cut-off lengths which are intended to separate young of the year, yearling and older fish as follows:

Young of the year	0 mm to Division 1
Yearling	Division 1 + 1 mm to Division 2
Older	Division 2 + 1 mm and larger
Yearling and older	Division 1 + 1 and larger.

APPENDIX TABLE 5. STRIPED BASS LENGTH FREQUENCY DISTRIBUTION FOR 1.0 m^2 EPIBENTHIC SLED SAMPLES FROM THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), AUGUST - SEPTEMBER 1984.

LENGTH GROUP	13-19 AUG		27 AUG - 2 SEP		10-16 SEP		24-30 SEP		13 AUG - 30 SEP	
(MM TL)	N	%	N	%	N	%	N	%	N	%
31-40	7	5.30	0	0.00	0	0.00	0	0.00	7	1.52
41-50	24	18.18	4	2.61	1	1.56	0	0.00	29	6.28
51-60	40	30.30	31	20.26	1	1.56	0	0.00	72	15.58
61-70	51	38.64	59	38.56	14	21.88	7	6.19	131	28.35
71-80	10	7.58	44	28.76	25	39.06	24	21.24	103	22.29
81-90	0	0.00	13	8.50	15	23.44	51	45.13	79	17.10
91-100	0	0.00	2	1.31	5	7.81	19	16.81	26	5.63
101-110	0	0.00	0	0.00	2	3.13	9	7.96	11	2.38
111-120	0	0.00	0	0.00	1	1.56	1	0.88	2	0.43
≥ 121	0	0.00	0	0.00	0	0.00	2	1.77	2	0.43
TOTAL	132		153		64		113		462	

APPENDIX TABLE 4. STRIPED BASS LENGTH FREQUENCY DISTRIBUTION FOR 3 m BEAM TRAWL SAMPLES FROM THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), AUGUST - SEPTEMBER 1984.

LENGTH GROUP	13-19 AUG		27 AUG - 2 SEP		10-16 SEP		24-30 SEP		13 AUG - 30 SEP	
(MM TL)	N	%	N	%	N	%	N	%	N	%
31-40	18	1.22	0	0.00	0	0.00	0	0.00	18	0.42
41-50	118	8.03	19	1.70	1	0.20	0	0.00	138	3.24
51-60	420	28.57	209	18.66	14	2.86	2	0.17	645	15.14
61-70	634	43.13	398	35.54	99	20.25	57	4.82	1188	27.88
71-80	256	17.41	366	32.68	198	40.49	339	28.68	1159	27.20
81-90	17	1.16	119	10.63	131	26.79	442	37.39	709	16.64
91-100	1	0.07	8	0.71	41	8.38	249	21.07	299	7.02
101-110	6	0.41	1	0.09	5	1.02	69	5.84	81	1.90
111-120	0	0.00	0	0.00	0	0.00	21	1.78	21	0.49
≥ 121	0	0.00	0	0.00	0	0.00	3	0.25	3	0.07
TOTAL	1470		1120		489		1182		4261	

APPENDIX TABLE 6. MEAN AREAL DENSITY (individuals per 1000 m^2) AND STANDARD ERROR OF MEAN AREAL DENSITY (S.E.) FOR YOUNG OF THE YEAR, AND YEARLING AND OLDER LIFE STAGES OF FISH CAUGHT DURING NIGHT SAMPLING WITH A 3 m BEAM TRAWL AND A 1.0 m^2 EPIBENTHIC SLED IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), AUGUST - SEPTEMBER 1984.

COMMON NAME	YOUNG OF THE YEAR				YEARLING AND OLDER			
	3 m BEAM TRAWL (N=257)		1.0 m^2 EPI-BENTHIC SLED (N=322)		3 m BEAM TRAWL (N=257)		1.0 m^2 EPI-BENTHIC SLED (N=322)	
	MEAN	S.E.	MEAN	S.E.	MEAN	S.E.	MEAN	S.E.
Bay anchovy	29.0	3.0	1261.2	61.9	0.6	0.1	11.2	1.2
American shad	0.4	0.1	4.4	3.0	0.0	0.0	0.0	0.0
Bluefish	0.1	<0.1	0.3	0.1	0.0	0.0	0.0	0.0
Brown bullhead	0.0	0.0	0.0	0.0	<0.1	<0.1	<0.1	<0.1
Pumpkinseed	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0
Carp	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0
American eel	0.0	0.0	0.0	0.0	0.5	0.1	0.6	0.2
Hogchoker	0.1	<0.1	0.1	<0.1	5.4	0.4	1.5	0.2
Tessellated darter	<0.1	<0.1	<0.1	<0.1	0.0	0.0	0.0	0.0
Atlantic menhaden	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.0
Blueback herring	<0.1	<0.1	0.9	0.1	<0.1	<0.1	0.0	0.0
Rainbow smelt	0.0	0.0	<0.1	<0.1	0.0	0.0	0.0	0.0
Atlantic sturgeon	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	<0.1
Striped bass	13.3	0.8	3.4	0.4	0.2	<0.1	0.1	<0.1
Atlantic tomcod	0.1	<0.1	<0.1	<0.1	0.0	0.0	0.0	0.0
White catfish	0.0	0.0	0.0	0.0	1.6	0.2	1.0	0.1
White perch	1.3	0.2	0.1	<0.1	22.1	1.6	6.4	1.3
Yellow perch	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0
Northern pipefish	0.0	0.0	0.5	0.1	0.0	0.0	<0.1	<0.1
Crevalle jack	0.0	0.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Weakfish	0.7	0.1	1.9	0.3	0.0	0.0	0.0	0.0
Lookdown	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Tidewater silverside	0.0	0.0	0.0	0.0	<0.1	<0.1	<0.1	<0.1
Butterfish	0.0	0.0	<0.1	<0.1	0.0	0.0	<0.1	<0.1
Rough silverside	0.0	0.0	0.1	<0.1	0.0	0.0	<0.1	<0.1
Summer flounder	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0
Striped searobin	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
All Species	45.1	3.1	1272.9	61.8	30.5	1.9	20.9	2.0

APPENDIX TABLE 7. MEAN VOLUMETRIC DENSITY (individuals per 1000 m^3) AND STANDARD ERROR OF MEAN VOLUMETRIC DENSITY (S.E.) FOR YOUNG OF THE YEAR, AND YEARLING AND OLDER LIFE STAGES OF FISH CAUGHT DURING NIGHT SAMPLING WITH A 3 m BEAM TRAWL AND A 1.0 m^2 EPIBENTHIC SLED IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), AUGUST - SEPTEMBER 1984.

	YOUNG OF THE YEAR				YEARLING AND OLDER			
	3 m BEAM TRAWL (N=257)		1.0 m^2 EPIBENTHIC SLED (N=322)		3 m BEAM TRAWL (N=257)		1.0 m^2 EPIBENTHIC SLED (N=322)	
COMMON NAME	MEAN	S.E.	MEAN	S.E.	MEAN	S.E.	MEAN	S.E.
Bay anchovy	26.5	2.7	1233.2	58.3	0.6	0.1	10.8	1.1
American shad	0.4	<0.1	4.7	3.4	0.0	0.0	0.0	0.0
Bluefish	0.1	<0.1	0.3	<0.1	0.0	0.0	0.0	0.0
Brown bullhead	0.0	0.0	0.0	0.0	<0.1	<0.1	<0.1	<0.1
Pumpkinseed	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0
Carp	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0
American eel	0.0	0.0	0.0	0.0	0.5	0.1	0.6	0.1
Hogchoker	0.1	<0.1	<0.1	<0.1	5.4	0.4	1.4	0.1
Tessellated darter	<0.1	<0.1	<0.1	<0.1	0.0	0.0	0.0	0.0
Atlantic menhaden	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.0
Blueback herring	<0.1	<0.1	0.9	0.1	<0.1	<0.1	0.0	0.0
Rainbow smelt	0.0	0.0	<0.1	<0.1	0.0	0.0	0.0	0.0
Atlantic sturgeon	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	<0.1
Striped bass	12.9	0.8	3.2	0.4	0.2	<0.1	0.1	<0.1
Atlantic tomcod	0.1	<0.1	<0.1	<0.1	0.0	0.0	0.0	0.0
White catfish	0.0	0.0	0.0	0.0	1.5	0.2	1.0	0.1
White perch	1.3	0.2	0.1	<0.1	21.7	1.7	6.5	1.7
Yellow perch	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0
Northern pipefish	0.0	0.0	0.4	0.1	0.0	0.0	<0.1	<0.1
Crevalle jack	0.0	0.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Weakfish	0.7	0.1	1.8	0.3	0.0	0.0	0.0	0.0
Lookdown	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
Tidewater silverside	0.0	0.0	0.0	0.0	<0.1	<0.1	<0.1	<0.1
Butterfish	0.0	0.0	<0.1	<0.1	0.0	0.0	<0.1	<0.1
Rough silverside	0.0	0.0	0.1	<0.1	0.0	0.0	<0.1	<0.1
Summer flounder	0.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0
Striped searobin	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0
All Species	42.2	2.8	1244.8	58.1	30.0	1.9	20.5	2.2

APPENDIX TABLE 8. FREQUENCY AND PERCENT OF ZERO SAMPLES FOR YOUNG OF THE YEAR, AND YEARLING AND OLDER LIFE STAGES OF FISH CAUGHT DURING NIGHT SAMPLING WITH A 1.0 m^2 EPIBENTHIC SLED, 3 m BEAM TRAWL TAPPAN ZEE, CROTON-HAVERSTRAW, AND INDIAN POINT REGIONS OF THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76), AUGUST-SEPTEMBER 1984.

COMMON NAME	YOUNG OF THE YEAR LIFE STAGE: 3 m BEAM TRAWL FREQUENCY(a) (N=257)	%(b)	YOUNG OF THE YEAR LIFE STAGE: 1.0 m^2 EPIBENTHIC SLED FREQUENCY (N=322)	%	YEARLING AND OLDER LIFE STAGES: 3 m BEAM TRAWL FREQUENCY (N=257)	%	YEARLING AND OLDER LIFE STAGES: 1.0 m^2 EPIBENTHIC SLED FREQUENCY (N=322)	%
Bay anchovy	18	7.0	2	0.6	165	64.2	111	34.5
American shad	173	67.3	229	71.1	257	100.0	322	100.0
Bluefish	226	87.9	289	89.8	257	100.0	322	100.0
Brown bullhead	257	100.0	322	100.0	249	96.9	321	99.7
Pumpkinseed	257	100.0	322	100.0	254	98.8	322	100.0
Carp	257	100.0	322	100.0	256	99.6	322	100.0
American eel	257	100.0	322	100.0	177	68.9	285	88.5
Hogchoker	248	96.5	319	99.1	46	17.9	203	63.0
Tessellated darter	254	98.8	321	99.7	257	100.0	322	100.0
Atlantic menhaden	254	98.8	320	99.4	252	98.1	322	100.0
Blueback herring	242	94.2	243	75.5	256	99.6	322	100.0
Rainbow smelt	257	100.0	320	99.4	257	100.0	322	100.0
Atlantic sturgeon	257	100.0	322	100.0	257	100.0	321	99.7
Striped bass	26	10.1	186	57.8	216	84.0	314	97.5
Atlantic tomcod	240	93.4	320	99.4	257	100.0	322	100.0
White catfish	257	100.0	322	100.0	112	43.6	232	72.0
White perch	145	56.4	304	94.4	15	5.8	165	51.2
Yellow perch	257	100.0	322	100.0	256	99.6	322	100.0
Northern pipefish	257	100.0	273	84.8	257	100.0	319	99.1
Crevalle jack	257	100.0	320	99.4	254	98.8	321	99.7
Weakfish	184	71.6	252	78.3	257	100.0	322	100.0
Lookdown	256	99.6	322	100.0	257	100.0	322	100.0
Tidewater silverside	257	100.0	322	100.0	256	99.6	321	99.7
Butterfish	257	100.0	320	99.4	257	100.0	320	99.4
Rough silverside	257	100.0	311	96.6	257	100.0	320	99.4
Summer flounder	257	100.0	322	100.0	251	97.7	322	100.0
Striped searobin	256	99.6	322	100.0	257	100.0	322	100.0
ALL SPECIES COMBINED	3	1.2	0	0.0	9	3.5	36	11.2

(a) N = number of samples which did not catch species, lifestage; Total N at top of each column.

(b) % = percent of samples which did not catch species, lifestage.

APPENDIX TABLE 9. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YOUNG OF THE YEAR BAY ANCHOVY DENSITY (CATCH PER 1000 m^3), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	516.4	73.7	301.63	0.0001
Gear	1	458.9		1876.25	0.0001
Week	3	48.6		66.24	0.0001
GearxWeek	3	13.0		17.65	0.0001
Error	571	139.7	0.2		
Total	578	656.1			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.79.

APPENDIX TABLE 10. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YOUNG OF THE YEAR BAY ANCHOVY DENSITY (CATCH PER 1000 m^2), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	519.7	74.2	313.35	0.0001
Gear	1	460.3		1942.68	0.0001
Week	3	51.0		71.70	0.0001
GearxWeek	3	15.0		21.13	0.0001
Error	571	135.3	0.2		
Total	578	655.0			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.79.

APPENDIX TABLE 11. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YOUNG OF THE YEAR AMERICAN SHAD DENSITY (CATCH PER 1000 m^3), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	7.1	1.0	13.07	0.0001
Gear	1	1.8		23.43	0.0001
Week	3	3.2		13.85	0.0001
GearxWeek	3	2.1		9.24	0.0001
Error	571	44.0	0.1		
Total	578	51.1			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.14.

APPENDIX TABLE 12. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YOUNG OF THE YEAR AMERICAN SHAD DENSITY (CATCH PER 1000 m^2), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	7.6	1.1	13.82	0.0001
Gear	1	2.0		24.89	0.0001
Week	3	3.3		14.05	0.0001
GearxWeek	3	2.4		10.32	0.0001
Error	571	45.0	0.1		
Total	578	52.6			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square

F = calculated F-ratio

p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant

R^2 = coefficient of determination = 0.15.

APPENDIX TABLE 13. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YEARLING AND OLDER HOGCHOKER DENSITY (CATCH PER 1000 m^3), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	36.1	5.2	45.43	0.0001
Gear	1	20.4		179.33	0.0001
Week	3	7.2		21.19	0.0C01
GearxWeek	3	12.4		36.31	0.0001
Error	571	64.8	0.1		
Total	578	100.9			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.36.

APPENDIX TABLE 14. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YEARLING AND OLDER HOGCHOKER DENSITY (CATCH PER 1000 m^2), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	35.6	5.1	43.97	0.0001
Gear	1	20.8		179.86	0.0001
Week	3	6.9		19.85	0.0001
GearxWeek	3	11.6		33.36	0.0001
Error	571	66.0	0.1		
Total	578	101.6			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.35.

APPENDIX TABLE 15. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YOUNG OF THE YEAR STRIPED BASS DENSITY (CATCH PER 1000 m^3), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	72.1	10.3	56.72	0.0001
Gear	1	42.2		232.37	0.0001
Week	3	25.8		47.28	0.0001
GearxWeek	3	3.6		6.64	0.0003
Error	571	103.7	0.2		
Total	578	175.8			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.41.

APPENDIX TABLE 16. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YOUNG OF THE YEAR STRIPED BASS DENSITY (CATCH PER 1000 m^2), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	73.3	10.5	56.39	0.0001
Gear	1	42.6		229.48	0.0001
Week	3	26.4		47.45	0.0001
GearxWeek	3	3.4		6.18	0.0005
Error	571	106.0	0.2		
Total	578	179.3			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.41.

APPENDIX TABLE 17. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YOUNG OF THE YEAR WHITE PERCH DENSITY (CATCH PER 1000 m^3), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	5.7	0.8	15.79	0.0001
Gear	1	4.6		90.62	0.0001
Week	3	0.4		2.73	0.0426
GearxWeek	3	0.2	0.05	1.16	0.3233
Error	571	28.7			
Total	578	34.3			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.16.

APPENDIX TABLE 18. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YOUNG OF THE YEAR WHITE PERCH DENSITY (CATCH PER 1000 m^2), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	5.8	0.8	16.00	0.0001
Gear	1	4.7		91.46	0.0001
Week	3	0.4		2.82	0.0379
GearxWeek	3	0.2		1.24	0.2945
Error	571	29.3	0.05		
Total	578	35.1			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.16.

APPENDIX TABLE 19. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YEARLING AND OLDER WHITE PERCH DENSITY (CATCH PER 1000 m^3), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	80.3	11.5	47.91	0.0001
Gear	1	67.2		280.73	0.0001
Week	3	9.2		12.77	0.0001
GearxWeek	3	9.5		13.25	0.0001
Error	571	136.8	0.2		
Total	578	217.1			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.37.

APPENDIX TABLE 20. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YEARLING AND OLDER WHITE PERCH DENSITY (CATCH PER 1000 m^2), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	81.4	11.6	47.75	0.0001
Gear	1	67.8		278.32	0.0001
Week	3	9.9		13.56	0.0001
GearxWeek	3	9.0		12.27	0.0001
Error	571	139.0	0.2		
Total	578	220.3			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.37.

APPENDIX TABLE 21. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YOUNG OF THE YEAR WEAKFISH DENSITY (CATCH PER 1000 m^3), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	26.8	3.8	66.87	0.0001
Gear	1	0.7		12.38	0.0005
Week	3	23.8		138.44	0.0001
GearxWeek	3	1.6		9.51	0.0001
Error	571	32.7	0.1		
Total	578	59.5			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.45.

APPENDIX TABLE 22. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN YOUNG OF THE YEAR WEAKFISH DENSITY (CATCH PER 1000 m^2), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	27.9	4.0	65.19	0.0001
Gear	1	0.8		13.80	0.0002
Week	3	24.4		133.15	0.0001
GearxWeek	3	1.9		10.46	0.0001
Error	571	34.9	0.1		
Total	578	62.7			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.44.

APPENDIX TABLE 23. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN ALL SPECIES COMBINED YOUNG OF THE YEAR DENSITY (CATCH PER 1000 m^3), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	306.6	43.8	231.27	0.0001
Gear	1	276.1		1457.80	0.0001
Week	3	19.7		34.72	0.0001
GearxWeek	3	2.8		4.96	0.0022
Error	571	108.1	0.2		
Total	578	414.7			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.74.

APPENDIX TABLE 24. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN ALL SPECIES COMBINED YOUNG OF THE YEAR DENSITY (CATCH PER 1000 m^2), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	308.5	44.1	243.92	0.0001
Gear	1	277.6		1536.28	0.0001
Week	3	22.0		40.47	0.0001
GearxWeek	3	3.0		5.42	0.0012
Error	571	103.2	0.2		
Total	578	411.7			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.75.

APPENDIX TABLE 25. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN ALL SPECIES COMBINED YEARLING AND OLDER DENSITY (CATCH PER 1000 m^3), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	40.7	5.8	25.27	0.0001
Gear	1	7.7		33.38	0.0001
Week	3	29.9		43.38	0.0001
GearxWeek	3	3.1		4.46	0.0044
Error	571	131.4	0.2		
Total	578	172.1			

Model:

$$\text{Log}_{10}\ (\text{density} + 1) = \text{Gear} + \text{Week} + \text{GearxWeek} + \text{Error}$$

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.24.

APPENDIX TABLE 26. TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN ALL SPECIES COMBINED YEARLING AND OLDER DENSITY (CATCH PER 1000 m^2), GEAR TYPE (3 m BEAM TRAWL OR 1.0 m^2 EPIBENTHIC SLED), AND SAMPLING WEEK (13-19 AUGUST, 27 AUGUST - 2 SEPTEMBER, 10-16 SEPTEMBER, OR 24-30 SEPTEMBER 1984) IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

SOURCE	df	SS	MS	F	p>F
Model	7	41.9	6.0	25.93	0.0001
Gear	1	7.4		32.04	0.0001
Week	3	30.8		44.57	0.0001
GearxWeek	3	3.1		4.42	0.0045
Error	571	131.7	0.2		
Total	578	173.5			

Model:

Log_{10} (density +1) = Gear + Week + GearxWeek + Error

df = degrees of freedom SS = sum of squares MS = mean square
F = calculated F-ratio
p = probability of obtaining a larger F-ratio; a p>F less than 0.05 is considered significant
R^2 = coefficient of determination = 0.24.

APPENDIX TABLE 27. LEAST SQUARES MEANS COMPARISON FOR SIGNIFICANT MODELS AND FACTORS FROM TWO-WAY ANALYSIS OF VARIANCE EXAMINING THE RELATIONSHIP BETWEEN DENSITY OF YOUNG OF THE YEAR STRIPED BASS AND SELECTED, ABUNDANT FISH SPECIES CAUGHT BY GEAR TYPE (3 m BEAM TRAWL OR 1.0 m² EPIBENTHIC SLED) AND SAMPLING WEEK IN THE LOWER HUDSON RIVER ESTUARY (RIVER KILOMETERS 39-76).

		LEAST SQUARES MEANS SIGNIFICANT ($p<0.05$) TREATMENT CONTRACTS (b)		
		MAIN FACTORS		INTERACTIONS
YOY FISH SPECIES	RESPONSE VARIABLE (DENSITY)(a)	GEAR	WEEK	GEAR×WEEK
Striped bass	Areal	B S	1 4 2 3	BX1 BX4 BX2 SX1 BX3 SX4 SX2 SX3
	Volumetric	B S	1 4 2 3	BX1 BX4 BX2 SX1 BX3 SX4 SX2 SX3
Bay anchovy	Areal	S B	4 3 2 1	SX4 SX2 SX3 SX1 BX4 BX3 BX2 BX1
	Volumetric	S B	4 3 2 1	SX4 SX2 SX3 SX1 BX4 BX3 BX2 BX1
American shad	Areal	S B	2 1 3 4	SX1 SX2 BX2 BX3 SX4 SX3 BX1 BX4
	Volumetric	S B	2 1 3 4	SX1 SX2 BX2 BX3 SX4 BX1 SX3 BX4
Weakfish	Areal	S B	1 2 4 3	SX1 BX1 SX2 BX4 BX2 SX4 SX3 BX3
	Volumetric	S B	1 2 4 3	SX1 BX1 SX2 BX4 BX2 SX4 SX3 BX3

(a) Areal density as Log_{10} (N per 1000 m² + 1)

Volumetric density as Log_{10} (N per 1000 m³ + 1)

(b) Treatment contrasts for significant models and factors from two-way analysis of variance are arranged in decreasing value from left to right. Values which are not significantly different are underlined. The following symbols are used to represent factor levels:

Main Factors
Gear: B = Beam trawl, S = Epibenthic Sled
Week: 1 = 13-19 August, 2 = 27 August-2 September 1984, 3 = 10-16 September 1984, 4 = 24-30 September 1984.

Interactions
WeekxRegion: interaction between sampling gear and sampling week with specified levels of the main factors connected by an "x".