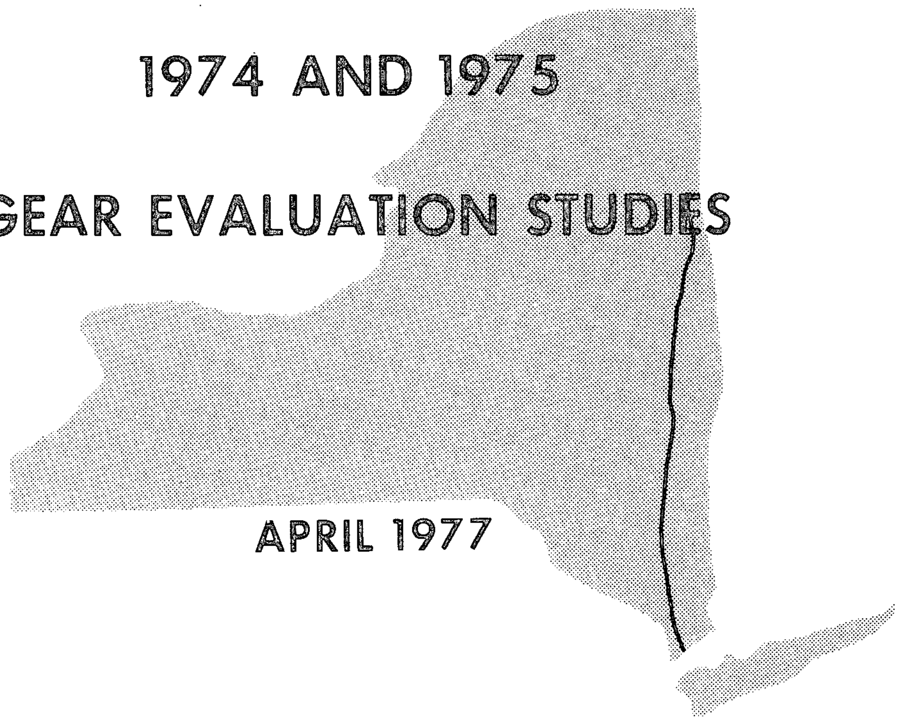
1974 AND 1975

GEAR EVALUATION STUDIES



APRIL 1977

Prepared for

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

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New York, New York 10003

by

TEXAS INSTRUMENTS INCORPORATED
ECOLOGICAL SERVICES

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SECTION I

INTRODUCTION

This report examines the efficiency of sampling gear relative to estimating ichthyoplankton density in the Hudson River estuary. Gear evaluation studies conducted by Texas Instruments Incorporated (TI) during 1974 and 1975 and reported herein deal with three major aspects of ichthyoplankton gear evaluation:

- Catch efficiency: the ability of sampling gear to catch all the organisms of a prescribed size or type that exist in the sampled volume of water

  Catch efficiency is reduced through gear avoidance by motile organisms, the gear's selectivity for certain sizes based on the net's mesh size, or some other factor such as reduced filtration efficiency.

- Filtration efficiency: the water-straining ability of the sampling gear

  This is best described as the ratio of the volume of water strained by a net to the volume of water that would have passed through the net frame had there been no net.

- Comparability: the ability to equate data collected by different sampling gear

  Comparability of data is diminished when sampling gear have different efficiencies.

A. HISTORICAL BACKGROUND

Ichthyoplankton studies on the Hudson River estuary have been conducted by several investigators since Rathjen and Miller (1957) collected eggs and larvae as part of an interstate Atlantic Coast striped bass (*Morone saxatilis*) survey:

- From 1966 through 1968, Northeast Biologists Incorporated (Carlson and McCann, 1969), as part of the Hudson River Fisheries Investigations (HRFI), conducted an ichthyoplankton survey to evaluate the potential impact of a pumped-storage facility in the Cornwall area as proposed by Consolidated Edison Company of New York, Inc. (Con Edison)

- Raytheon Company (1971) studied ichthyoplankton distribution in 1969 and 1970 in the vicinity of Con Edison's Indian Point nuclear plant to establish baseline information prior to the operation of Units 2 and 3.

- In 1971, New York University (NYU) initiated studies to determine the effects of entrainment of ichthyoplankton in the vicinity of the Indian Point nuclear power plant (NYU, 1973, 1974, 1976). These studies are still in progress.

- In 1971, Quirk, Lawler and Matusky Engineers (QLM), now Lawler, Matusky and Skelly Engineers (LMS), began ichthyoplankton investigations (QLM, 1974) to study the composition and distribution of fish eggs and larvae and the effects of their entrainment at the Bowline, Lovett, Danskammer, and Roseton power plants. These investigations are still under way.

- TI (1973a) conducted a study in the Ossining area for Con Edison in 1972 and 1973 and began a continuing longitudinal river survey (TI, 1973b) encompassing the Hudson River from Yonkers to Albany in 1973. Since 1974, the longitudinal river studies by TI have been jointly funded by Con Edison, Central Hudson Gas and Electric Company, and Orange and Rockland Utilities, Incorporated.

Because these investigators have used many types of ichthyoplankton sampling gear and deployment procedures (Appendix A), direct comparisons of data from these studies may not be valid. These differences in gear and procedures necessitate studies to quantify the important variables affecting the operation of the gear.

Gear efficiency and comparability have been discussed and/or evaluated several times earlier in an attempt to establish a quantitative basis for cross-study comparisons of ichthyoplankton data. Carlson and McCann (1969) observed that an 18 in. (46 cm) diameter conical (or ring) net with 500 x 800 μ mesh was more efficient for catch than the same net with smaller mesh (300 x 500 μ) or a 3 ft (1 m) square frame net with 500 x 800 μ mesh. Selectivity for larval striped bass was noted when larger mesh nets (1525 x 1650 μ and 3300 x 3300 μ) were used.

QLM (1973) conducted the first study explicitly designed to evaluate the ichthyoplankton sampling gear used in the Hudson River prior to 1972. Using a 1.0 m diameter Hensen net with 571 μ mesh as a reference, QLM tested the HRFI gear (18 in. [46 cm] diameter conical net and 3 ft [0.9 m] square frame net) with four mesh sizes (300 x 500 μ, 500 x 800 μ, 11500 x 1700 μ, 2000 x 2000 μ) and a 0.5 m diameter conical net with two mesh sizes (363 and 571 μ). The effects of six variables on the catch per volume filtered were studied: the presence of a TSK flowmeter mounted in the center of the net mouth; the presence of a polyethlene collar at the net mouth; mesh size; tow speed; size of the net mouth; and time of day (day or night). QLM concluded that the presence of a flowmeter, the mesh size, and the size of the net mouth significantly affected the number of larvae collected per volume of water filtered. The other variables--collar, tow speed, and time of day--produced no significant differences. Overall, nets with flowmeters captured fewer larvae per volume than did unmetered nets, and nets with larger mouth openings collected more larvae than did nets with smaller mouths. The most efficient mesh size differed for the gear tested--300 x 500 μ mesh for the 18 in. (46 cm) conical net and 1500 x 1700 μ mesh for the 3 ft (0.9 m) square frame net. Since all these nets were towed in a frame, no net bridles were necessary. QLM compared the catch per volume strained by the reference net with the catch by a net identical except for the presence of a bridle and found that more larvae per volume were captured in the net without a bridle.

In 1973 when TI began evaluating ichthyoplankton gear used in the Hudson River, preliminary studies (TI, 1973a, b) noted that a 0.5 m diameter conical net with 500 μ mesh caught more fish eggs than a 1.0 m conical net with 1000, 1500, or 2000 μ mesh. This held true for larvae, including those of striped bass, during May-July. As the season progressed, the 1.0 m net with 1000 to 2000 μ mesh first (August and September) equaled and then (October) exceeded the 0.5 m net in the catch of larvae per volume strained. A 1.0 m^2 epibenthic sled and 2.0 m^2 Tucker trawl, both equipped with 500 μ mesh, caught more striped bass larvae per volume of water filtered than did the other gear tested (0.5 m and 1.0 m diameter conical nets and a 3 ft [0.9 m] square net, with mesh sizes ranging from 500 to 2500 μ).

B. 1974 AND 1975 GEAR EVALUATION

TI undertook the gear evaluation described in this report to provide the information necessary to permit valid comparisons of catch data from the three groups of investigators (NYU, LMS, and TI) currently collecting ichthyoplankton data in the Hudson River. The studies also assessed the effects of net mouth size (Tucker trawl and epibenthic sled) and tow speed (Tucker trawl) on the catch efficiency of TI sampling gear to determine whether changes in these factors would change catch efficiency. The nets' filtration efficiency, or the ability to strain water, and the changes in filtration efficiency with the duration of tow were also studied. Specifically, the objectives of the 1974-1975 studies conducted by TI were to:

- Develop a method of comparing data from 0.5 m and 1.0 m ring (or conical) nets (NYU and QLM-LMS gear), 1.0 m Hensen nets (NYU and QLM-LMS gear) and the 1.0 m^2 epibenthic sled and 1.0 m^2 Tucker trawl (TI gear) by applying correction factors

- Determine the effect of net mouth size on the catch efficiency of the epibenthic sled and Tucker trawl

- Determine the effect of tow speed on the catch efficiency of the 1.0 m^2 Tucker trawl

- Determine the ratio of the volume of water strained through both a 1.0 m^2 epibenthic sled and a 1.0 m^2 Tucker trawl equipped with 500 μ mesh to the volume of water that would have passed through the net frame had no net been present (filtration efficiency)

- Describe the effect of tow duration on filtration efficiency for the 1.0 m^2 Tucker trawl and 1.0 m^2 epibenthic sled

SECTION II

METHODS AND MATERIALS

Ichthyoplankton sampling gear used in this study and the experimental design employed for evaluating the gear's comparability and efficiency are described in this section. The evaluation procedures differed between 1974 and 1975; therefore the studies are described separately by year. The analytical procedures for each study are presented at the conclusion of this section.

A. FIELD AND LABORATORY PROCEDURES

1. Gear Comparability Studies

During 1974 and 1975, ichthyoplankton sampling gear used by New York University (NYU) and Lawler, Matusky and Skelly Engineers (LMS) were compared with that used by Texas Instruments Incorporated (TI) by comparing the catch of striped bass eggs and larvae per unit volume sampled by each gear. The objective was to obtain a method for comparing past and future data obtained by the use of these gear in the Hudson River estuary.

a. 1974 Comparability Study

From late June through early August 1974, five gear types (1.0 m Hensen net, 1.0 m ring net, 0.5 m ring net, 1.0 m^2 Tucker trawl, and 1.0 m^2 epibenthic sled) were towed in pairs to determine the relative catchability of striped bass post yolk-sac larvae and early juveniles between these gear. Each gear type used by TI (Tucker trawl and epibenthic sled) was paired with each gear type used by LMS and NYU (Table II-1), resulting in a total of six pairings. The paired gear were towed side by side using two 40 ft (12 m) converted lobster boats which were 10 to 30 m apart. The Tucker trawl was towed at mid-depth, while the epibenthic sled was run on the river bottom. Mesh sizes matched those normally used for each gear in the Hudson River: 505 μ for the Tucker trawl and epibenthic sled and 571 μ for the Hensen trawl and ring nets. Each gear type is described in detail in Appendix A.

Table II-1

Pairings of Ichthyoplankton Sampling Gear Employed during 1974 and 1975 Gear Comparability Studies

LMS,NYU Gear	Texas Instruments Gear (1.0 m^2) 1974 Tucker Trawl	1974 Epibenthic Sled	1975 Tucker Trawl	1975 Epibenthic Sled
1.0 m Hensen net	x	x	x	x
0.5 m ring net	x	x	x	x
1.0 m ring net*	x	x		

* not studied during 1975

Each pair was towed for 5 min; tow speed, measured with a General Oceanics (G.O.) Model 2031 electronic flowmeter mounted just above the gear, was approximately 80 cm/s. Velocity was monitored on a G.O. Model 2035 electronic meter mounted on the boat. Volume of water sampled was determined using G.O. Model 2030 digital flowmeters centered in each gear.

The experimental design specified 10 samples for each of the six gear pairings, or a total of 60 samples. Pairings were replicated four times, twice during daylight and twice during darkness (Table II-2) for a grand total of 240 samples. Daylight sampling commenced at least 0.5 hr after sunrise; night sampling, at least 0.5 hr after sunset. Samplings were taken from 24 June through 1 August in areas of known striped bass larval presence near Cornwall-on-the-Hudson (river miles 55-57 [kilometre 88-91]) or Croton-on-Hudson (RM 35-38 [KM 56-61]). The variable measured was the catch of striped bass larvae per 1000 m^3. After each sample was taken, the net was washed with river water to concentrate the sample in the collection cup at the cod end of the net. The sample was preserved in 5% buffered formalin stained with rose bengal.

In the laboratory, samples were placed in enamel pans and picked and sorted with the aid of illuminated magnifiers; rose bengal stain facilitated separation of larvae and juvenile fish from organic detritus and inorganic matter. Identification was made with binocular microscopes having a maximum power of 70X. The following are the phenotypic characteristics (Mansueti, 1958; Doroshev, 1971; Bayless, 1972) used to identify striped bass larvae:

Table II-2

1974 Comparability Study Design Showing Gear Pairings, Time, and Date of Sampling and Number of Samples Taken per Gear Pairing

LMS,NYU Gear	Samples per Gear Pairing: Texas Instruments Gear							
	1.0 m^2 Tucker Trawl				1.0 m^2 Epibenthic Sled			
	Daylight		Darkness		Daylight		Darkness	
	6/24-25	7/22-23	7/8-11	7/29-30	6/26-7/2	7/23-24	7/10-11	7/30-8/1
1.0 m Hensen net	10	10	10	10	10	10	10	10
0.5 m ring net	10	10	10	10	10	10	10	10
1.0 m ring net	10	10	10	10	10	10	10	10

- Hatching length approximately 3.0 mm
- Head attached to yolk-sac; back straight
- Oil globule in anterior yolk mass generally extending beyond anterior margin of eye
- Teeth well-developed and early (4-5) branchiostegal rays formed when urostyle becomes oblique
- Oil possibly visible in thoracic region until urostyle develops heterocercal bend
- Preopercular spine development during or just after development of seventh branchiostegal ray
- Anal fin that includes two spines and 10-13 soft rays; spines of relatively equal thickness
- Total of 12 preanal and 11-13 postanal myomeres
- Snout-to-vent length approximately 55% of total length

b. 1975 Comparability Study

The 1975 comparability study made the following changes to the 1974 study:

- The 1.0 m ring net (Table II-I) was excluded.
- At time of sampling, striped bass eggs and yolk-sac larvae were more common than during the 1974 study.
- Sampling was conducted only during daylight between RM 35 and 39 (KM 56 and 62) on 30 May 1975.
- One complete set (40 samples) of gear pairings (Table II-3) was run, with 10 samples collected per pairing.
- G.O. flowmeters were checked for precision of measurement by tests in the Johns Hopkins flume; from these tests, individual conversion factors for each flowmeter were determined.

- Trawl samples were taken near the river surface rather than at midwater depths.

- In 1975, the Tucker trawl was towed alongside the boat whereas the 0.5 m ring net was towed 40 ft (12 m) and the 1.0 m Hensen net 200 ft (61 m) behind the boat.

- The 1.0 m Hensen net was mounted on an epibenthic sled frame for sampling near the river bottom.

All tows were against the prevailing current. Sample processing and laboratory analyses remained the same as those used in 1974.

Table II-3

1975 Comparability Study Design Showing Gear Pairings and Number of Samples Taken per Gear Pairing on 30 May 1975 (Daylight Only)

	Samples per Gear Pairing	
	Texas Instruments Gear	
LMS, NYU Gear	1.0 m^2 Tucker Trawl	1.0 m^2 Epibenthic Sled
1.0 m Hensen net	10	10
0.5 m ring net	10	10

2. Gear Efficiency Studies

The effects of gear mouth size and tow speed on larval striped bass catches were examined as follows: in 1974, the effect of the mouth size of the Tucker trawl and epibenthic sled; in 1975, the effect of Tucker trawl tow speed.

a. 1974 Mouth Size Efficiency Study

The effect of the net's mouth size on the catch of larval striped bass per unit volume sampled was determined for TI sampling gear, i.e., the Tucker trawl and the epibenthic sled. Different net mouth sizes were achieved by changing the mouth width while the mouth height remained the same. The height of the net mouth of both gear was always 1.0 m but mouth widths were 0.25, 0.5, 0.75, and 1.0 m for the epibenthic sled and 0.5, 0.75, 1.0, and 1.25 m for the Tucker trawl.

During July and August 1974 between RM 55 and 58 (KM 88-93), six complete sets of comparisons (Table II-4) were made for each gear: three during daylight and three during darkness. A set consisted of six or nine samples for each mouth size. One boat towed the Tucker trawl and another towed the epibenthic sled side by side 10 to 30 m apart, pairing mouth sizes in every combination. All tows were against the current. Tows with the Tucker trawl were at mid-depth, while the sleds were towed along the river bottom. The towing vessels maintained a speed of approximately 80 cm/s for 5 min. Gear were as described for the 1974 gear comparability study (see Appendix A).

G.O. digital flowmeters centered in each gear determined the volume of water sampled. To be consistent with the 1974 data used in a previous report (TI, 1975), the analysis used only tows for which flowmeter differences were between 3566 and 19007 counts. Sample processing and laboratory analyses were as described for the 1974 comparability study.

Table II-4

1974 Gear Mouth Size Efficiency Study Design Showing Number of Samples for Each Gear and Mouth Size and Time and Dates of Sampling

Width of Mouth (m)	Number of Samples											
	Epibenthic Sled						Tucker Trawl					
	Daylight			Darkness			Daylight			Darkness		
	7/1	7/16	8/5-6	7/3	7/18-19	8/7-9	7/1	7/15	8/5-6	7/3	7/17-18	8/7-9
0.25	6	9	9	6	9	9	*	*	*	*	*	*
0.5	6	9	9	6	9	9	6	9	9	6	9	9
0.75	6	9	9	6	9	9	6	9	9	6	9	9
1.0	6	9	9	6	9	9	6	9	9	6	9	9
1.25	6	9	9	6	9	9	6	9	9	6	9	9

*Not tested

b. 1975 Tow Speed Efficiency Study

The effects of tow speed on the collection efficiency of a single gear, the 1.0 m^2 Tucker trawl, were examined in 1975 by sampling in an area of known striped bass larval presence, RM 43 to 64 (km 69-102), on 9-11 July. Catches at tow speeds of 80 and 120 cm/s were compared; at each tow speed, 25 samples were taken by two boats running parallel about 45 m apart and each towing a 1.0 m^2 Tucker trawl at identical depths. The faster boat (120 cm/s) towed for 4 min, and the slower boat (80 cm/s) towed for 6 min; therefore, each boat sampled comparable volumes of water in approximately the same area of the river. The Tucker trawl towed at 120 cm/s weighed approximately 230 lb (104 kg), while the trawl towed at 80 cm/s weighed approximately 180 lb (82 kg); weight was adjusted to assure that the sampling angle (appendix Figure A-3) remained constant.

Sample processing and laboratory procedures were identical to those used for the comparability studies.

3. Filtration Efficiency Studies

A pair of studies performed in 1975 tested the filtration or straining efficiency of the nets used in TI sampling gear, the 1.0 m^2 epibenthic sled and the 1.0 m^2 Tucker trawl. The first study--a net/no-net experiment--compared flow of water through gear fitted with a 505 μ mesh net to gear without a net in order to determine if the net had a significant effect on water flow by its resistance to the passage of water. The second study--the sustained efficiency experiment--compared mean water flow for several towing durations to determine if increased towing duration affected the net's water-straining ability.

The net/no-net experiment was conducted during daylight on 3-4 September 1975 at RM 35 (km 59). Each gear type was towed 15 times with and 15 times without a net; all tows were against the current for 5 min at approximately 100 cm/s. A G.O. electronic flowmeter with a boat-mounted readout meter indicated the tow speed. The epibenthic sled was towed at depths of 15 ft (4.6 m), and the Tucker trawl was towed near the river surface; all gear were set and retrieved in an open position. Three calibrated G.O. digital flowmeters were mounted in the mouth frame of each gear (Figure II-1): one in the upper left corner, one in the center, and one in the lower right corner. The experimental variable was digital flowmeter readings, which were recorded for each tow.

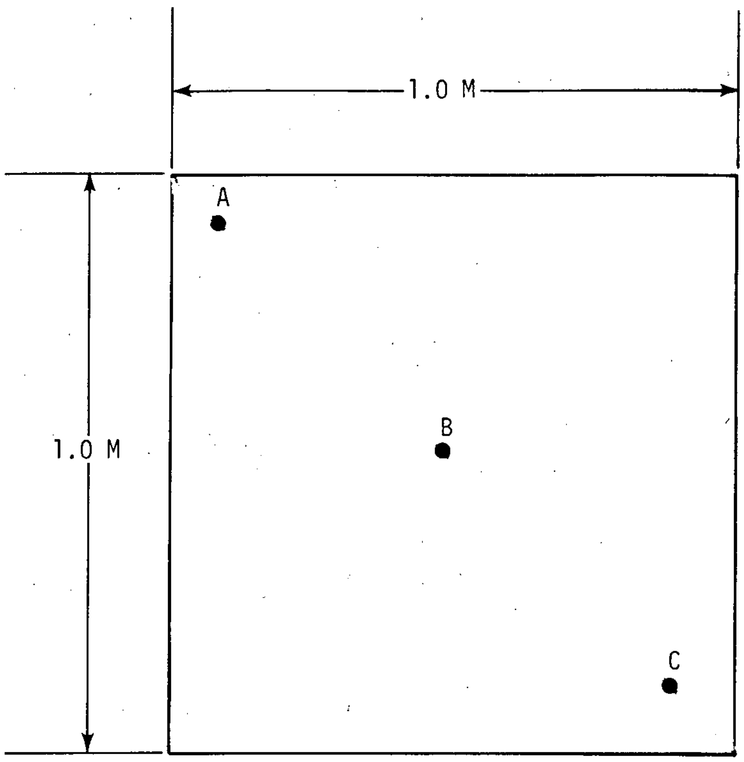

Figure II-1. Approximate Positions of Three Flowmeters in Mouths of Sampling Gear during 1975 Filtration Efficiency Studies

The sustained efficiency experiment was conducted 5-17 September 1975 during daylight within RM 34-39 (KM 54-62). There were 10 tows for each of eight duration intervals (Table II-5) and each gear, the epibenthic sled and Tucker trawl (with nets mounted); the tow duration intervals (in minutes) were 2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5, and 20. All tows were made against the current at approximately 100 cm/s. As with the net/no-net experiment, three calibrated G.O. digital flowmeters were mounted in the mouth of each gear (Figure II-1): one in the upper left corner, one in the center, and one in the lower right corner. Other sampling procedures were the same as for the net/no-net experiment. Digital flowmeter readings represented the experimental variable.

Table II-5

Design of Sustained Efficiency Experiment Showing Number of Samples for Each Tow Duration and Gear

Duration of Tows (min)	Number of Samples	
	Tucker Trawl	Epibenthic Sled
2.5	10	10
5.0	10	10
7.5	10	10
10.0	10	10
12.5	10	10
15.0	10	10
17.5	10	10
20.0	10	10

B. ANALYTICAL PROCEDURES

This subsection discusses the statistical models used for data analysis, their advantages, and the assumptions necessary for making the models both realistic and precise.

1. Gear Comparability Studies

a. 1974 Comparability Study

Differences between estimated density and actual density underlie the theory of comparing efficiencies of ichthyoplankton sampling gear. Because of gear avoidance by motile ichthyoplankton and the gears' size selectivity, the gear may catch fewer organisms than are in the volume they strain and this, in turn, makes them less efficient. Thus, the catches are not absolute indices of abundance of ichthyoplankton; instead, they are estimates of abundance that differ because of differing efficiencies of the gear.

A statistical model that would account for differing efficiencies had to be devised in order to compare data for different gear. The statistical model with which the 1974 catch data were compared was as follows:

$$D_{ij} = K_i \, \mu \, \varepsilon_{ij}$$

where

D_{ij} = catch of larval striped bass per 1000 m^3 in tow j with gear i

μ = expected number of larvae per 1000 m^3 in sampling area

K_i = proportion of μ caught by gear i ($0 \le K_i \le 1$)

ε_{ij} = random error, and error associated with gear and natural variation in distribution of larvae

and was based on the assumptions that:

- The random error was multiplicative rather than additive.
- The efficiency term K was constant; this means that the number of larvae missed did not remain constant for all densities and that the proportion missed was not a function of density.
- The linearized model was a fixed-effects model.

The term K_i represented the relative catch efficiency, expressed as the ratio of number of larvae caught to total number of larvae present in the sampled volume of water prior to sampling.

An advantage of the model was that it could yield a realistic method for arriving at correction factors to adjust catch data obtained from gear having differences in efficiency (see Appendix B). Statistical tests performed on the catch data (D_{ij}) ultimately were tests for significant difference between the efficiencies (K_i) of the compared gear. During the sampling period (24 June-2 August), post yolk-sac larvae were the predominant life stage caught for striped bass; thus, the analysis was univariate.

To normalize the catch data and stabilize its variance, a log transformation was used. The model was linearized to be consistent with least squares theory by using the natural logarithm of the data:

$$\log_e (D_{ij} + 1) = \log_e K_i + \log_e \mu + \log_e \varepsilon_{ij}$$

Addition of 1 to D_{ij} facilitated analysis of small catch values (Steel and Torrie, 1960). The transformed data from each gear comparison were tested for normality by the Shapiro-Wilks test (Dunn and Clark, 1974) and for homogeneity of variance by an F test (Brownlee, 1967). A 2-tailed unpaired t test was then performed on data for which the Shapiro-Wilks test and F test were nonsignificant ($\alpha = 0.05$). All data were subjected also to the nonparametric Wilcoxon rank sum test (Hollander and Wolfe, 1973) since no assumptions of normality and equality of variance were necessary for this test.

b. 1975 Comparability Study

The 1975 comparability model was identical to that used for the 1974 study with one exception: when the 1975 comparability samples were taken, three planktonic life stages of striped bass were common rather than only one being predominant, which had been the case during the 1974 study; thus, a multivariate test of means had to be performed rather than a univariate test in order to compare all three life stages in a hypothesis-testing situation.

The model with which the 1975 data were analyzed was as follows:

$$D_{rij} = K_{ri} \mu_r \varepsilon_{rij}$$

where r = 1...3 were the three life stages present (eggs, yolk-sac larvae, and post yolk-sac larvae). The other variables in the model were the same as for the 1974 model. The linearization of the model by natural logarithms then became:

$$\log_e (D_{rij} + 1) = \log_e \mu_r + \log_e K_{ri} + \log_e \varepsilon_{rij}$$

The data were first tested for equality of covariance matrices between gears (Morrison, 1967). If this test was nonsignificant, then the test of equality of mean vectors (Morrison, 1967) was performed. Additionally, the nonparametric Wilcoxon rank sum test was performed univariately on the data for each life stage.

In addition to assumptions and analyses used in 1974, the 1975 model was based also on the analytical assumption that the vector $\log_e \varepsilon_{rij}$ was multivariately normal with a mean of zero and constant variance for gear and samples.

2. Gear Efficiency Studies

a. 1974 Gear Mouth-Size Efficiency Study

The efficiencies of various gear mouth sizes were tested for both the epibenthic sled and the Tucker trawl. The purpose was to find if adequate gear mouth sizes were being used and if there would be any significant change in efficiency if mouth area were increased or decreased. Analysis of results was based on the principle that a relationship exists between gear mouth area and number of organisms caught in a volume of water; theoretically, this relationship is a function that is asymptotic and strictly monotonic (Figure II-2). Statistical testing of mean catch for equivalent gear would indicate if gear efficiency could be improved by changing the size of the mouth. Equality of means would imply that the mouth sizes were of the range

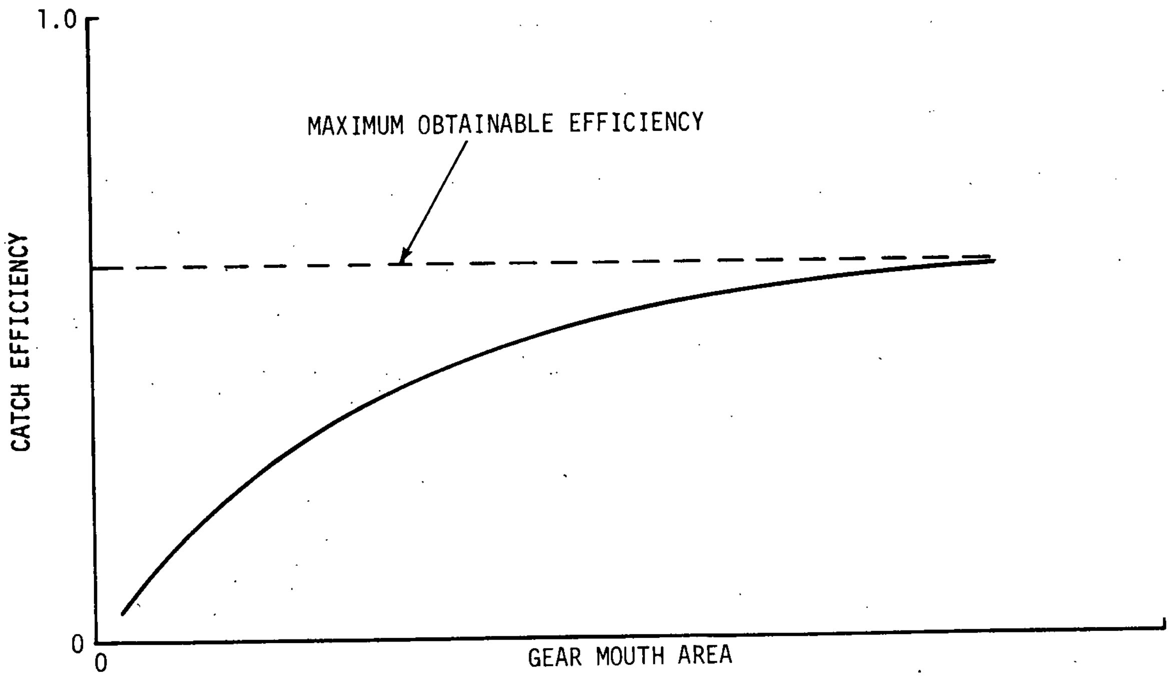

Figure II-2. Theoretical Relationship between Gear Mouth Area and Catch Efficiency

where catch efficiencies were asymptotic (Figure II-2), i.e., at the maximum obtainable efficiency for the gear design and deployment procedure.

The statistical model used to analyze the catch data was a variation of the gear comparability model, using assumptions identical to those for the 1974 gear comparability study. The new model was:

$$D_{ij} = C_i \, X_i^{\phi} \, \mu \, \varepsilon_{ij}$$

where

D_{ij} = catch of larval striped bass per 1000 m^3 in tow j with gear i

C_i = a fractional constant for gear i

X_i = mouth area of gear i

ϕ = a constant exponent

μ = expected number of larvae per 1000 m^3 in water column

ε_{ij} = random error

This model was chosen because, for the range of X_i (0.5 m^2 to 1.25 m^2 for the Tucker trawl and 0.25 m^2 to 1.0 m^2 for the epibenthic sled), it could be used to reasonably describe the theoretical function (Figure II-2) or another monotonic function. This model also was consistent with the comparability model $D_{ij} = K_i \mu \varepsilon_{ij}$ in which the relative efficiency term K_i was analogous to the term $C_i X_i^{\phi}$ of this model. If ϕ were not significantly different from 0 in the present model, mouth area would have little effect on the catch per volume, and efficiency would be stable and perhaps maximal with respect to design and deployment (e.g., for a constant tow speed).

The data were tested for normality by the Shapiro-Wilkes test (Dunn and Clark, 1974) and for homogeneity of variance by Bartlett's test (Brownlee, 1967) after a natural log transformation:

$$\log_e (D_{ij} + 1) = \log_e C_i + \phi \log_e X_i + \log_e \mu + \log_e \varepsilon_{ij}$$

If these tests were nonsignificant, an ANOVA test for $\phi = 0$ (i.e., equality of means) and for lack of fit was performed (Draper and Smith, 1966). In addition to this parametric analysis, a nonparametric Kruskal-Wallis test

(Hollander and Wolfe, 1973) for equality of median densities of gears was performed for all data; if the latter was nonsignificant, this too implied that $\phi = 0$, i.e., gear mouth area did not influence catch efficiency.

b. 1975 Tow-Speed Efficiency Study

Tow speed replaced mouth size (Figure II-2) as the independent variable in the theoretical model that formed the basis for analyzing 1975 gear efficiency with respect to tow speed. Catch data analysis would indicate whether the asymptotic maximum obtainable efficiency had been reached for the tow speeds used.

The statistical model used for comparing tow speeds was identical to that used for comparing gear:

$$D_{ij} = K_i \mu \varepsilon_{ij}$$

where

D_{ij} = catch of larval striped bass per 1000 m^3 in tow j with tow speed i

K_i = proportion of μ caught at tow speed i ($0 \leq K_i \leq 1$)

μ = expected [redacted] number of larvae per 1000 m^3

ε_{ij} = random error

Assumptions were identical to those for the 1974 comparability study.

For analysis, the model was linearized by the following transformation:

$$\log_e (D_{ij} + 1) = \log_e K_i + \log_e \mu + \log_e \varepsilon_{ij}$$

The transformed data were analyzed for normality by the Shapiro-Wilks test and for equality of variances by an F test. If both tests were nonsignificant, an unpaired t test for equal means was performed. All data also were subjected to a nonparametric Wilcoxon sum rank test.

3. 1975 Filtration Efficiency Studies

a. Net/No-Net Experiment

The net/no-net experiment of 1975 investigated the effects a 505 μ mesh net on the filtration efficiency of an epibenthic sled and Tucker trawl; i.e., it tested for a reduction in flow of water through the gear as a result of the resistance of the net. Unlike the earlier tests dealing with catch data, the observed dependent variable was water flow, as measured by flowmeters.

The flowmeter data were analyzed by a simple analysis of covariance. The statistical model was:

$$X_{ij} = \alpha_i + \beta Z_{ij} + \varepsilon_{ij}$$

where

X_{ij} = distance (cm) as measured by center flowmeter divided by tow duration for j^{th} tow of the i^{th} gear

α_i = effect due to net in gear i

Z_{ij} = recorded boat speed (cm/s) from electronic flowmeter

β = slope or rate of change of X with Z

ε_{ij} = random error

Spurious flowmeter readings or tow-speed errors were excluded from the analyses by examining profiles of digital flowmeter readings adjusted by electronic flowmeter readings, assuming $\beta = 1$. The profiles and methods for data exclusion appear in Appendix C.

The data were tested first for normality by the Shapiro-Wilks test, then for equality of variance of the tow treatment (βZ_{ij}) by an F test. The assumptions used were that $\beta = 1$ for both tests and that the effect of a net (α_i) on the gear speed was equal to the no-net effect for the second test. The equality of the effect (α_i) of a net to that of no-net was tested by an analysis of covariance (Brownlee, 1967), which "adjusts" the means of the net/no-net effects for changes in boat speed. Had this adjustment not been made, changes in speed would have confounded the results of the experiment.

The following were the assumptions necessary for applying the statistical model:

- The effect of boat speed is a first-order polynomial.
- Boat-speed effects are the same for net and no-net data.
- Random errors are independently and identically normal, with a mean of 0 and constant variance of σ^2.

b. Sustained Efficiency Experiment

This 1975 experiment investigated the effects of tow duration (2.5 to 20 min) on the filtration efficiency or water-straining ability of the epibenthic sled and Tucker trawl. As with the net/no-net experiment, the observed dependent variable was water flow, as measured by flowmeters. If flow rates change significantly as tow duration increases, then net clogging or some other phenomenon is occurring. Flowmeter outlier data were detected and excluded in the same manner as with the net/no-net experiment (Appendix C).

The statistical model used for data analysis was:

$$f_{ijk} = \mu_k + \alpha_{ik} + \beta Z_{ijk} + \varepsilon_{ijk}$$

where

f_{ijk} = distance (cm) as measured by center flowmeter divided by tow duration (i = 2.5, 5.0, 7.5... 20 min) in j^{th} tow of k^{th} gear

μ_k = overall mean flow rate (cm/s) for gear k

α_{ik} = mean flow rate effect of i^{th} duration for gear k

Z_{ijk} = boat speed (cm/s) recorded on electronic flowmeter

β = slope or rate of change of f with Z

ε_{ijk} = random error

The adjusted flowmeter data were tested for normality (assuming $\beta = 1$) by the Shapiro-Wilks test and for homogeneity of variance (again assuming $\beta = 1$) by Bartlett's test. Differences in flow rate among tow durations were detected by using a simple analysis of covariance and adjustments to free the mean flow rates from the influence of changing tow speeds.

SECTION III

RESULTS AND DISCUSSION

A. GEAR COMPARABILITY STUDIES

1. 1974 Comparability Study

The ichthyoplankton sampling gear of TI, NYU, and LMS usually appeared to have similar catch efficiencies. This would imply directly comparable larval striped bass catch data if the gear are deployed in the same manner as during this study, with no need for correction factors. There was at least one statistical comparison between each TI gear and its NYU or LMS counterpart.

Of the 24 gear pairings run during the 1974 comparability study (Section II, Table II-1; Appendix C), 14 had sufficient catch for analysis; catch data for a gear pairing were judged to be sufficient if five or more of the 10 samples taken had non-zero catch. All but one of the 10 gear pairings with insufficient catch were run during the last week of July. The lower catch in late July may have been caused by increased gear avoidance by larval and early juvenile striped bass or lower densities of planktonic striped bass; however, since the catch was low both day and night and ichthyoplankton are more likely to avoid gear during daylight (Clutter and Anraku, 1968), gear avoidance probably was less important than decreased density due to mortality and dispersal.

Parametric statistical analysis was possible for seven of the 14 gear pairings (Table III-1). For these seven pairings, log-transformed

Table III-1

Tests for Normality and Equality of Variance
of 1974 Gear Comparability Data

Gear	Time	Date	Normality W		n	Equality of Variance F		df
1.0 m ring; 1.0 m^2 Tucker trawl	Day	6/24	0.938	ns	18	1.13	ns	9,7
0.5 m ring; 1.0 m^2 Tucker trawl	Day	6/24	0.917	ns	20	1.057	ns	9,9
1.0 m Hensen; 1.0 m^2 Tucker trawl	Day	6/25	0.887	ns	13	4.254	ns	5,6
0.5 m ring; 1.0 m^2 Epibenthic sled	Day	6/26	0.941	ns	16	1.568	ns	5,9
1.0 m ring; 1.0 m^2 Epibenthic sled	Day	6/26	0.816	*	19	12.079	*	8,9
1.0 m Hensen; 1.0 m^2 Epibenthic sled	Day	7/2	0.944	ns	10	2.541	ns	4,4
1.0 m ring; 1.0 m^2 Tucker trawl	Night	7/8	0.948	ns	20	1.570	ns	9,9
1.0 m Hensen; 1.0 m^2 Tucker trawl	Night	7/9-10	0.967	ns	20	1.298	ns	9,9
0.5 m ring; 1.0 m^2 Tucker trawl	Night	7/11	0.716	*	17	3.453	ns	7,8
1.0 m Hensen; 1.0 m^2 Epibenthic sled	Night	7/10	0.853	*	17	1.325	ns	9,6
1.0 m ring; 1.0 m^2 Epibenthic sled	Night	7/11	0.878	*	15	2.022	ns	4,9
0.5 m ring; 1.0 m^2 Epibenthic sled	Night	7/11	0.613	*	15	1.053	ns	6,7
1.0 m ring; 1.0 m^2 Tucker trawl	Day	7/22	✓			✓		
0.5 m ring; 1.0 m^2 Tucker trawl	Day	7/22	✓			✓		
1.0 m Hensen; 1.0 m^2 Tucker trawl	Day	7/23	✓			✓		
1.0 m Hensen; 1.0 m^2 Epibenthic sled	Day	7/23	0.818	*	14	1.083	ns	3,9
1.0 m ring; 1.0 m^2 Epibenthic sled	Day	7/24	✓			✓		
0.5 m ring; 1.0 m^2 Epibenthic sled	Day	7/24	✓			✓		
1.0 m ring; 1.0 m^2 Tucker trawl	Night	7/29	✓			✓		
0.5 m ring; 1.0 m^2 Tucker trawl	Night	7/29-30	✓			✓		
1.0 m Hensen; 1.0 m^2 Tucker trawl	Night	7/30	✓			✓		
1.0 m Hensen; 1.0 m^2 Epibenthic sled	Night	7/30	✓			✓		
1.0 ring; 1.0 m^2 Epibenthic sled	Night	8/1	0.674	*	12	2.109	ns	3,7
0.5 m ring; 1.0 m^2 Epibenthic sled	Night	8/1	✓			✓		

✓ = catch not sufficient for analysis; fewer than five samples with non-zero catch
* = significatn at α = 0.05
ns= not significant at α = 0.05
n = number of valid samples
df= degrees of freedom

data appeared to be normally distributed with equal variances, as determined by nonsignificant (α = 0.05) Shapiro-Wilks and F tests. Thus, t tests for equality of mean catch, signifying equal efficiency coefficients (K_i), could be performed on the catch data from the following gear comparisons:

1.0 m ring net vs 1.0 m^2 Tucker trawl, daylight
1.0 m ring net vs 1.0 m^2 Tucker trawl, darkness
0.5 m ring net vs 1.0 m^2 Tucker trawl, daylight
1.0 m Hensen net vs 1.0 m^2 Tucker trawl, daylight
1.0 m Hensen net vs 1.0 m^2 Tucker trawl, darkness
0.5 m ring net vs 1.0 m^2 epibenthic sled, daylight
1.0 m Hensen net vs 1.0 m^2 epibenthic sled, daylight

Unpaired t tests were nonsignificant (2-tailed; α = 0.05) for all of the above (Table III-2) except one that showed that the catch from a 1.0 m ring net was significantly greater than that from a 1.0 m^2 Tucker trawl during darkness (Figure III-1).

The nonparametric Wilcoxon rank sum test, for which no assumptions of normality and equal variance are necessary, indicated significantly different (α = 0.05) mean catches in two of the 14 gear pairings having sufficient catch data (Table III-2). The 1.0 m ring net caught significantly more larvae during daylight than did the 1.0 m^2 epibenthic sled (Figure III-2), and the 1.0 m ring net caught significantly more than did the 1.0 m^2 Tucker trawl at night (in agreement with the results of the parametric analysis). In these two cases, there was an apparent contradiction with the results of a pairing of the same gear during a different time (daylight vs darkness). This contradiction may have truly reflected differences in gear efficiency with respect to light

Table III-2

Parametric and Nonparametric Tests for Equality of Mean Catch from 1974 Gear Comparability Study

Gear	Time	Date	t-Test of Equality of Means t		df	Wilcoxon Rank Sum Test Z	
1.0 m ring; 1.0 m^2 Tucker trawl	Day	6/24	0.505	ns	16	0.62	ns
0.5 m ring; 1.0 m^2 Tucker trawl	Day	6/24	1.178	ns	18	1.29	ns
1.0 m Hensen; 1.0 m^2 Tucker trawl	Day	6/25	1.668	ns	11	1.59	ns
0.5 m ring; 1.0 m^2 Epibenthic sled	Day	6/26	0.632	ns	14	0.54	ns
1.0 m ring; 1.0 m^2 Epibenthic sled	Day	6/26	†			2.37	*
1.0 m Hensen; 1.0 m^2 Epibenthic sled	Day	7/2	0.612	ns	8	0.73	ns
1.0 m ring; 1.0 m^2 Tucker trawl	Night	7/8	2.411	*	18	2.12	*
1.0 m Hensen; 1.0 m^2 Tucker trawl	Night	7/9,10	1.362	ns	18	1.13	ns
0.5 m ring; 1.0 m^2 Tucker trawl	Night	7/11	†			0.00	ns
1.0 m Hensen; 1.0 m^2 Epibenthic sled	Night	7/10	†			0.83	ns
1.0 m ring; 1.0 m^2 Epibenthic sled	Night	7/11	†			0.00	ns
0.5 m ring; 1.0 m^2 Epibenthic sled	Night	7/11	†			0.12	ns
1.0 m ring; 1.0 m^2 Tucker trawl	Day	7/22	✓			✓	
0.5 m ring; 1.0 m^2 Tucker trawl	Day	7/22	✓			✓	
1.0 m Hensen; 1.0 m^2 Tucker trawl	Day	7/23	✓			✓	
1.0 m Hensen; 1.0 m^2 Epibenthic sled	Day	7/23	†			0.51	ns
1.0 m ring; 1.0 m^2 Epibenthic sled	Day	7/24	✓			✓	
0.5 m ring; 1.0 m^2 Epibenthic sled	Day	7/24	✓			✓	
1.0 m ring; 1.0 m^2 Tucker trawl	Night	7/29	✓			✓	
0.5 m ring; 1.0 m^2 Tucker trawl	Night	7/29,30	✓			✓	
1.0 m Hensen; 1.0 m^2 Tucker trawl	Night	7/30	✓			✓	
1.0 m Hensen; 1.0 m^2 Epibenthic sled	Night	7/30	✓			✓	
1.0 m ring; 1.0 m^2 Epibenthic sled	Night	8/1	†			0.18	ns
0.5 m ring; 1.0 m^2 Tucker trawl	Night	8/1,2	✓			✓	

✓ = Catch not sufficient for analysis; fewer than five samples with non-zero catch
* = Significant at α = 0.05
ns = Not significant at α = 0.05
† = Assumptions of normality and equality of variance not met; see Table III-1
df = degrees of freedom

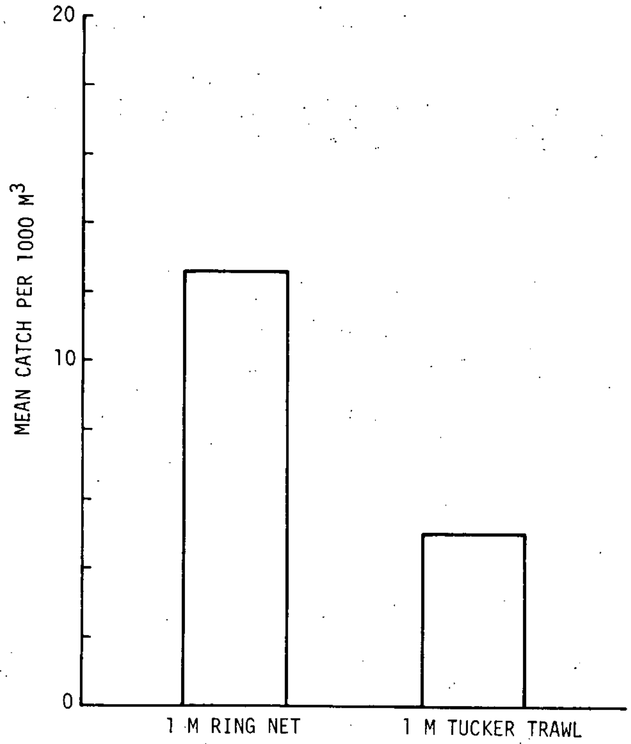

Figure III-1. Mean Catch of Striped Bass Post Yolk-Sac Larvae by 1.0 m Ring Net and 1.0 m^2 Tucker Trawl during Darkness, 8 July 1974

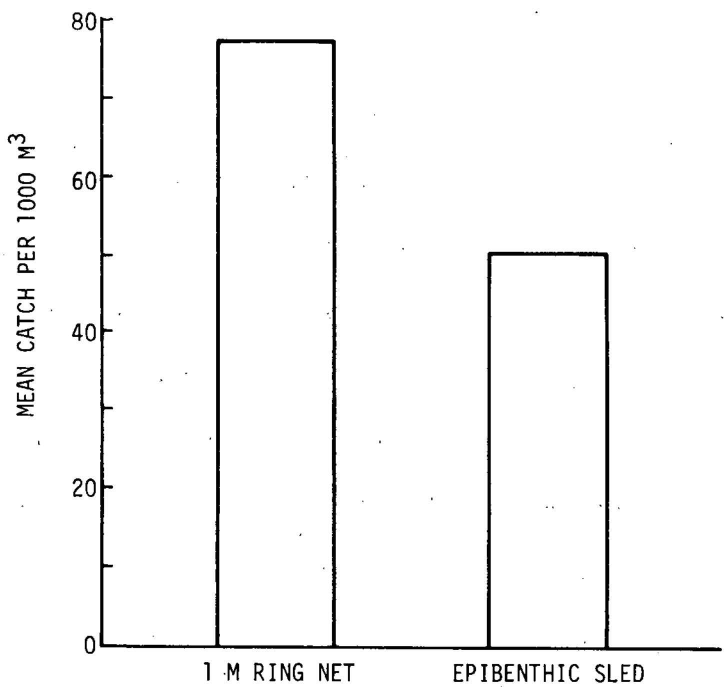

Figure III-2. Mean Catch of Striped Bass Post Yolk-Sac Larvae by 1.0 m Ring Net and 1.0 m^2 Epibenthic Sled during Daylight, 26 June 1974 and gear avoidance by ichthyoplankters or occurred purely by chance (probability of a type 1 error occurring in one or two of 14 tests at $\alpha = 0.05$ is 0.48).

2. 1975 Comparability Study

The 1975 gear comparability study afforded the opportunity to compare catch efficiencies of each gear for three life stages of striped bass--eggs, yolk-sac larvae, and post yolk-sac larvae--instead of primarily one (post yolk-sac larvae) as had been the case in the 1974 study. Generally, the 1975 study results indicated no significant difference in gear sampling for larval striped bass near the river bottom; the 0.5 m ring net appeared to be more efficient than the 1.0 m^2 epibenthic sled for sampling eggs near the river bottom. For sampling near the surface, the Tucker trawl appeared to be more efficient than either the 0.5 m ring net or the 1.0 m Hensen net in collecting larval striped bass.

Parametric statistical analysis of the catch data was possible for only one of the four gear comparisons (Table III-3): the 1.0 m Hensen net (mounted on a sled frame) vs the 1.0 m^2 epibenthic sled. For this gear comparison, the mean vectors were not significantly different ($\alpha = 0.05$), indicating that the epibenthic sled and Hensen net were equally efficient for the collection of the three life stages (Figure III-3). Nonparametric analysis by univariate testing of the life stages with the Wilcoxon rank sum test corroborated the results of the parametric test comparing the epibenthic sled and Hensen net (Table III-3). (Statements of significance about multivariate data, i.e., life

Table III-3

Tests of Equality of Covariance Matrices, Equality of Mean Vectors, and Nonparametric Equality of Mean Catch for 1975 Gear Comparability Study

Gear	Equality of Covariance Matrix			Parametric Equality of Mean Vectors			Nonparametric Equality of Mean Catch		
	χ^2	df		F	df		Z		Life Stage
1 m^2 Epibenthic sled vs 0.5 m ring net	17.3	6	*	---			2.73	*	Egg
							0.88	ns	Yolk-sac larvae
							0.88	ns	Post yolk-sac Larvae
1 m^2 Epibenthic sled vs 1 m Hensen net (on sled)	11.6	6	ns	0.2867	3 16	ns	0.11	ns	Egg
							0.38	ns	Yolk-sac larvae
							0.15	ns	Post yolk-sac larvae
1 m^2 Tucker trawl vs 0.5 m ring net	∞		*	---			1.25	ns	Egg
							3.42	*	Yolk-sac larvae
							3.61	*	Post yolk-sac larvae
1 m^2 Tucker trawl vs 1 m Hensen net	∞		*	---			1.17	ns	Egg
							2.53	*	Yolk-sac larvae
							3.48	*	Post yolk-sac larvae

ns = not significant at $\alpha = 0.05$
 * = significant at $\alpha = 0.05$
df = degrees of freedom

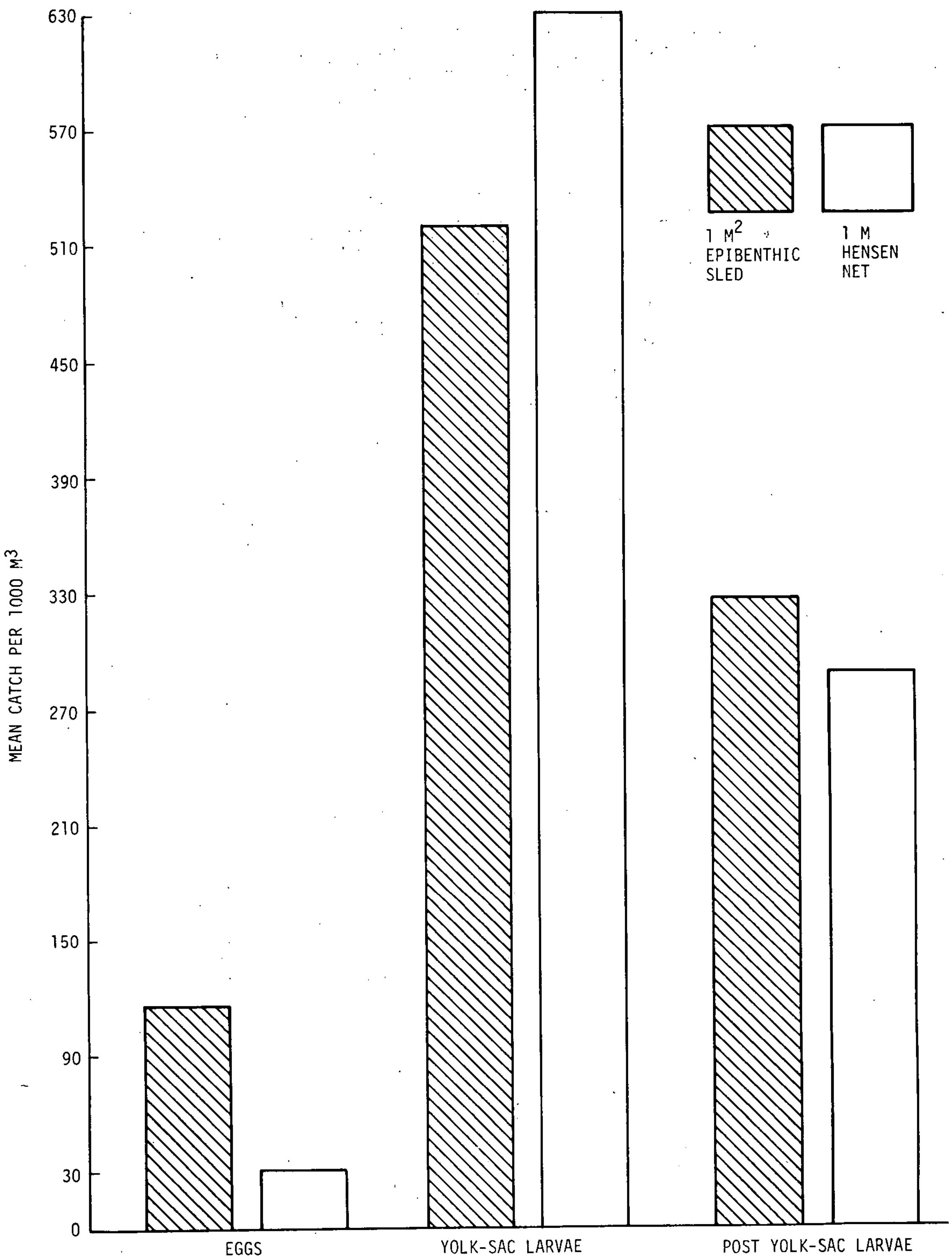

Figure III-3. Mean Catch of Striped Bass Eggs, Yolk-Sac Larvae, and Post Yolk-Sac Larvae by 1.0 m^2 Epibenthic Sled and 1.0 m Hensen Net during Daylight, 30 May 1975 stages, using a univariate test requires the assumption of noncorrelation between variables.) There were no significant differences in catch efficiences for eggs, yolk-sac larvae, and post yolk-sac larvae between these tow gear.

For the three gear comparisons that could be analyzed only with nonparametric statistical methods, significant differences ($\alpha = 0.05$) in catch were frequently noted. The 1.0 m^2 epibenthic sled caught significantly fewer eggs (Figure III-4 and Table III-3) than did the 0.5 m ring net. The 1.0 m^2 Tucker trawl caught significantly more yolk-sac and post yolk-sac larvae (Table III-3) than did either the 0.5 m ring net (Figure III-5) or the 1.0 m Hensen net (Figure III-6).

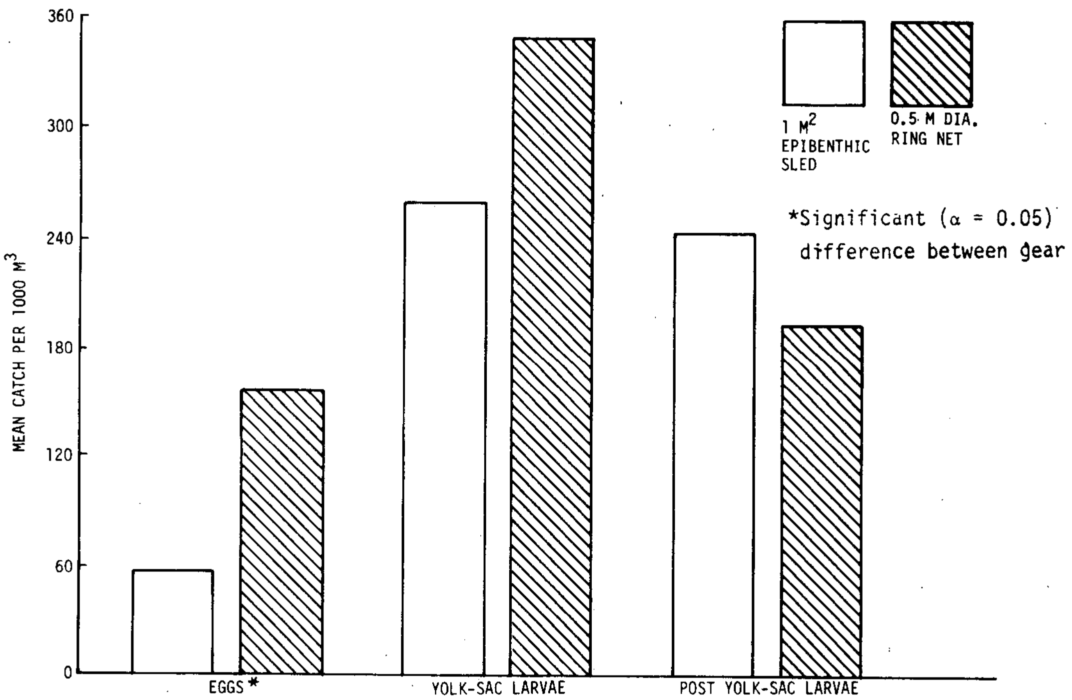

Figure III-4. Mean Catch of Striped Bass Eggs, Yolk-Sac Larvae, and Post Yolk-Sac Larvae by 1.0 m^2 Epibenthic Sled and 0.5 m Ring Net during Daylight, 30 May 1975

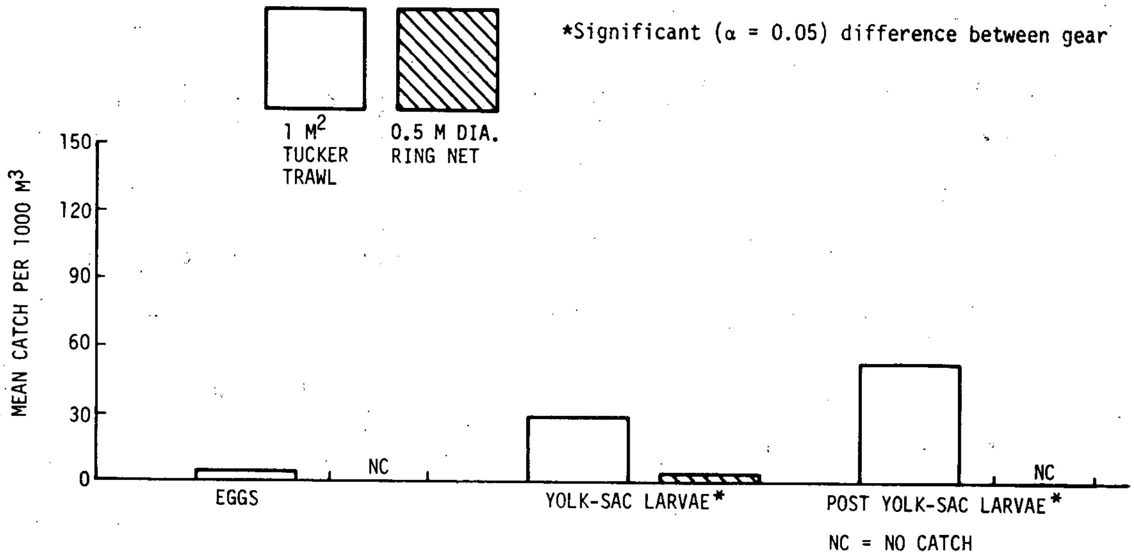

Figure III-5. Mean Catch of Striped Bass Eggs, Yolk-Sac Larvae, and Post Yolk-Sac Larvae by 1.0 m^2 Tucker Trawl and 0.5 m Ring Net during Daylight, 30 May 1975

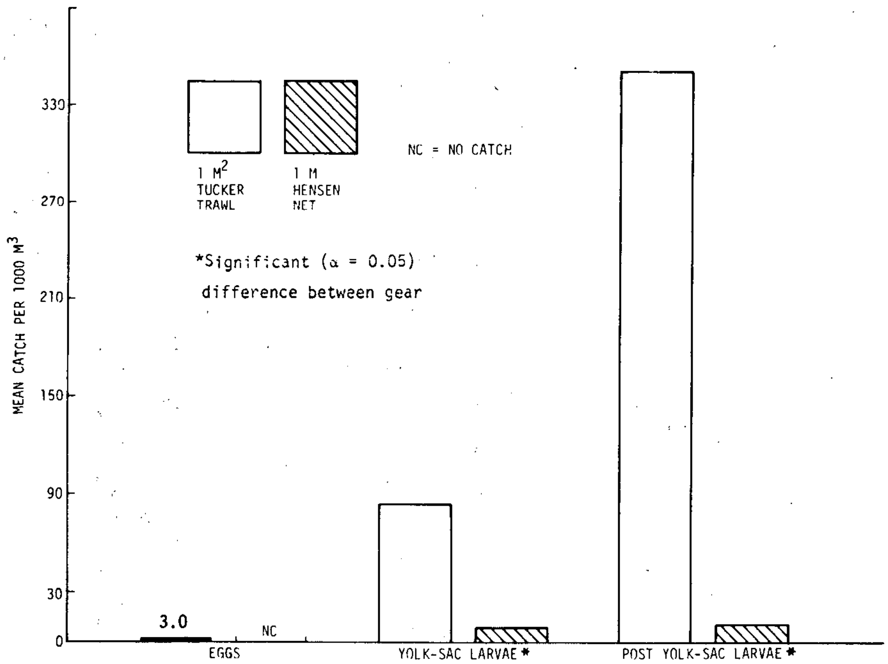

Figure III-6. Mean Catch of Striped Bass Eggs, Yolk-Sac Larvae, and Post Yolk-Sac Larvae by 1.0 m^2 Tucker Trawl and 1.0 m Hensen Net during Daylight, 30 May 1975

Differences in catch efficiency noted in the 1975 comparability study for the surface or midwater sampling gear (Tucker trawl, Hensen net, and 0.5 m ring net) contradicted 1974 study results in which these gear appeared equal in efficiency. The deployment of the gear may have caused the differences in the results of the two studies.

B. GEAR EFFICIENCY STUDIES

1. 1974 Gear Mouth-Size Efficiency Study

In all but one test, increasing the mouth width of the epibenthic sled and the Tucker trawl had no effect on their catch efficiency for larval striped bass. With respect to gear mouth size, both gear were sampling at or near their maximum obtainable efficiency (Section II, Figure II-2) for the methods of deployment used and the range of mouth sizes tested.

Seven of the 12 sets of samples taken during the 1974 efficiency study (Section II, Table II-4) had sufficient catch for analysis; catch data for a set of samples were judged to be sufficient if five or more samples had non-zero catch (Table III-4). All but one of the sets with insufficient catch occurred during early August. Only one set--daylight sampling with the epibenthic sled on 1 July--met the necessary assumptions (Table III-4) for parametrically testing the log-transformed catch data. The analysis-of-variance test for this data set (Table III-5) indicated that changing the mouth size of the epibenthic sled did not significantly ($F = 1.80$; $\alpha = 0.05$) affect mean catch per volume.

Table III-4

Tests for Normality, Homogeneity of Variance, and Lack of Fit in Gear Mouth Size Efficiency Study of 1974

Gear	Time	Date	Normality W		n	Homogenity of Variance F	Lack of Fit F		df
1 m Epibenthic sled	Day	7/1	0.97	ns	19	0.39	0.53	ns	2,15
1 m Tucker trawl	Day	7/1	0.83	*	24	---	---		
1 m Epibenthic sled	Night	7/3	0.88	*	17	---	---		
1 m Tucker trawl	Night	7/3	0.84	*	13	---	---		
1 m Epibenthic sled	Day	7/16	0.80	*	24	---	---		
1 m Tucker trawl	Day	7/15	✓			✓	✓		
1 m Epibenthic sled	Night	7/18,19	0.86	*	25	---	---		
1 m Tucker trawl	Night	7/17,18	0.87	*	33	---	---		
1 m Epibenthic sled	Day	8/5	✓			✓	✓		
1 m Tucker trawl	Day	8/6	✓			✓	✓		
1 m Epibenthic sled	Night	8/7,8	✓			✓	✓		
1 m Tucker trawl	Night	8/8,9	✓			✓	✓		

* Significant at $\alpha = 0.05$
ns Not significant at $\alpha = 0.05$
✓ Insufficient data for analysis; fewer than five samples with non-zero catch
df Degrees of freedom
n Number of valid samples

Table III-5

Analysis of Variance of Larval Striped Bass Catch per Volume Using Epibenthic Sleds with Five Different Mouth Sizes During Daylight of 1 July 1976

Source	d.f.	Sum of Squares	Mean Square	F
Slope	1	1.1804	1.1804	1.80+
Residual	17	11.1446	0.6556	
lack of fit	2	0.7377	0.3688	0.53+
pure error	5	10.4069	0.6933	
Total	18	12.325		

+ not significant at $\alpha = 0.05$

Nonparametric analysis of the seven sets by the Kruskal-Wallis test indicated no significant ($\alpha = 0.05$) change in catch per volume with change in gear mouth size except for one set--nighttime sampling with an epibenthic sled on 3 July (Table III-6). Those tests showing no significant differences included at least one replicate of each of the four combinations of day and night sampling with the epibenthic sled and Tucker trawl. The exceptional case having a significant Kruskal-Wallis test (Table III-6) did not show a consistent increase in catch with an increase in gear mouth size (Figure III-7), as might have been expected. Other studies (Fleminger and Clutter, 1965; McGowan and Fraundorf, 1966; Clutter and Anraku, 1968) have found an increase in catch with larger nets towed at the same speed and have attributed this increase to reduced gear avoidance by the sampled organisms.

Table III-6

Kruskal-Wallis Test for Difference in Mean Catch with Gear Mouth Size

Gear	Time	Date	χ^2_3		df
1 m Epibenthic sled	Day	7/1	2.35	ns	3
1 m Tucker trawl	Day	7/1	5.32	ns	3
1 m Epibenthic sled	Night	7/3	8.35	*	3
1 m Tucker trawl	Night	7/3	2.58	ns	3
1 m Epibenthic sled	Day	7/16	5.35	ns	3
1 m Tucker trawl	Day	7/15	✓		
1 m Epibenthic sled	Night	7/18,19	3.07	ns	3
1 m Tucker trawl	Night	7/17,18	6.16	ns	3
1 m Epibenthic sled	Day	8/5	✓		
1 m Tucker trawl	Day	8/6	✓		
1 m Epibenthic sled	Night	8/7,8	✓		
1 m Tucker trawl	Night	8/8,9	✓		

* Significant at $\alpha = 0.05$
ns Not significant at $\alpha = 0.05$
✓ Insufficient data for analysis; fewer than five samples with non-zero catch
df Degrees of freedom

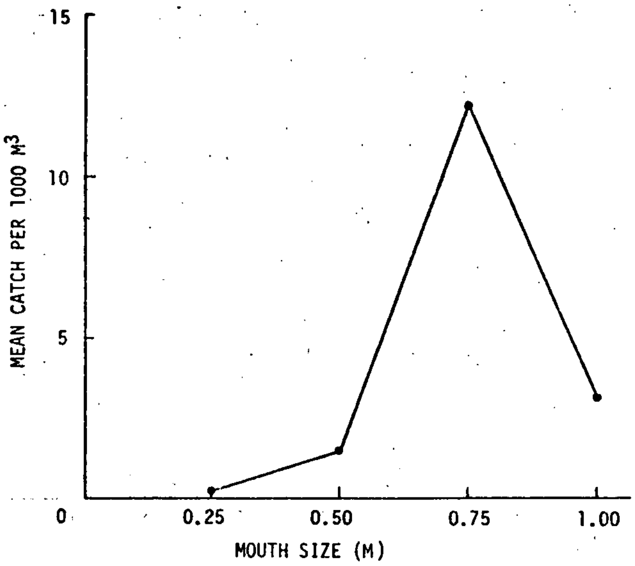

Figure III-7. Mean Catch of Larval Striped Bass by Epibenthic Sleds with Four Mouth Sizes, during Darkness, 3 July 1974

2. 1975 Tow Speed Efficiency Study

Nonparametric analysis by the Wilcoson rank sum test indicated that a 1.0 m^2 Tucker trawl caught significantly ($Z = 6.64$; $\alpha = 0.05$) more post yolk-sac striped bass per volume at a tow speed of 120 cm/s than at 80 cm/s; the 50% increase in tow speed approximately tripled the mean catch from 2.55 to 8.61 larvae/1000 m^3. Gear efficiency with respect to tow speed depends on the size and type of organisms sampled (Aron and Collard, 1969) and the organism's ability to perceive the gear and avoid it (Barkley, 1964; Sissenwine et al, 1974). The Tucker trawl's maximum obtainable efficiency for post yolk-sac larvae had not been reached at 80 cm/s--and may not have been reached at 120 cm/s. TI, in its ichthyoplankton surveys of the Hudson River, usually tows the Tucker trawl at 90-120 cm/s; tow speeds greater than 120 cm/s reduce depth control and stability of this gear.

The catch data from this study were not normally distributed (W = 0.55 at 80 cm/s and W = 0.90 at 120 cm/s; both significant at $\alpha = 0.05$) when transformed and thus were not subjected to parametric analysis.

C. FILTRATION EFFICIENCY STUDIES

1. Net/No-Net Experiment

The presence of a 505 μ mesh net had no detectable effect on the ability of the 1.0 m^2 epibenthic sled and the 1.0 m^2 Tucker trawl to strain water. Digital flowmeter data collected during the 1975 net/no-net experiment appeared to be normal, with equal variance for both gear (Table III-7). Tests for equality of mean flow rate for the gear with and without a 505 μ mesh net mounted, were nonsignificant (Table III-7) at $\alpha = 0.05$. The filtration efficiency of a particular gear depends on the porosity of the net gauze and its surface area in relation to the net mouth area: filtration efficiency increases with increasing open area (pores) of the gauze until the open area is approximately three times the area of the net mouth, then efficiencies of 85% or greater may result (Tranter and Smith, 1968). The open gauze area of 505 μ mesh nets used on the Tucker trawl and epibenthic sled was sufficient to avoid reduction of efficiency caused by the net's presence.

2. Sustained Efficiency Experiment

The results of the sustained efficiency experiment were inconclusive. Tow duration had a significant effect ($\alpha = 0.05$) on the

Table III-7

Tests for Normality, Equality of Variance, and Equality of Mean Flow Rates Recorded by Digital Flowmeters in Net/No-Net Experiment

Gear	Date	Normality W		n	Equality of Variance F	df	Equality of Means F		df
Epibenthic sled	9/4	0.952	ns	28	1.62	13,13	0.04	ns	1,25
Tucker trawl	9/3	0.932	ns	29	1.19	13,14	0.19	ns	1,26

df Degrees of freedom
ns Not significant at $\alpha = 0.05$
n Number of valid samples

filtration efficiency of the epibenthic sled (F = 13.42; df = 7,60) and Tucker trawl (F = 7.08; df = 7,69), as determined by an analysis of covariance; yet there was no clearly discernible trend in the data with increasing tow duration (Figures III-8 and III-9). Clogging of the mesh by plankton or detritus reduces the effective mesh size and straining area of the net, thus reducing the filtration efficiency of the gear (Fraser, 1968). If increased tow duration had increased clogging of the net, one would have expected a decrease in the measured flow rate at greater tow durations (Tranter and Smith, 1969). Unmeasured variation in tow speed caused by electronic flowmeter error among samples may have been the source of the great variability in the data observed for this experiment and may have obscured the effect of tow duration.

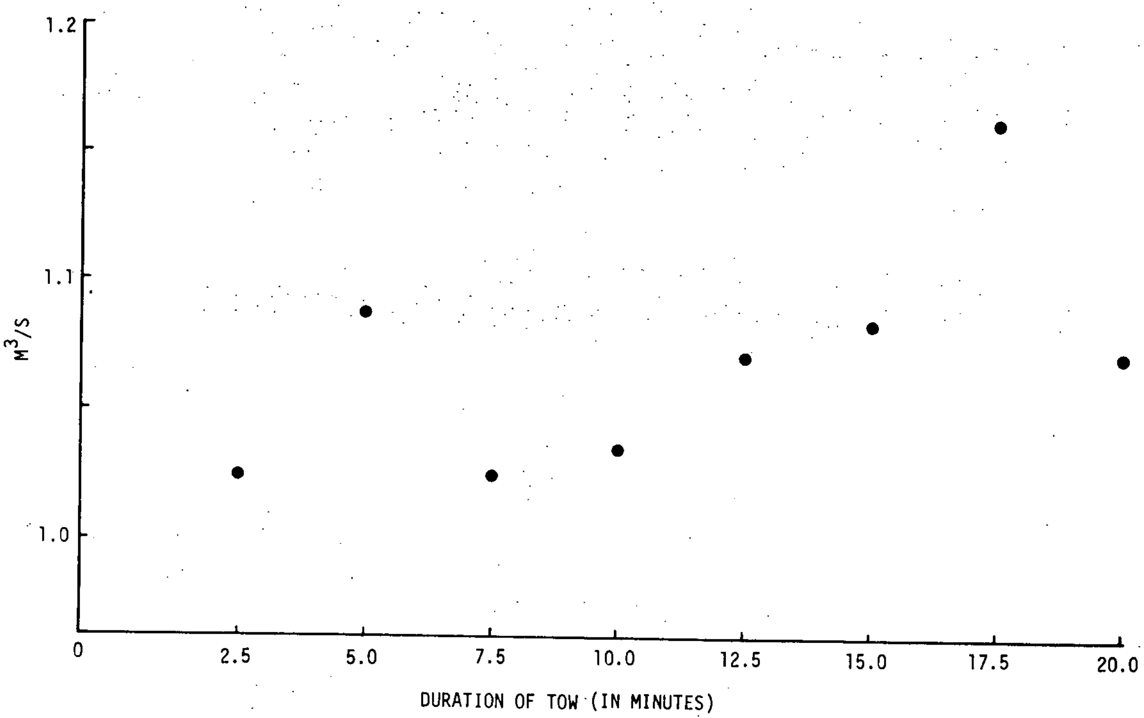

Figure III-8. Mean Volume per Second of Water Strained by 1.0 m^2 Tucker Trawl during 2.5 to 20 Min Tow

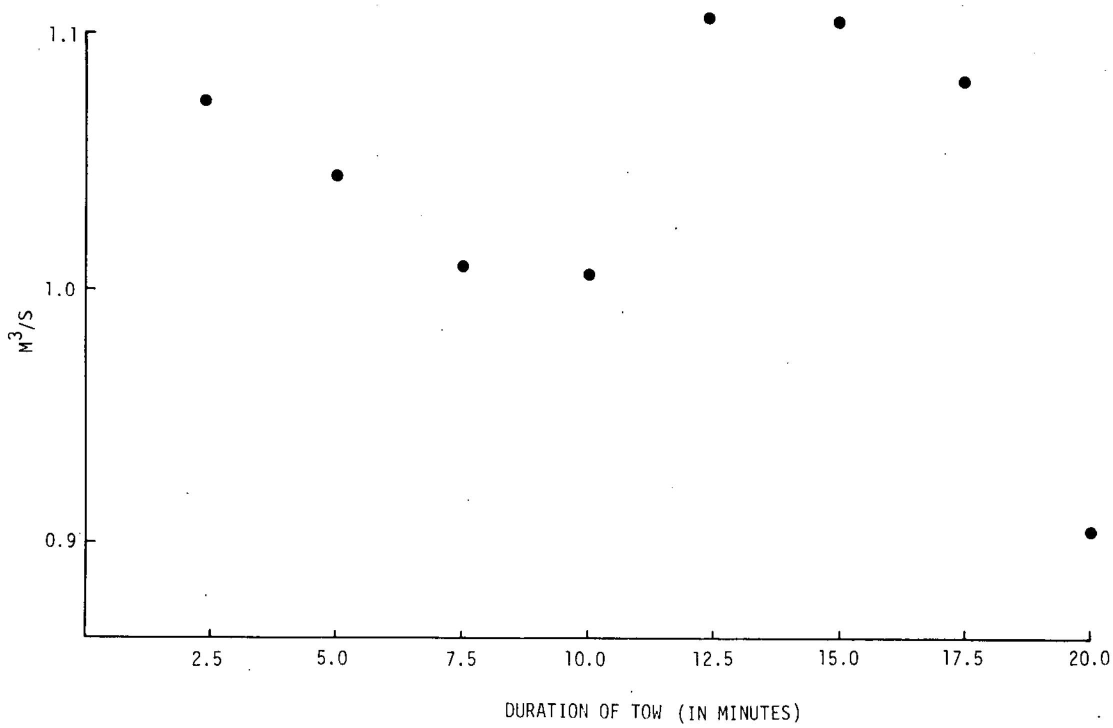

Figure III-9. Mean Volume per Second of Water Strained by 1.0 m^2 Epibenthic Sled during 2.5 to 20 Min Tow

SECTION IV

SUMMARY AND CONCLUSIONS

Much information has been obtained on the abundance and distribution of fish eggs and larvae, particularly striped bass, in the Hudson River estuary since 1965, but the reliability of comparisons of data collected with the different sampling gear was questionable because of potential differences in gear efficiency. Comparability of ichthyoplankton data would be enhanced if surveys conducted in the river used gear that (1) had similar abilities to catch all ichthyoplankters of the type desired from the sampled volume of water (catch efficiencies) and (2) had similar abilities to strain water (filtration efficiencies). Since catch efficiency often changes with the size or motility of the organism sampled, data from various surveys and sampling gear might be comparable for one life stage or species but not for another. The studies reported herein were concerned with the comparability of striped bass ichthyoplankton data collected by gear presently in use by investigators in the Hudson River estuary.

A. COMPARABILITY

The five gear types compared during 1974 and 1975 (1.0 m^2 epibenthic sled, 1.0 m^2 Tucker trawl, 1.0 m Hensen net, 1.0 m ring or conical net, and 0.5 m ring or conical net) usually had similar catch efficiencies (catch per volume) when deployed in the manner prescribed by the investigators using them. Most similar were the near-bottom sampling gear--the epibenthic sled, the Hensen net (towed separately or mounted on a sled frame), and the 0.5 m and 1.0 m ring nets. The only detectable difference occurred between the 0.5 m ring net and the 1.0 m^2 epibenthic sled in the collection of eggs during 1975, when the ring net proved more efficient. The gear towed at mid-depths during 1974--the 1.0 m^2 Tucker trawl, the 1.0 m Hensen net, and the 1.0 and 0.5 m ring nets--generally were indistinguishable with respect to their catch efficiency for striped bass post yolk-sac larvae. During 1975, however, when these gear (excluding the 1.0 m ring net) were towed near the surface, there were significant differences among their catch per volume of striped bass yolk-sac and post yolk-sac larvae; for these life stages, the Tucker trawl appeared to be more efficient than the Hensen net or 0.5 m ring net. There were no differences among catch efficiencies for striped bass eggs near the surface in the 1975 comparisons.

For analysis a statistical model was used that could also be adapted easily for applying correction factors to catch data for differing catch efficiencies. Based on the 1974 and 1975 results, however, correction factors usually would have equaled unity and thus would be unnecessary. Although the results of the comparability studies indicated similar efficiencies for the gear as deployed, it would be improper to equate catch-per-volume data without further study if deployment procedures or monitoring methods (e.g., use of flowmeters) differed among investigators.

B. GEAR MOUTH SIZE AND TOW SPEED VS CATCH EFFICIENCY

The effects of mouth size (epibenthic sled and Tucker trawl) and tow speed (Tucker trawl) on catch efficiency were studied for sampling gear used by TI. Size of the gear and the speed at which it is towed, in conjunction with the sampled organism's ability to perceive and avoid gear, have been frequently shown to affect catch. Both of these variables (tow speed and mouth size) are controllable within limits.

The maximum obtainable efficiency in collecting striped bass post yolk-sac larvae was apparently reached for the range of gear mouth sizes employed for the epibenthic sled and Tucker trawl. Increasing the sled's mouth width from 0.25 to 1.0 m and the trawl's from 0.5 to 1.25 m had no significant effect on catch per volume at a tow speed of 80 cm/s. An increase in tow speed of the 1.0 m^2 Tucker trawl from 80 to 120 cm/s significantly increased the catch per volume (approximately tripling it). Apparently, tow speed is a very important variable that must be standardized within a survey, and preferably between surveys, to maximize comparability.

C. FILTRATION EFFICIENCY

Two aspects of the filtration efficiency of TI sampling gear were studied during 1975: the ability of a 505 μ mesh net to strain water (i.e., filtration efficiency) and to sustain its filtration efficiency for tows lasting up to 20 min. The net's filtration efficiency was tested by observing water flow rates, as recorded by flowmeters, for an epibenthic sled and Tucker trawl towed with and without the net mounted. Flow rates were observed also for 2.5- to 20-min tows of each gear (with net mounted).

The presence of a 505 μ mesh net had no significant effect on either gear's flow rates. It may be concluded that the open area of net gauze in relation to the mouth area was sufficiently large to permit efficient filtration. The results of the test for effects of tow duration on the net's sustained filtration efficiency were inconclusive.

D. CONCLUSION

It may be concluded from the 1974 and 1975 gear evaluation studies that:

- Ichthyoplankton sampling gear used by TI, NYU, and LMS on the Hudson River estuary have similar efficiencies as deployed and, in most cases, would not require correction factors to make the data obtained with them comparable.
- Catch-per-volume data from independent investigators should not be equated without further study if the deployment or monitoring methods differ from those employed in the comparability studies.
- Mouth sizes used for the epibenthic sled and Tucker trawl are sufficiently large to permit maximal catch efficiency within the range of tow speeds tested.
- Tow speeds should be standardized at the highest speed possible while maintaining control of the gear.
- Net surface area:mouth-size ratios used for TI gear (epibenthic sled and Tucker trawl) are sufficiently large to insure efficient filtration.

SECTION V

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SECTION VI

GLOSSARY

Absolute abundance:	actual total population in a volume.
Bridle:	the assembly affixed to a plankton net's mouth in order to tow it.
Catchability:	the fraction of a fish population that is caught by a defined unit of fishing.
Clogging:	debris (organic or inorganic) accumulation between strands of net mesh, causing smaller organisms to be retained and reducing the rate of flow of water through the net.
Comparability:	the ability to equate data collected by different sampling gear.
Depressor:	an underwater device used with plankton samplers to eliminate erratic towing behavior and maintain consistent tow depth; its high lift/drag ratio allows for high depressing force without great weight.
Digital flowmeter:	a metering device that records the distance traveled through the water.
Detritus:	finely divided settleable material of organic or inorganic origin.
Drag:	resistance experienced by a net being towed through the water; it is dependent on the shape of the sampler, mesh size, and tow speed.

Electronic flowmeter:	a device that generates electrical impulses as it moves through the water, the rate of the impulses being proportioned to the velocity.
Epibenthic:	the layer of water just above the river bottom.
Filtration efficiency:	ratio of volume of water strained through the net to volume of water that would have passed through the net frame had no net been present.
Formalin:	a chemical composed of 47% solution of formaldehyde gas dissolved in water; it is used both as a preservative and as a treatment for external fish parasites.
Gauze:	a general term referring to the material used in plankton netting.
Gear avoidance:	the behavior of organisms that enables them to escape capture in a sampling gear.
Gear efficiency:	ratio of number of organisms caught by a particular sampling gear to number of organisms actually present in the volume of water sampled.
Ichthyoplankton:	a general term referring to the early, planktonic, life stages of fish (eggs, yolk-sac larvae, post yolk-sac larvae, and early juveniles).
Outlier:	an observation lying far away from most of the other observations and, for "explainable" reasons, excluded from analysis.
Phenotypic characteristics:	the visible characters of an organism resulting from the interaction of its genetic makeup and the physical environment.

Plankton:	organisms floating passively or swimming weakly in a body of water.
Porosity:	ratio of the area of openings in the net material to the area of the material.
Rose bengal:	dye that stains the cytoplasm of organisms red.
Spurious:	false or erroneous.

APPENDIX A

SAMPLING GEAR AND DEPLOYMENT PROCEDURES

Table A-1

Description of Gear Used in Gear Comparability Studies

Gear	Mesh Size (μ)	Net		Weighting		Position of Boat Speed Device
		Lenth:Mouth	Closing Device	Method	Position	
1.0 m^2 Tucker trawl	505	8:1	Double-trip mechanism*	82 kg weight	Bottom bar	0.5 m above net
1.0 m^2 epibenthic sled	505	8:1	Double-trip mechanism*	None	None	0.5 m above net
1.0 m Hensen net	571	6:1	None	None (1975)†	None (1975)†	Hanging from boat side
				23 kg depressor (1974)	Off-bridle (1974)	
1.0 m conical net	571	3.8:1	None	23 kg depressor	1.5 m below net	Hanging from boat side
0.5 m conical net	571	7.6:1	None	23 kg depressor	1.5 m below net	Hanging from boat side

*General Oceanics

†Mounted on sled frame in 1975

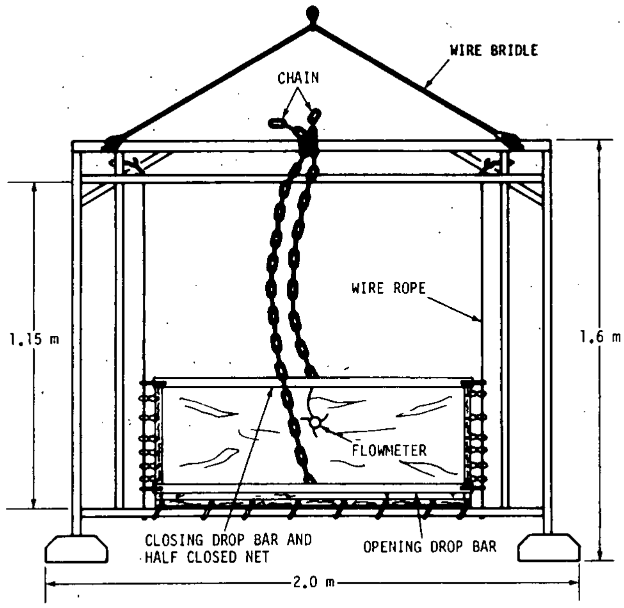


Figure A-1. Front View of 1.0 m^2 Epibenthic Sled

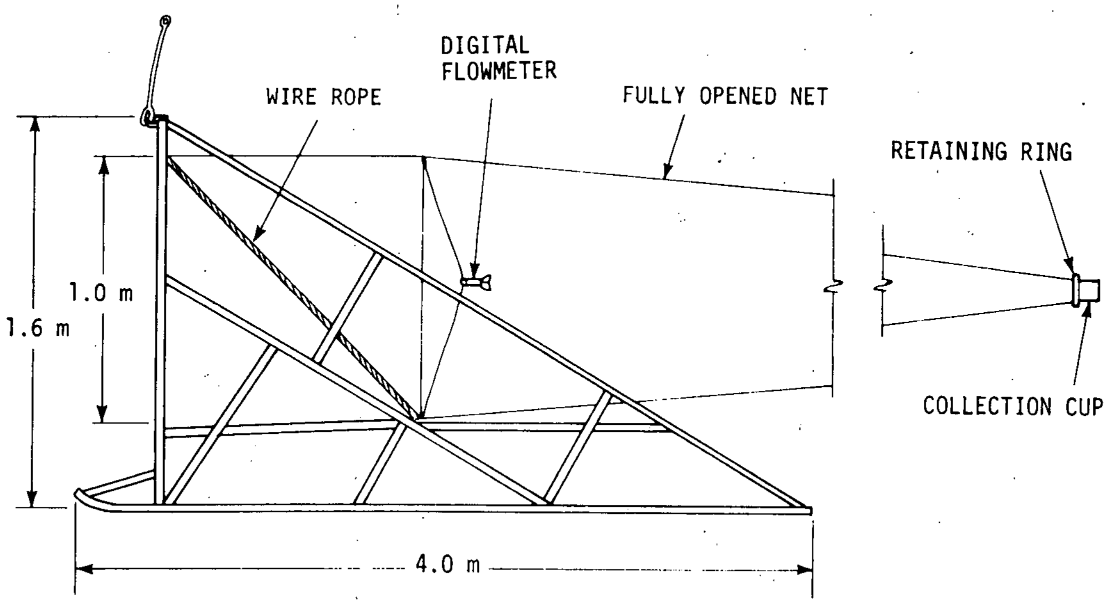


Figure A-2. Side View of 1.0 m^2 Epibenthic Sled

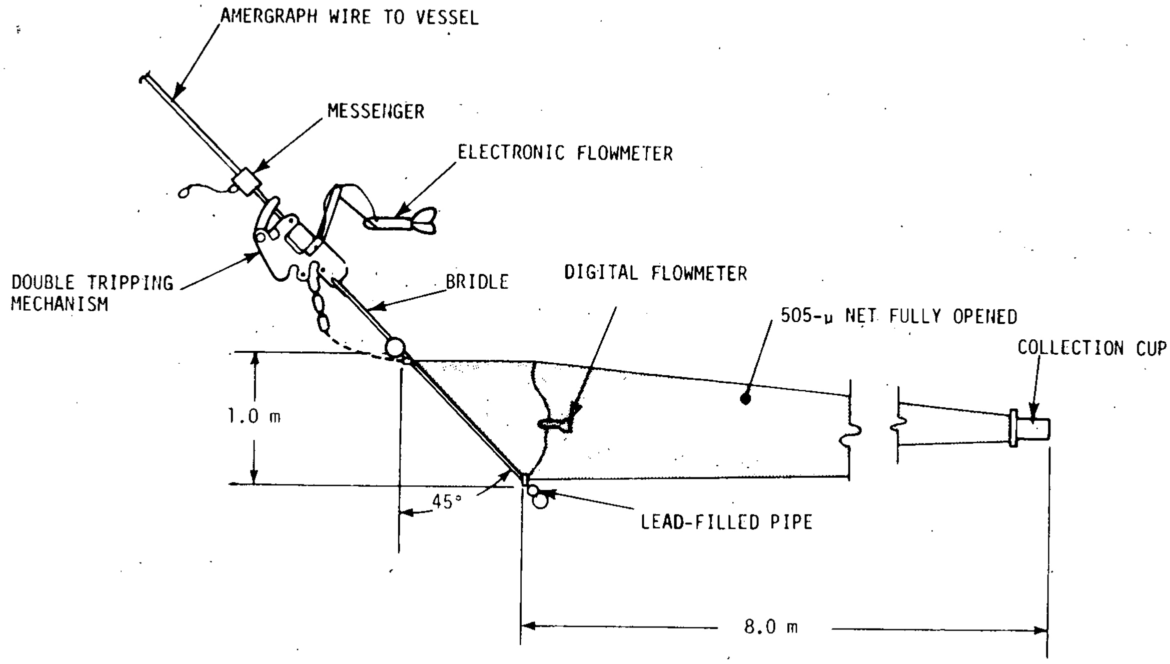


Figure A-3. Side View of 1.0 m^2 Tucker Trawl

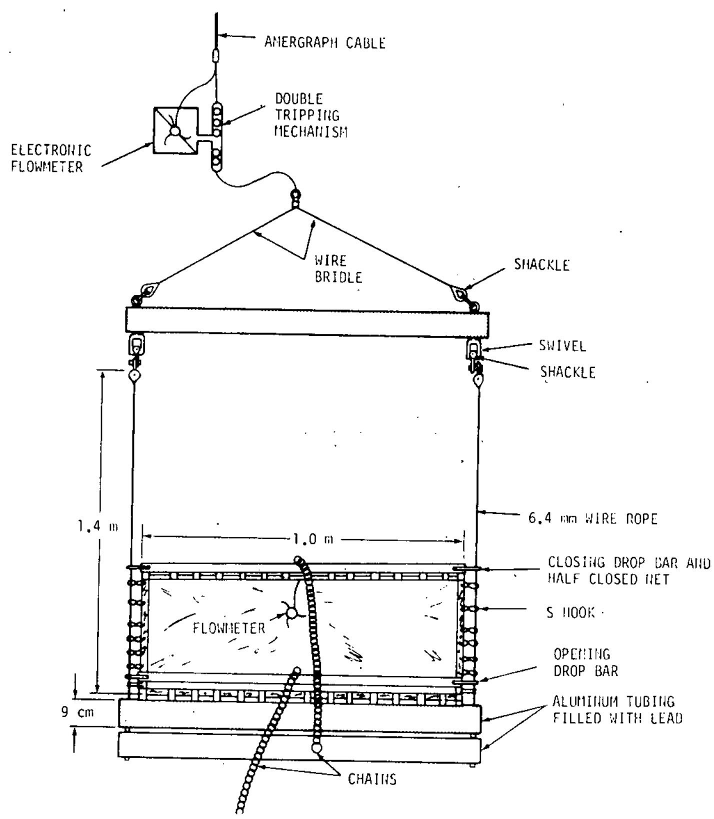


Figure A-4. Front View of 1.0 m^2 Tucker Trawl

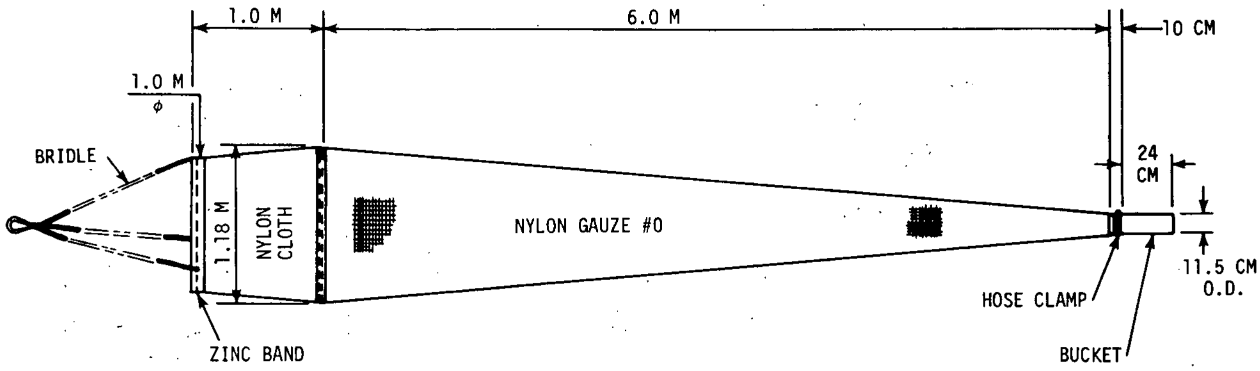
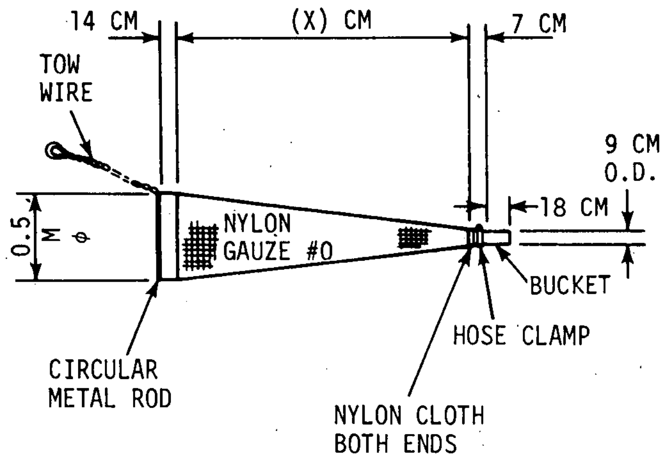


Figure A-5. Side View of 1.0 m Hensen Net (Adapted from QLM, 1973)



NET NO.	(X) LENGTH
1	140
2	200

Figure A-6. Side View of 0.5 m Ring or Conical Net (Adapted from QLM, 1973)

Table A-2

Description of Gear Used To Collect Ichthyoplankton in Hudson River Estuary, 1966-1974

Contractor: Northeast Biologist (HRFI)
Reference: Carlson and McCann, 1969

Period	Gear	Length:Mouth	Mesh Size (μ)	Flowmeter	Closing Device	Weighting
1966	1.5' (0.46m) conical net	4.3:1	300x500 500x800	Impeller type	None	Anchored
1967	1.5' (0.46m) conical net	4.3:1	300x500	Impeller type	None	3.6 kg mushroom anchor
1968	1.5' (0.46m) conical net	4.3:1	300x500 500x800 1500x1650 3300x3300	Impeller type	None	3.6 kg mushroom anchor
	3'x 3' (0.91m) pyramidal net	8:1	300x500 500x800 1500x1650 3300x3300	Impeller type	None	3.6 kg mushroom anchor

Contractor: Raytheon
Reference: Raytheon Company, 1971. Personal communication, David Crestin

Period	Gear	Length:Mouth	Mesh Size (μ)	Flowmeter	Closing Device	Weighting
Jul 1969-Feb 1970	1.5' (0.46m) conical net	4.7:1	300x500	None	None	17 kg depressor
Mar-Jul 1970	1.5' (0.46m) conical net	4.7:1	500	Mechanical	Throttling band	17 kg depressor

Contractor: NYU
Reference: New York University, 1973; 1974; 1976

Period	Gear	Length:Mouth	Mesh Size (μ)	Flowmeter	Closing Device	Weighting
1971-1972	0.5m conical net 1.0m conical net	7.6:1 3.8:1	571 1000	TSK TSK	None None	23 kg depressor 23 kg depressor
1973-1974	0.5m conical net 1.0m conical net 1.0m Hensen net	7.6:1 3.8:1 6:1	571 1000 571	G.O. 1031* G.O. 1031* G.O. 1031*	None None None	23 kg depressor 23 kg depressor 23 kg depressor

Contractor: QLM;LMS
Reference: Quirk, Lawler and Matusky Engineers, 1974; Lawler, Matusky and Skelly Engineers, 1975a, b. Personal communication with LMS staff

Period	Gear	Length:Mouth	Mesh Size (μ)	Flowmeter	Closing Device	Weighting
1971	0.5m conical net	3:1	363	TSK	None	14 to 18 kg depressor
1972	0.5m conical net	3:1	571	TSK	None	14 to 18 kg depressor
1973-1974	0.1m Hensen net	6:1	571	TSK	None	23 kg depressor

Contractor: TI, Ossining
Reference: Texas Instruments Incorporated, 1973

Period	Gear	Length:Mouth	Mesh Size (μ)	Flowmeter	Closing Device	Weighting
1972-1974	0.5m conical net 1.0m conical net	5:1 5:1	500 1000 1500 2000	G.O. 2030 G.O. 2030	None None	23 kg depressor 23 kg depressor

Contractor: TI, longitudinal river survey
Reference: Texas Instruments Incorporated, 1975a, 1975b

Period	Gear	Length:Mouth	Mesh Size (μ)	Flowmeter	Closing Device	Weighting
1973	1.0 m^2 Tucker trawl	8:1	505	G.O. 2030	Double-trip mechanism*	59 kg bar
	2.0 m^2 Tucker trawl	5:1	1800 3000	G.O. 2030	Double-trip mechanism*	141 kg bar
	1.0 m^2 epibenthic sled	8:1 5:1	505 1000 1800 3000	G.O. 2030	Double-trip mechanism*	None
1974	1.0 m^2 Tucker trawl	8:1	505	G.O. 2030	Double-trip mechanism*	110 kg bar
	1.0 m^2 epibenthic sled	8:1 5:1	505 3000	G.O. 2030	Double-trip mechanism*	None

*General Oceanics

Table A-3

Description of Gear Deployment Procedures Used To Collect Ichthyoplankton in Hudson River Estuary, 1966-1974

Contractor: Northeast Biologist
Reference: Carlson and McCann, 1969

Period	Speed	Duration (min)	Direction	Depth	Time of Day
1966	Anchored	15	NA	Surface to 1.5m from bottom	Day
1967-1968	0.8-0.9m/s	10	Countercurrent	Surface to bottom at 4.6m intervals	Day and Night

Contractor: Raytheon
Reference: Raytheon Co., 1971. Personal communication, David Crestin

Period	Speed	Duration (min)	Direction	Depth	Time of Day
Jul 1969-Feb 1970	Adjusted to keep surface net at surface	10	Countercurrent	Surface, bottom, and mid-depth	Day and Night
Mar-Jul 1970	Adjusted to keep surface net at surface	10	Countercurrent	Surface, mid-depth, and bottom	Day and Night

Contractor: NYU
Reference: New York University, 1973, 1974, 1976

Period	Speed	Duration (min)	Direction	Depth	Time of Day
1971-1973	0.7-1.1m/s	10	Countercurrent	Surface, mid-depth, and bottom	Day and Night
1974	Engine speed adjusted to 2000 rpm	10	Countercurrent	Surface, mid-depth, and bottom	Day and Night

Contractor: QLM;LMS
Reference: Quirk, Lawler and Matusky Engineers, 1974; Lawler Matusky and Skelly Engineers, 1975a, b

Period	Speed	Duration (min)	Direction	Depth	Time of Day
1971	1.2-1.7m/s	5	Countercurrent	Surface, mid-depth, and bottom	Day
1972	0.7-1.7m/s	5	Countercurrent	Surface, mid-depth, and bottom	Day and Night
1973	0.7-1.7m/s	5	Countercurrent	Surface to bottom at 3.0m intervals	Day and Night
1974	0.85-0.55m/s	5	Countercurrent	Surface, mid-depth, and bottom	Day and Night

Contractor: TI, Ossining
Reference: Texas Instruments Incorporated, 1973

Period	Speed	Duration (min)	Direction	Depth	Time of Day
1972-1973	0.9-1.2m/s	10	Countercurrent	Surface, bottom	Day and Night

Contractor: TI, longitudinal river survey
Reference: Texas Instruments Incorporated, 1975

Period	Speed	Duration (min)	Direction	Depth	Time of Day
1973	Tucker trawl, 0.9-1.2m/s Epibenthic sled 0.5-1.0m/s	5 or 2	Downriver	Surface, mid-depth, and bottom	Day and Night
1974	Tucker trawl, 0.9-1.2m/s Epibenthic sled, 0.5-1.0m/s	5	Downriver	Surface to bottom	Day and Night

NA = not applicable

APPENDIX B

METHODS FOR CALCULATING CORRECTION COEFFICIENTS
FOR COMPARING CATCH DATA FROM DIFFERENT GEAR

APPENDIX B

METHODS FOR CALCULATING CORRECTION COEFFICIENTS FOR COMPARING CATCH DATA FROM DIFFERENT GEAR

A correction coefficient $\widehat{\left(\frac{K_1}{K_2}\right)}$ for comparing catch efficiencies of different gear can be derived from the log transformation of the statistical model presented in Section II:

$$\log_e (D_{ij} + 1) = \log_e K_i + \log_e \mu + \log_e \varepsilon_{ij}$$

where

D_{ij} = catch per 1000 m^3 in tow j with gear i

K_i = proportion of μ caught by gear i

μ = expected number of organisms per 1000 m^3 in sampling area

ε_{ij} = random error

The "best linear unbiased" estimate of the natural log of the correction coefficient $\left(\log_e \frac{K_1}{K_2}\right)$ or $(\log_e K_1 - \log_e K_2)$ can be obtained (Graybill, 1961, theorem 11.1) by:

$$\widehat{\log_e K_1 - \log_e K_2} = \frac{\sum_{j=1}^{n_1} \log_e (D_{1j} + 1)}{n_1} - \frac{\sum_{j=1}^{n_2} \log_e (D_{2j} + 1)}{n_2}$$

where

n_i = number of tows for gear i

An untransformed estimate of the correction coefficient can be taken as

$$\widehat{\left(\frac{K_1}{K_2}\right)} = \exp\left(\frac{\sum_{j=1}^{n_1} \log_e (D_{1j} +1)}{n_1} - \frac{\sum_{j=1}^{n_2} \log_e (D_{2j} + 1)}{n_2}\right)$$

APPENDIX C

CATCH DATA OF THE 1974 GEAR COMPARABILITY STUDY

Table C-1

Mean Catch of Larval Striped Bass during 1974 Gear Comparability Study

Gear	Time	Date	No. of Samples	Mean Catch per 1000 m^3	Standard Deviation
1.0 m ring net	Day	6/24	10	5.5777	0.6698
1.0 m^2 Tucker trawl			8	5.7338	0.6295
0.5 m ring net	Day	6/24	10	5.6763	0.7460
1.0 m^2 Tucker trawl			10	5.2778	0.7669
1.0 m Hensen net	Day	6/24	6	5.3104	0.9843
1.0 m^2 Tucker trawl			7	6.0080	0.4772
0.5 m ring net	Day	6/26	6	3.6078	0.8463
1.0 m^2 Epibenthic sled			10	3.8498	0.6758
1.0 m ring net	Day	6/26	10	4.3183	0.2394
1.0 m^2 Epibenthic sled			9	3.7249	0.8321
1.0 m Hensen net	Day	7/2	5	3.2436	0.7857
1.0 m^2 Epibenthic sled			5	2.9895	0.4929
1.0 m ring net	Night	7/8	10	2.2168	1.0403
1.0 m^2 Tucker trawl			10	0.9450	1.3037
1.0 m Hensen net	Night	7/9,10	10	1.4382	1.3842
1.0 m^2 Epibenthic sled			10	2.2319	1.2148
0.5 m ring net	Night	7/11	8	0.7731	1.4646
1.0 m^2 Tucker trawl			9	0.5249	0.7881
1.0 m Hensen net	Night	7/10	10	1.5671	1.7204
1.0 m^2 Epibenthic sled			7	0.8139	1.4964
1.0 m ring net	Night	7/11	10	1.3130	0.9733
1.0 m^2 Epibenthic sled			5	1.3553	1.3839
0.5 m ring net	Night	7/11	8	0.6287	1.1643
1.0 m^2 Epibenthic sled			7	0.6816	1.1944
1.0 m Hensen net	Day	7/23	10	0.8481	0.9135
1.0 m^2 Epibenthic sled			4	0.4752	0.9505
1.0 m ring net	Night	8/1	8	0.3214	0.5953
1.0 m^2 Epibenthic sled			4	0.4900	0.9800

APPENDIX D

FLOWMETER READINGS FROM 1975 FILTRATION EFFICIENCY EXPERIMENTS

APPENDIX D

FLOWMETER READINGS FROM 1975 FILTRATION EFFICIENCY EXPERIMENTS

This appendix presents the graphical method for detecting erroneous flowmeter readings taken during the 1975 filtration efficiency experiments (net/no-net and sustained efficiency). The three flowmeter positions (A,B,C) shown in Figures D-1 through D-20 correspond to the flowmeter positions illustrated in Figure II-1 of Section II.

Readings from digital flowmeters were compared with the electronic flowmeter reading taken during the same tow. An adjusted flow index was computed by:

$$\text{Adjusted flow index} = \frac{X}{T} - S$$

where

X = distance traveled (cm) as measured by digital flowmeter

T = tow duration(s)

S = tow speed (cm/s) as measured by electronic flowmeter

Profiles, depicted by a line drawn between plots of the adjusted flow indices for the three flowmeter positions, were examined visually for outliers. Outliers could be caused by malfunction of one of the flowmeters, possibly because of clogging or the tow speed's effect on the precision of the meter. Since only the center flowmeter (position B) was used for analysis, data from a particular tow were excluded from analysis if the position B reading obviously fell outside the distribution of the majority of the readings (e.g., Figure D-2), indicating a malfunction of digital flowmeter B; or if the entire profile (positions A, B, and C) for a tow appeared aberrant (e.g., Figure D-3), indicating a malfunction of the electronic flowmeter.

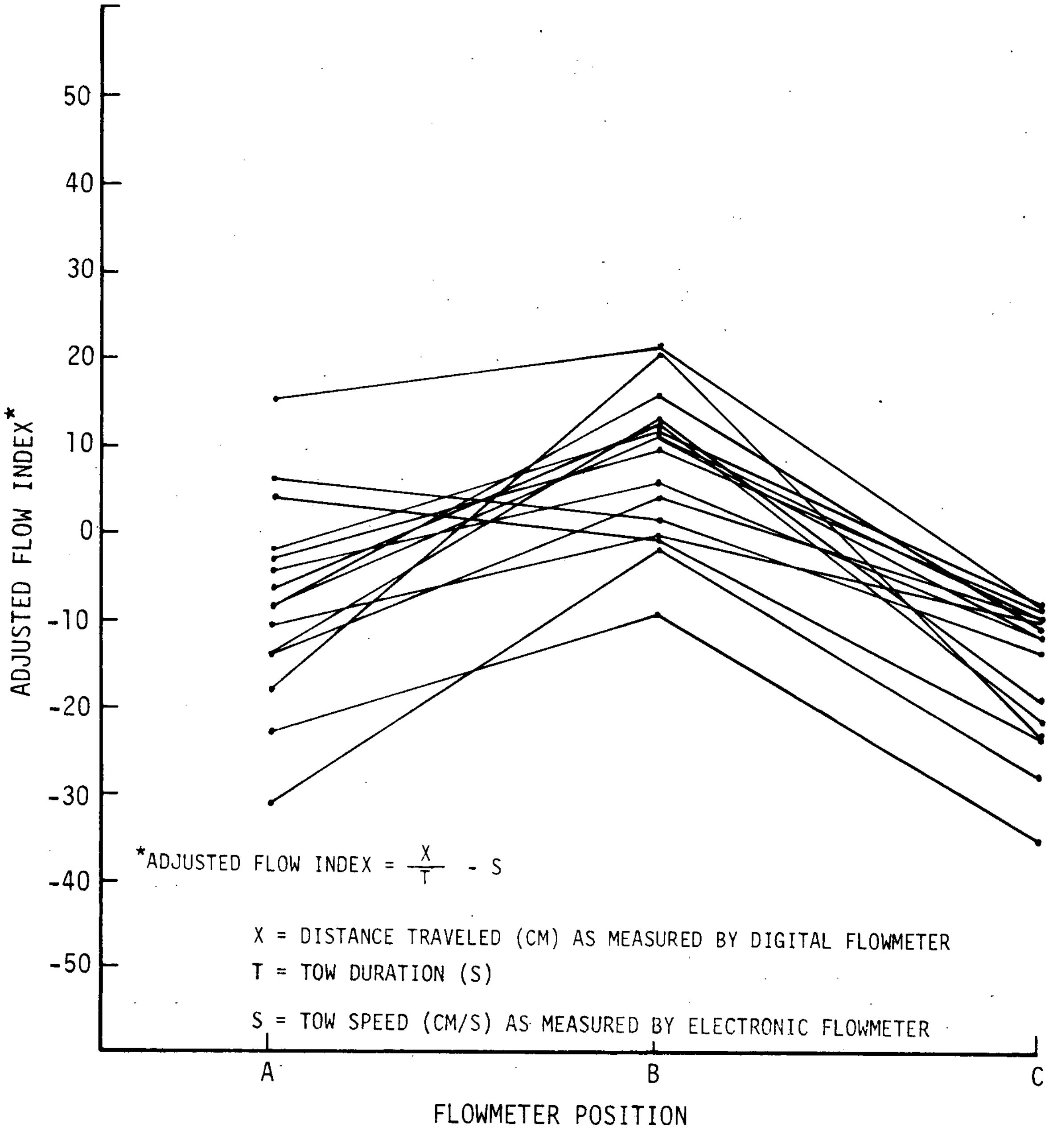


Figure D-1. Flowmeter Profiles for 15 Tows by 1.0 m^2 Tucker Trawl (with Net), 3 September 1975

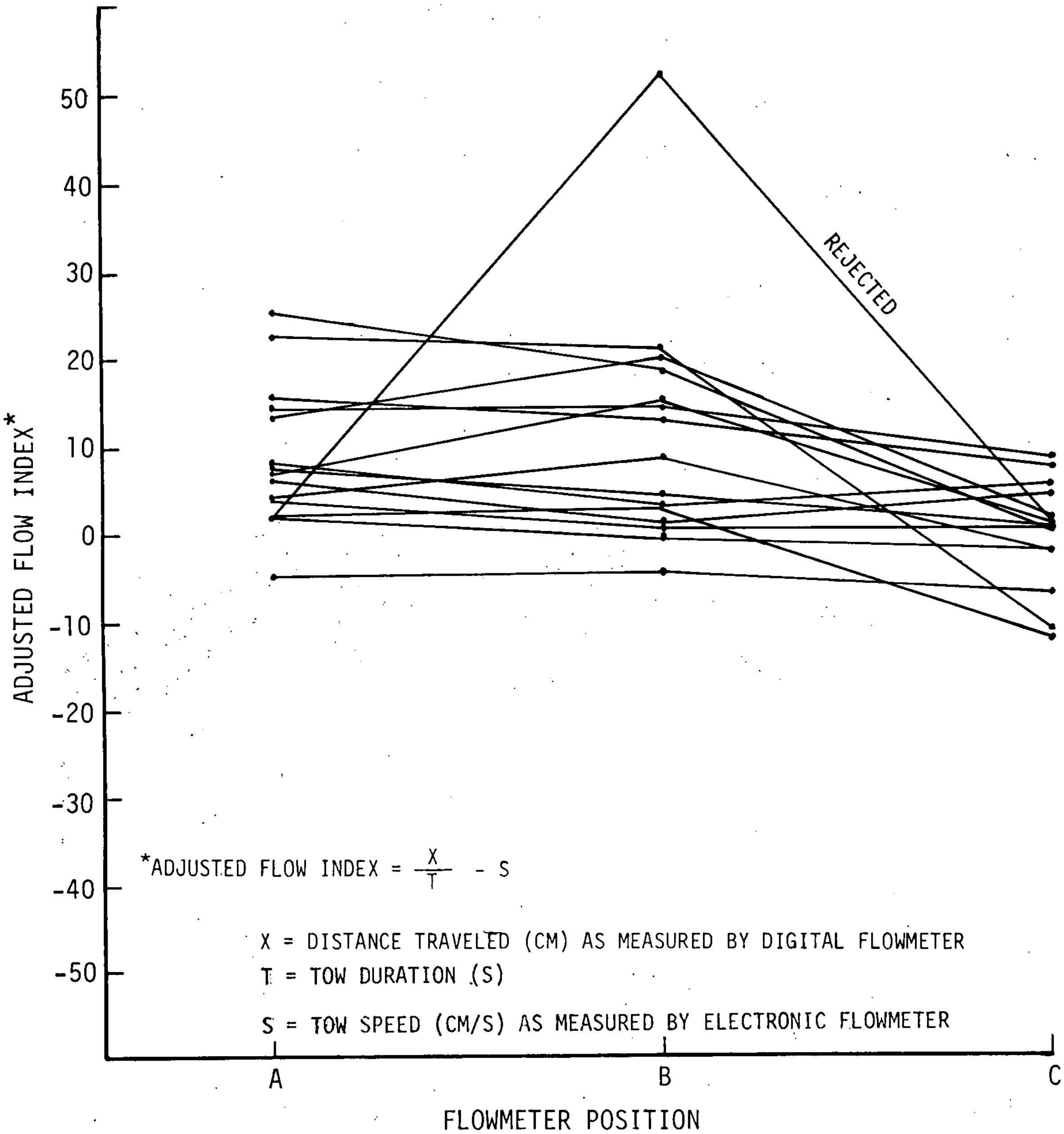


Figure D-2. Flowmeter Profiles for 15 Tows by 1.0 m^2 Tucker Trawl (without Net), 3 September 1975

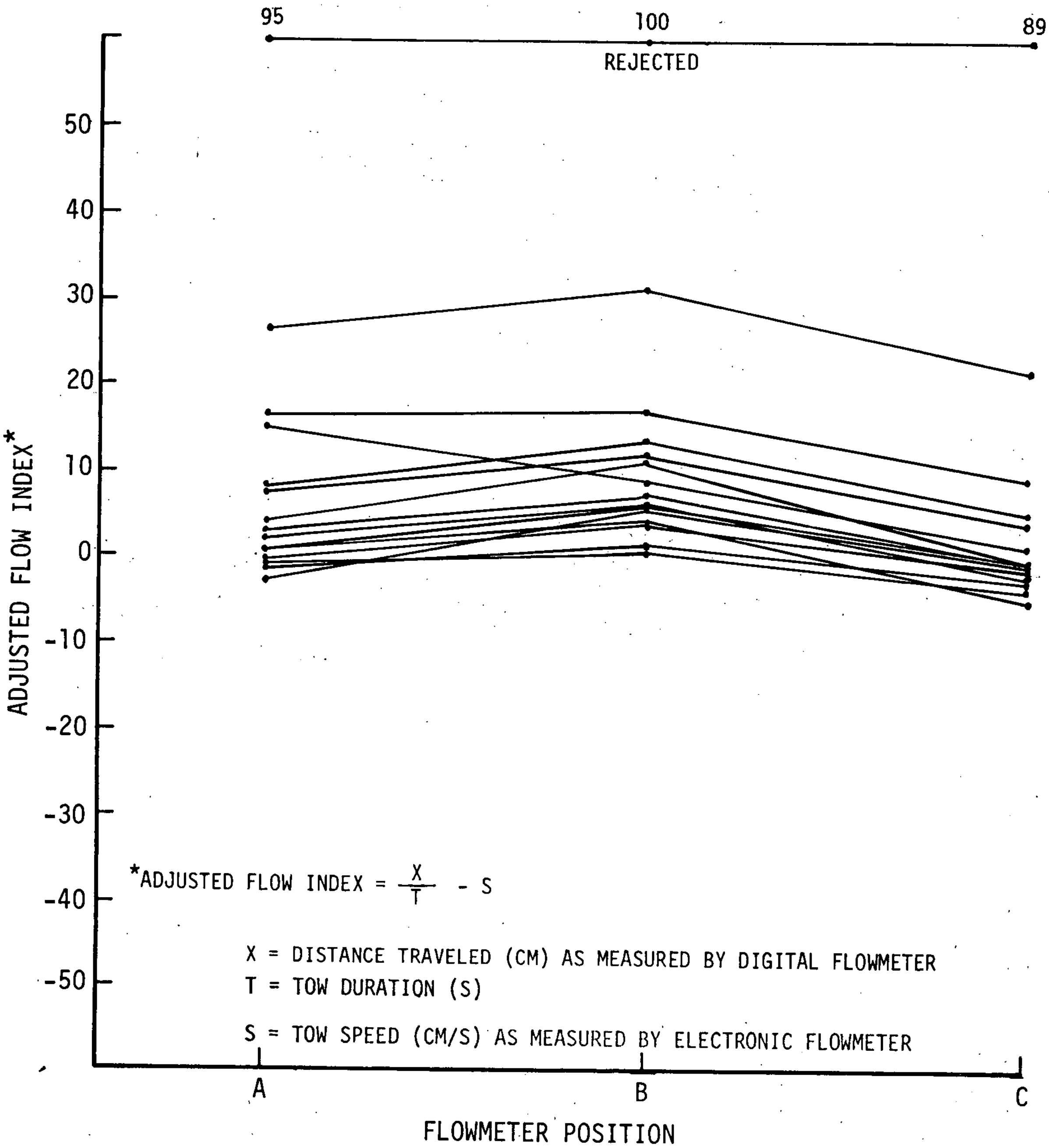


Figure D-3. Flowmeter Profiles for 15 Tows by 1.0 m^2 Epibenthic Sled (with Net), 4 September 1975

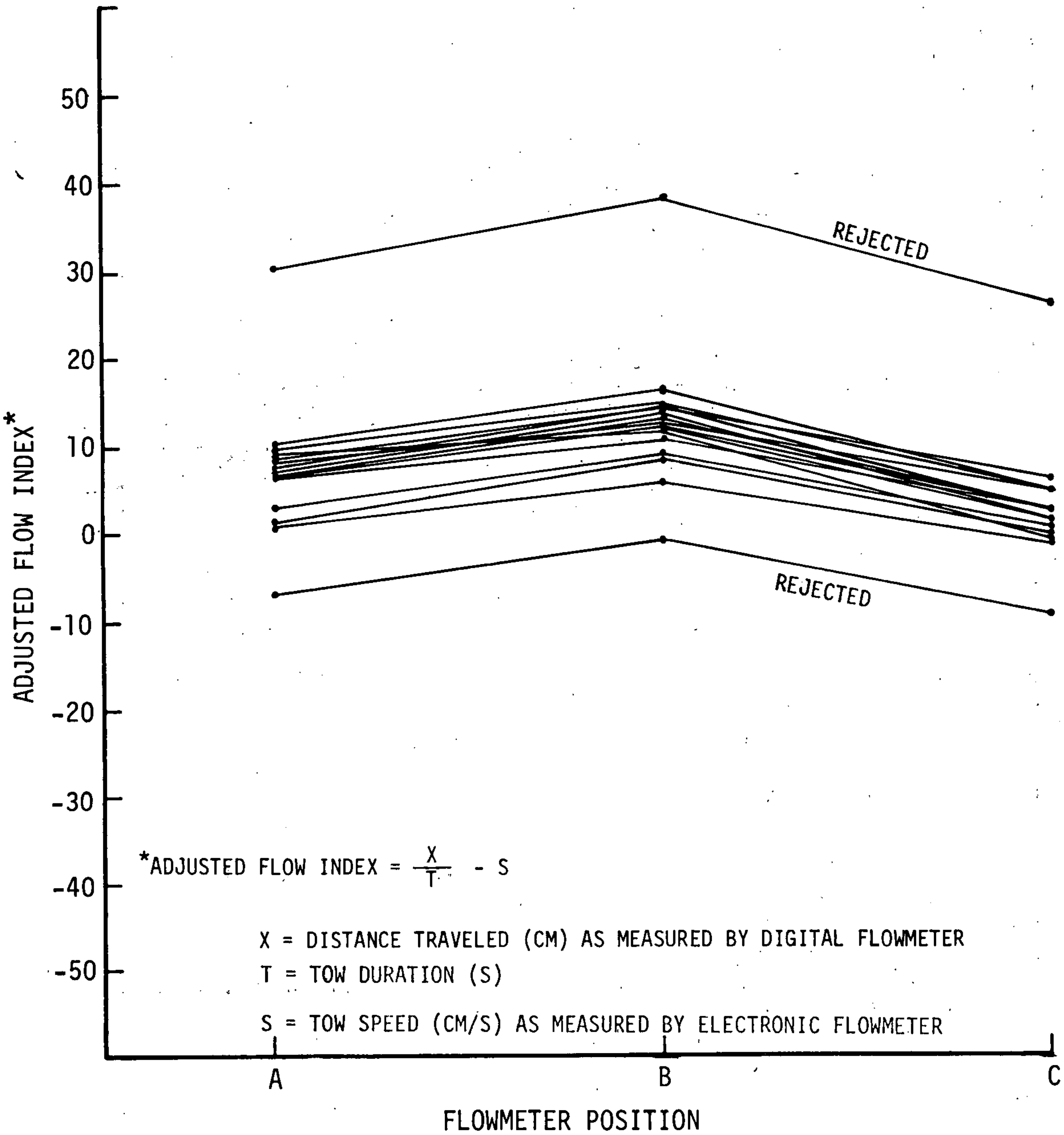


Figure D-4. Flowmeter Profiles for 15 Tows by 1.0 m^2 Epibenthic Sled (without Net), 4 September 1975

*ADJUSTED FLOW INDEX = $\frac{X}{T} - S$

X = DISTANCE TRAVELED (CM) AS MEASURED BY DIGITAL FLOWMETER

T = TOW DURATION (S)

S = TOW SPEED (CM/S) AS MEASURED BY ELECTRONIC FLOWMETER

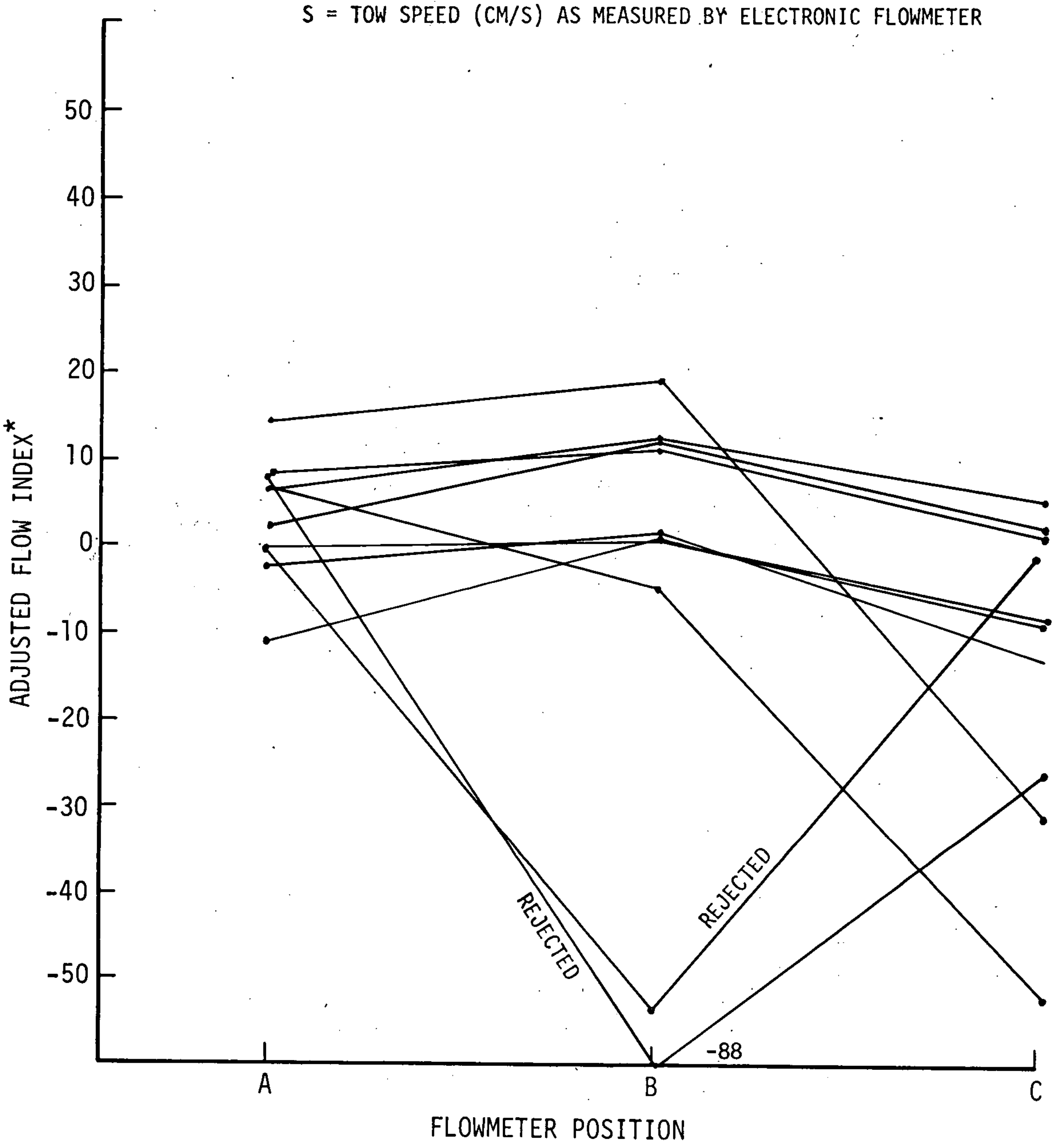


Figure D-5. Flowmeter Profiles for 2.5 Min Tows with 1.0 m^2 Epibenthic Sled, 5 September 1975

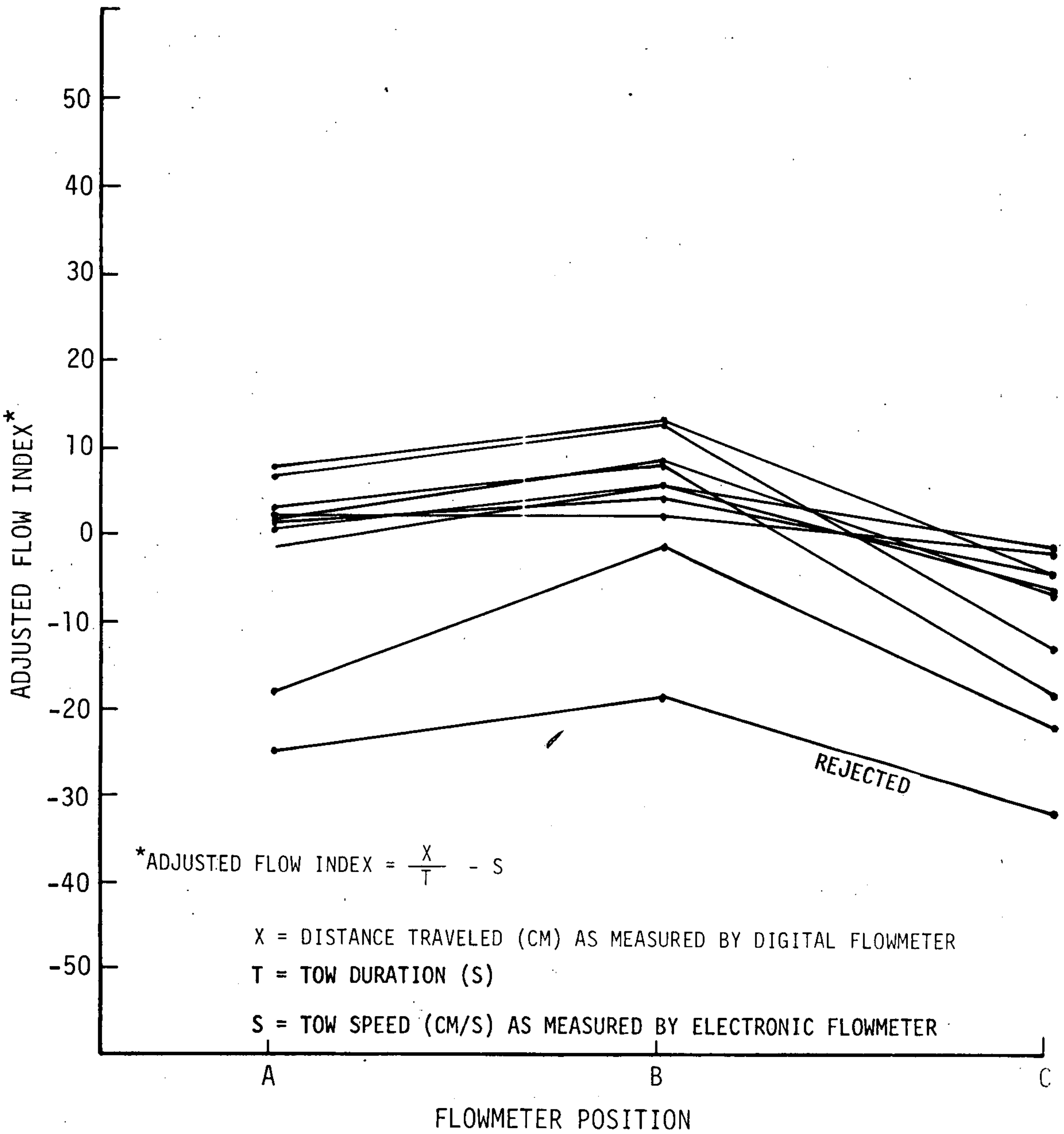


Figure D-6. Flowmeter Profiles for 5.0 Min Tows with 1.0 m^2 Epibenthic Sled, 8 September 1975

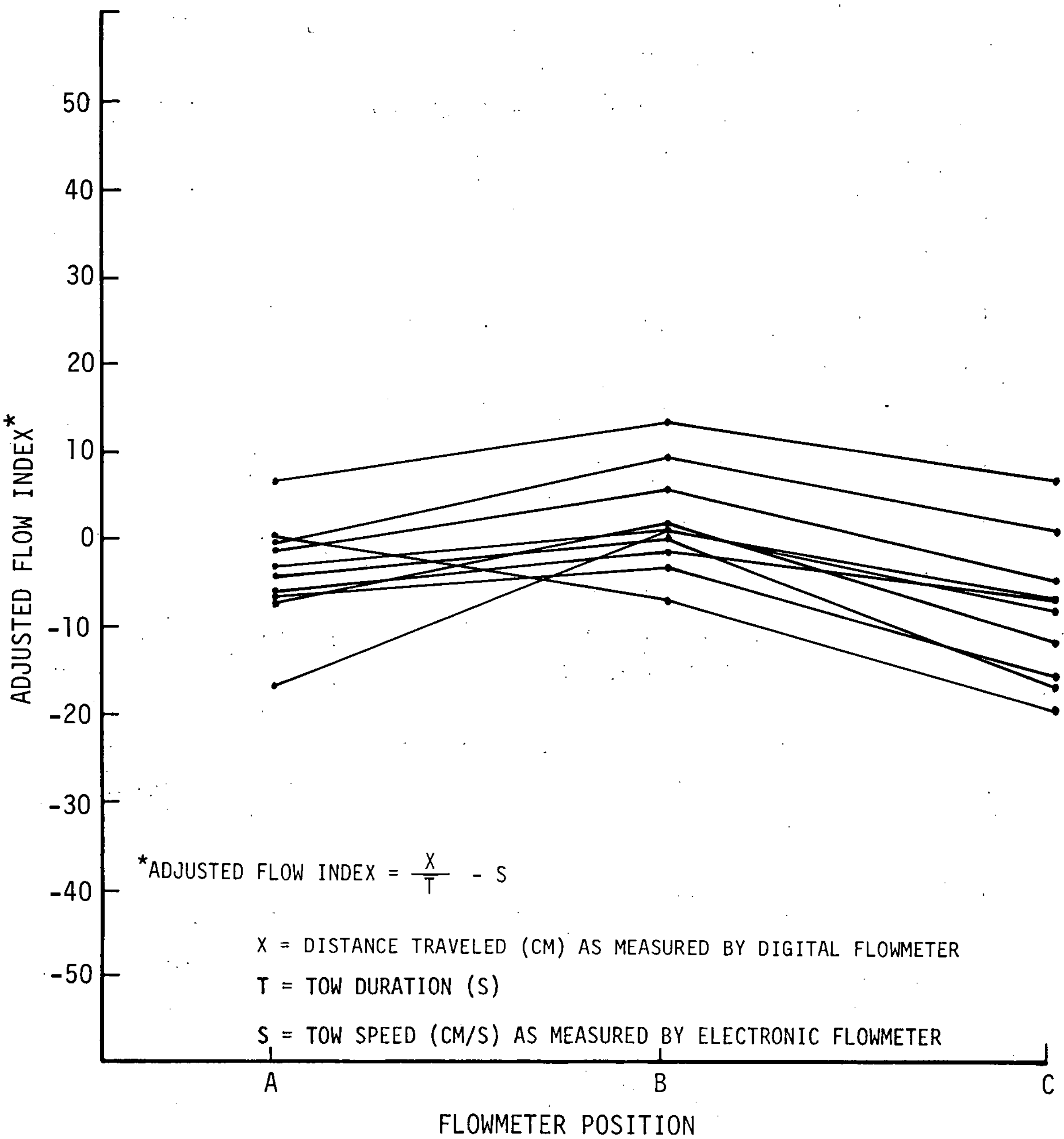


Figure D-7. Flowmeter Profiles for 7.5 Min Tows with 1.0 m^2 Epibenthic Sled, 8 September 1975

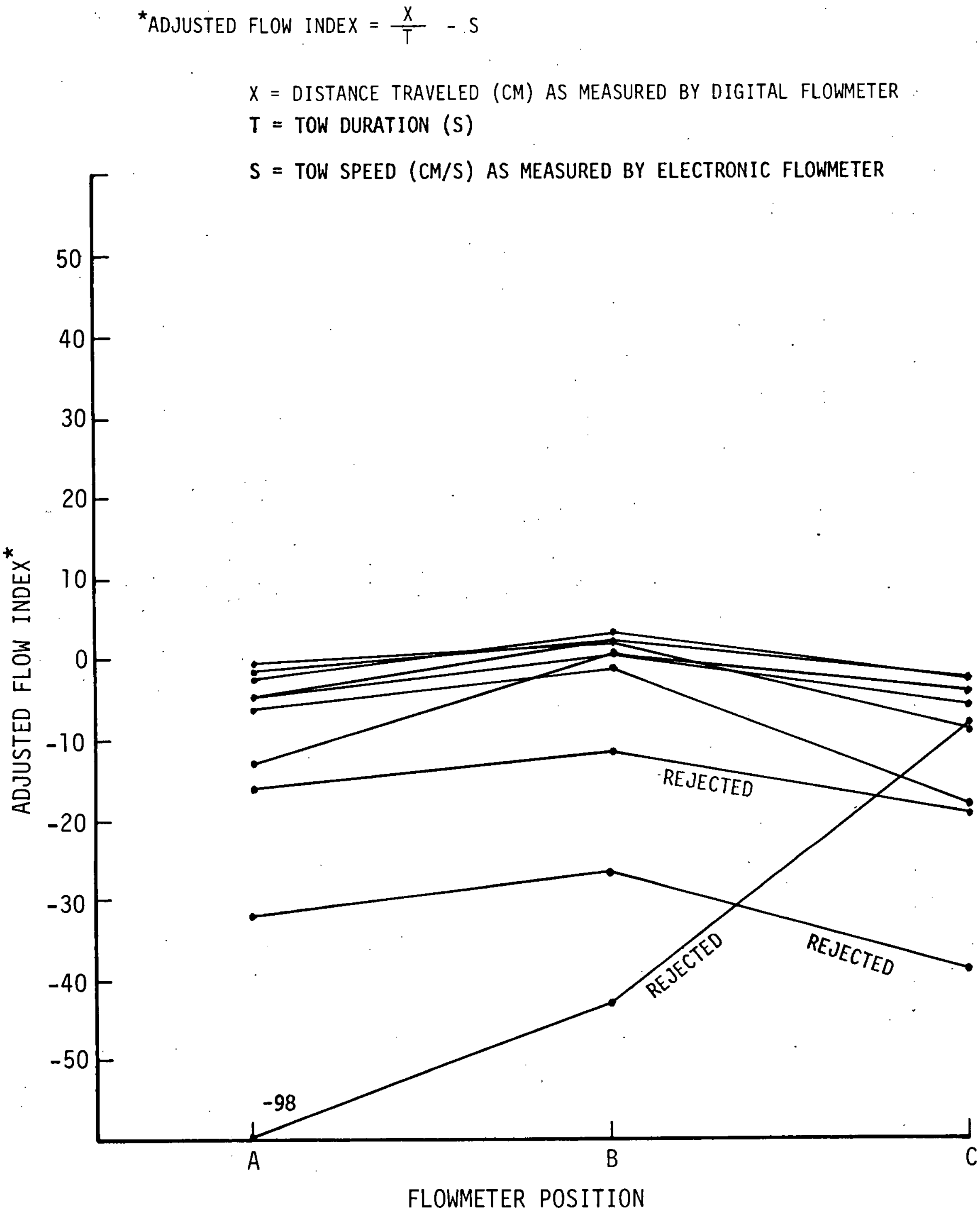


Figure D-8. Flowmeter Profiles for 10.0 Min Tows with 1.0 m^2 Epibenthic Sled, 9 September 1975

*ADJUSTED FLOW INDEX = $\frac{X}{T}$ - S

X = DISTANCE TRAVELED (CM) AS MEASURED BY DIGITAL FLOWMETER
T = TOW DURATION (S)
S = TOW SPEED (CM/S) AS MEASURED BY ELECTRONIC FLOWMETER

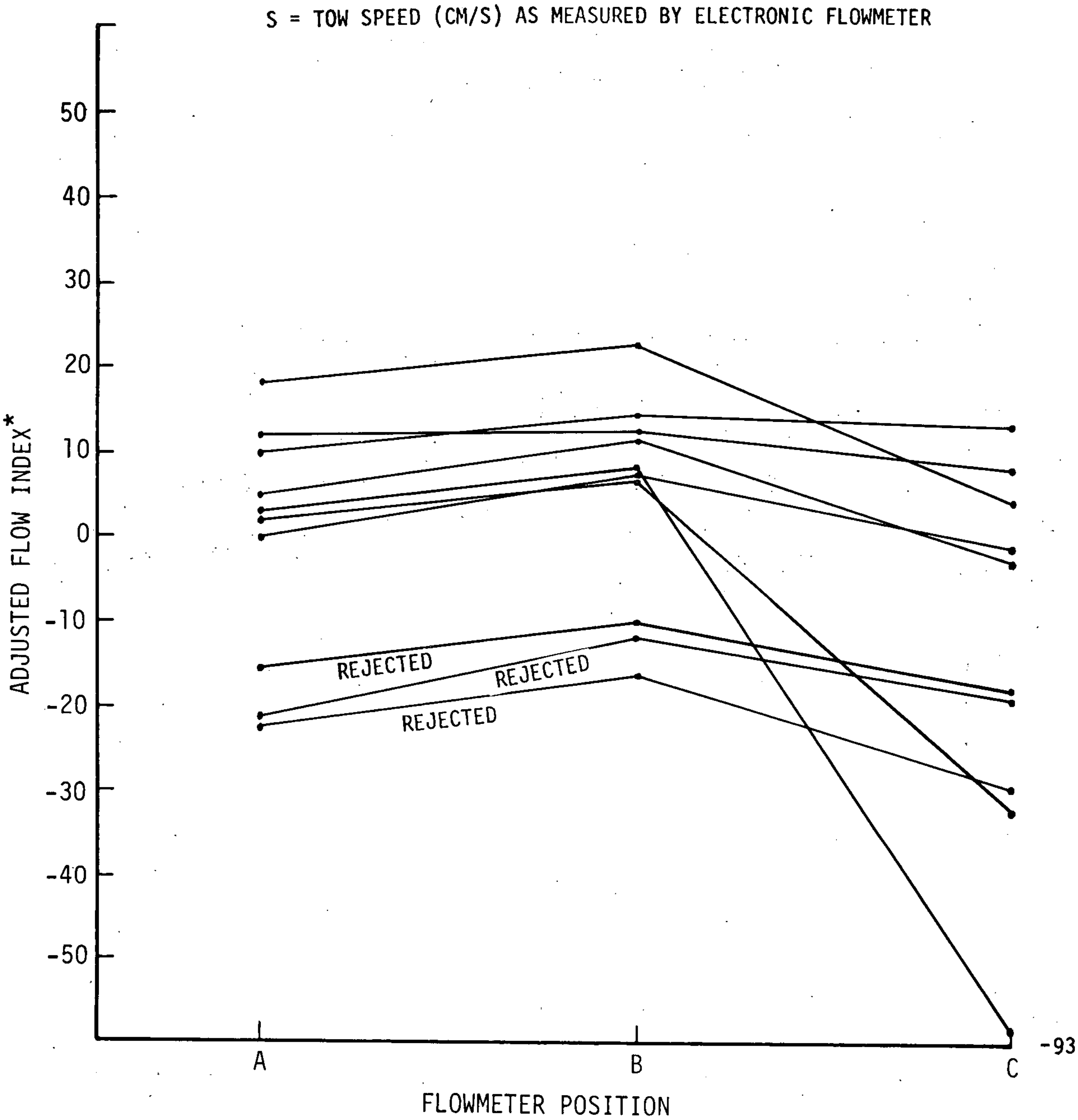


Figure D-9. Flowmeter Profiles for 12.5 Min Tows with 1.0 m^2 Epibenthic Sled, 9 September 1975

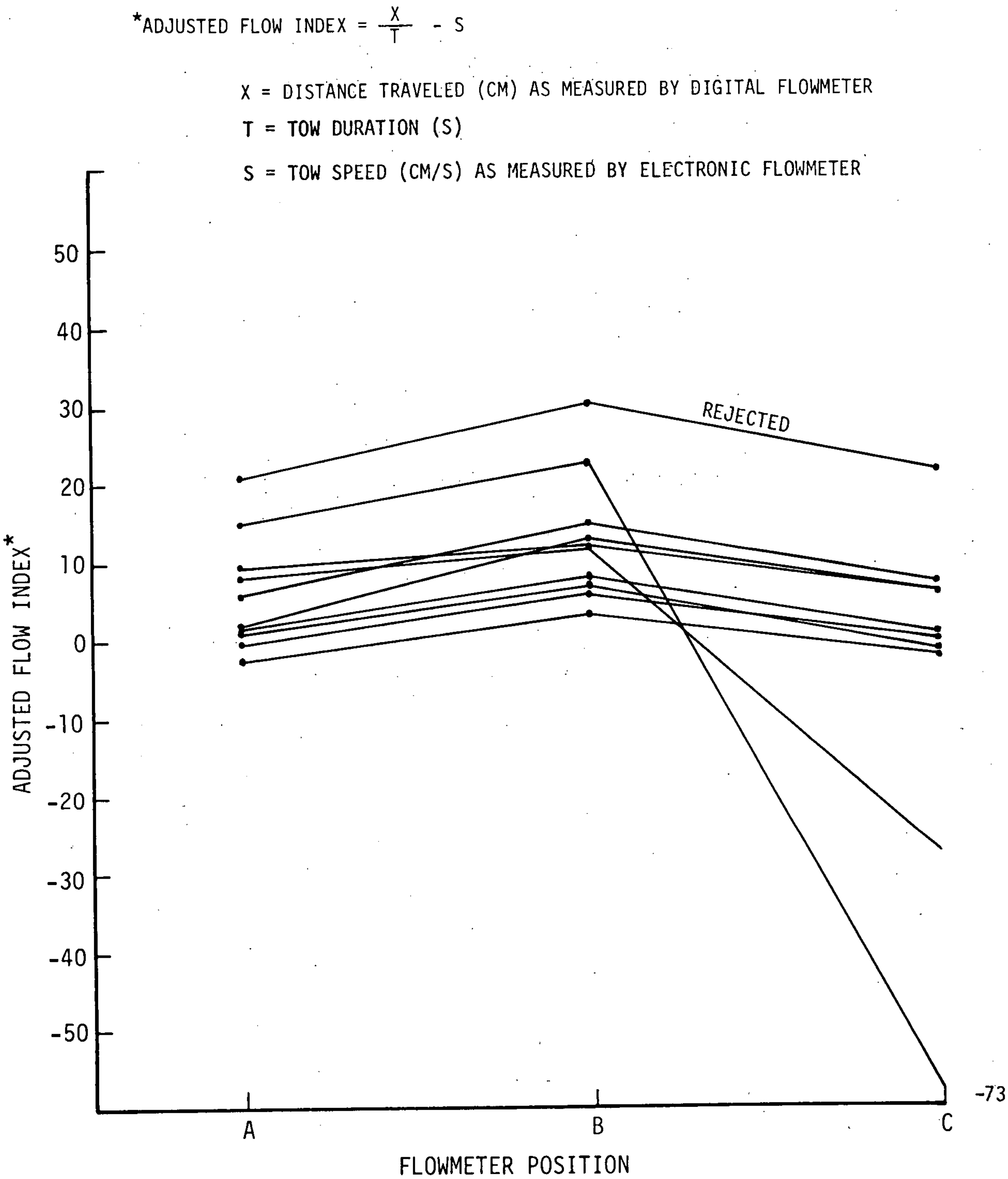


Figure D-10. Flowmeter Profiles for 15.0 Min Tows with 1.0 m^2 Epibenthic Sled, 10 September 1975

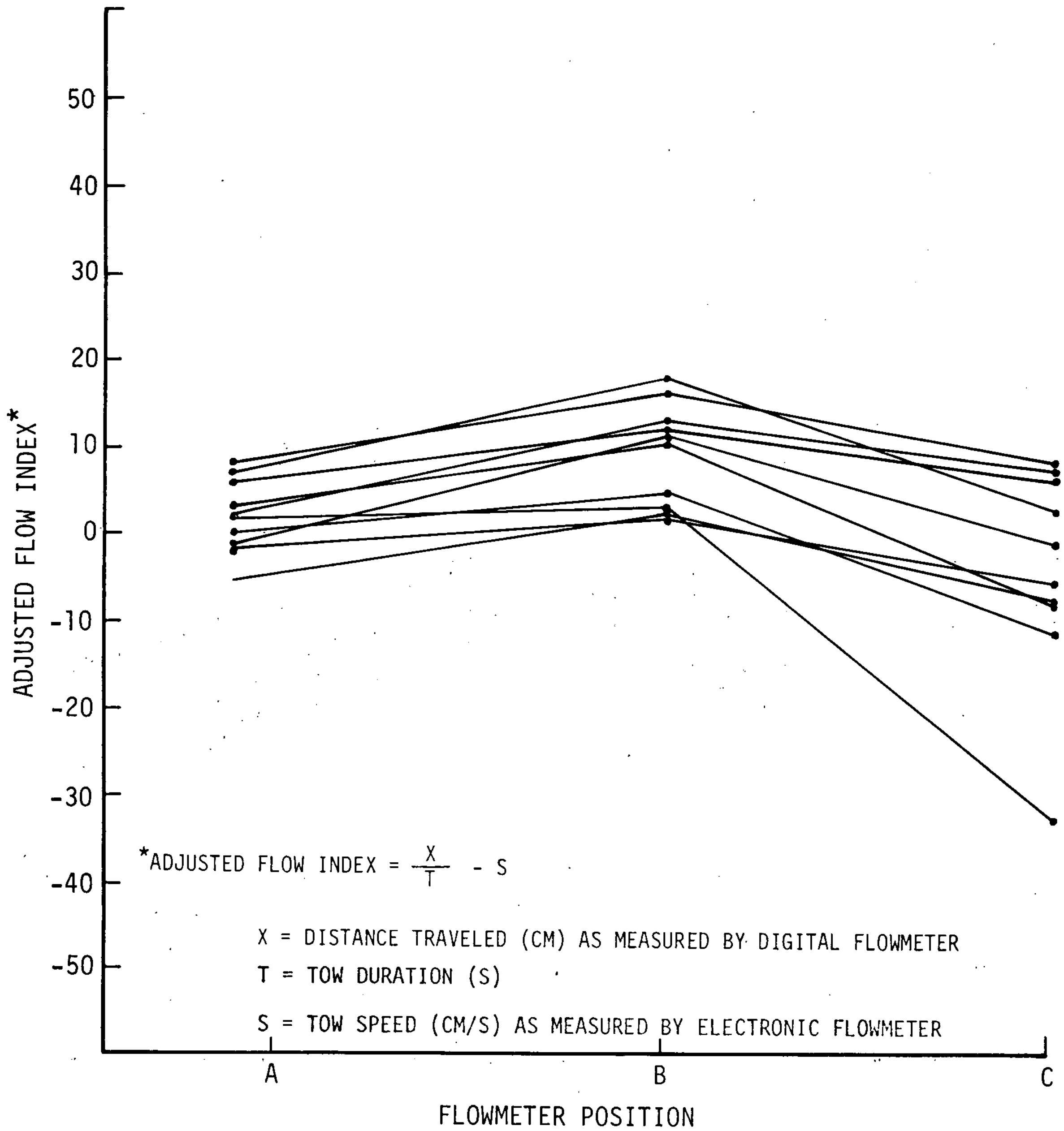


Figure D-11. Flowmeter Profiles for 17.5 Min Tows with 1.0 m^2 Epibenthic Sled, 10 September 1975

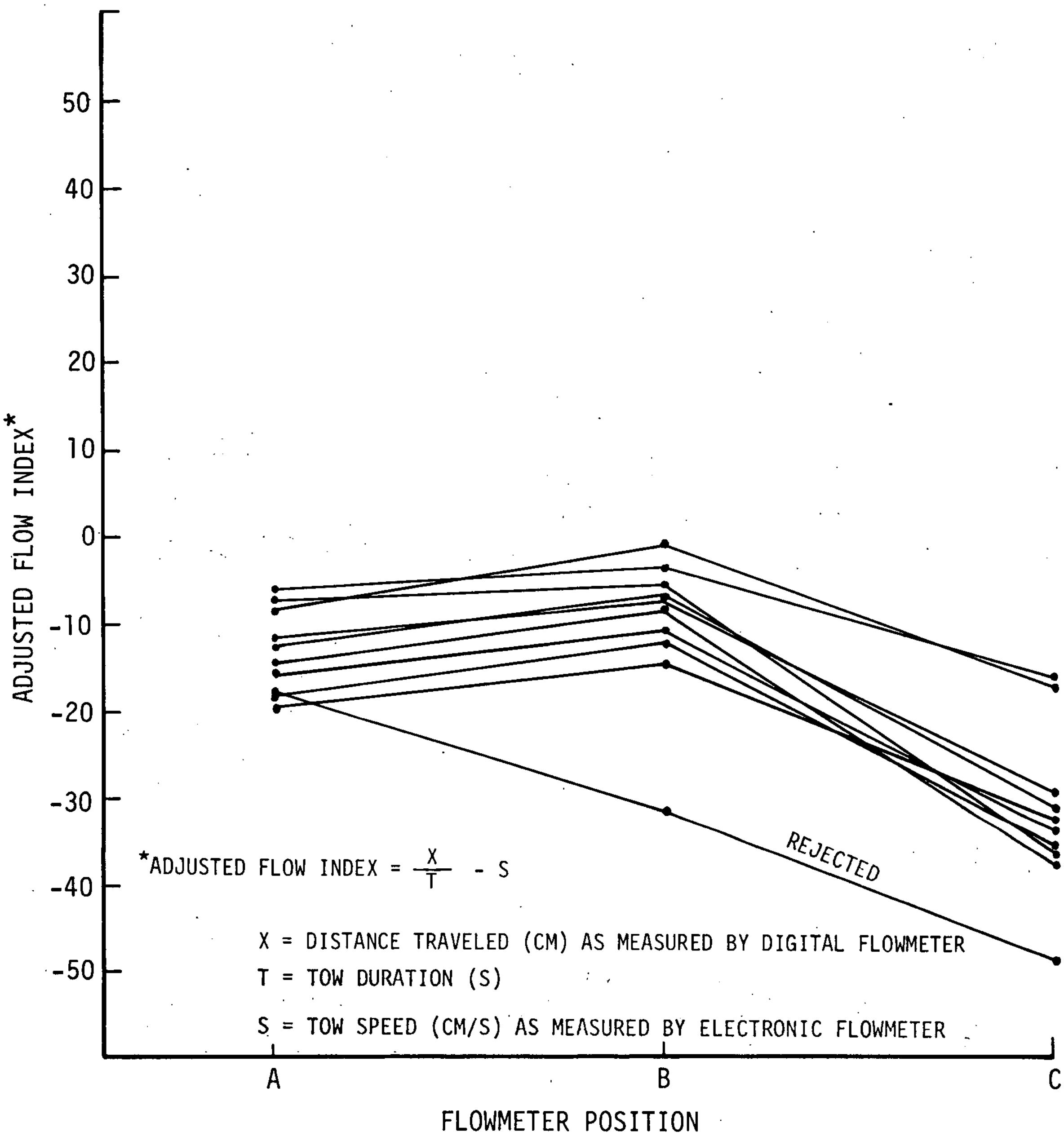


Figure D-12. Flowmeter Profiles for 20.0 Min Tows with 1.0 m^2 Epibenthic Sled, 11 September 1975

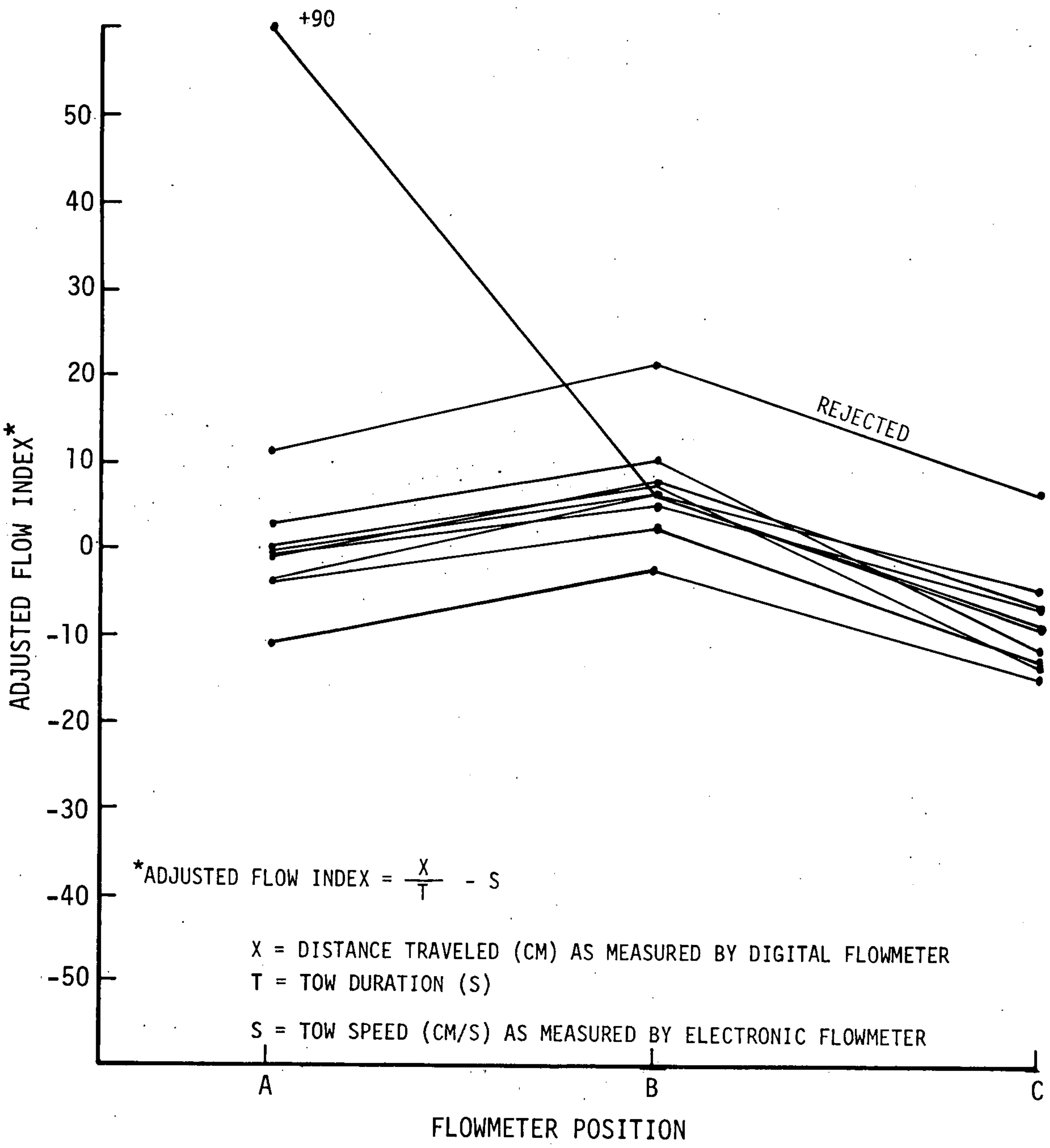


Figure D-13. Flowmeter Profiles for 2.5 Min Tows with 1.0 m^2 Tucker Trawl, 12 September 1975

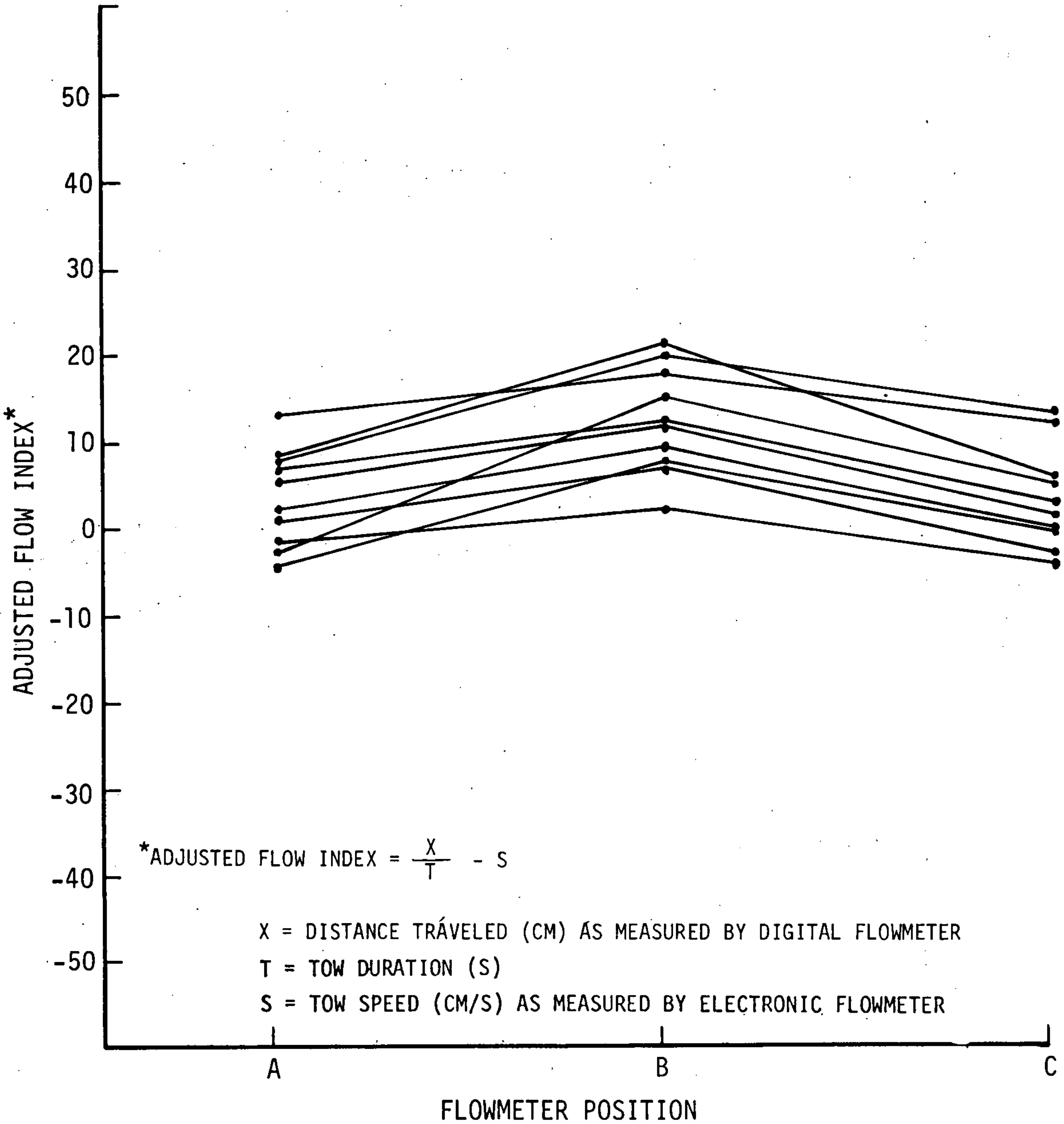


Figure D-14. Flowmeter Profiles for 5.0 Min Tows with 1.0 m^2 Tucker Trawl, 12 September 1975

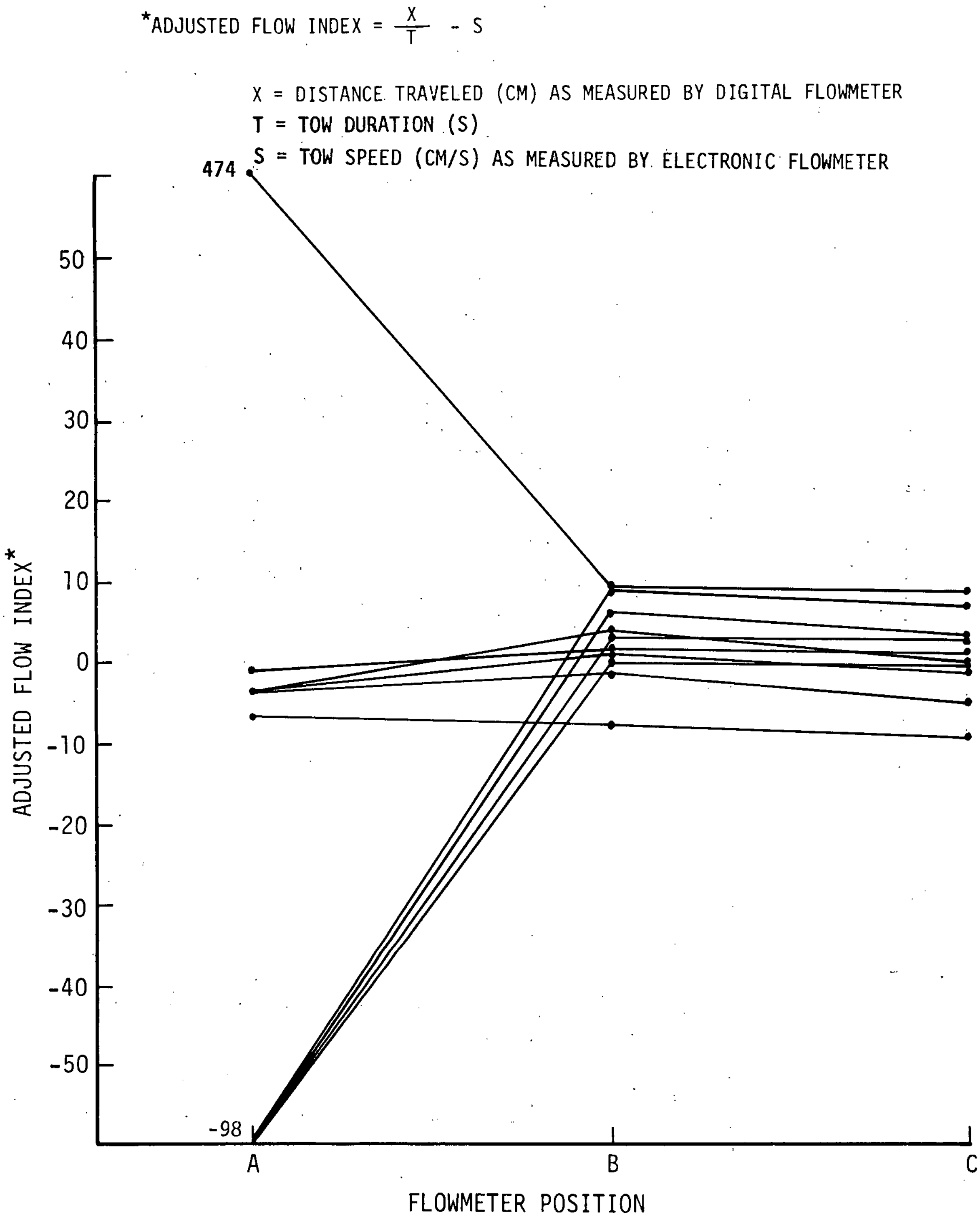


Figure D-15. Flowmeter Profiles for 7.5 Min Tows with 1.0 m^2 Tucker Trawl, 12 September 1975

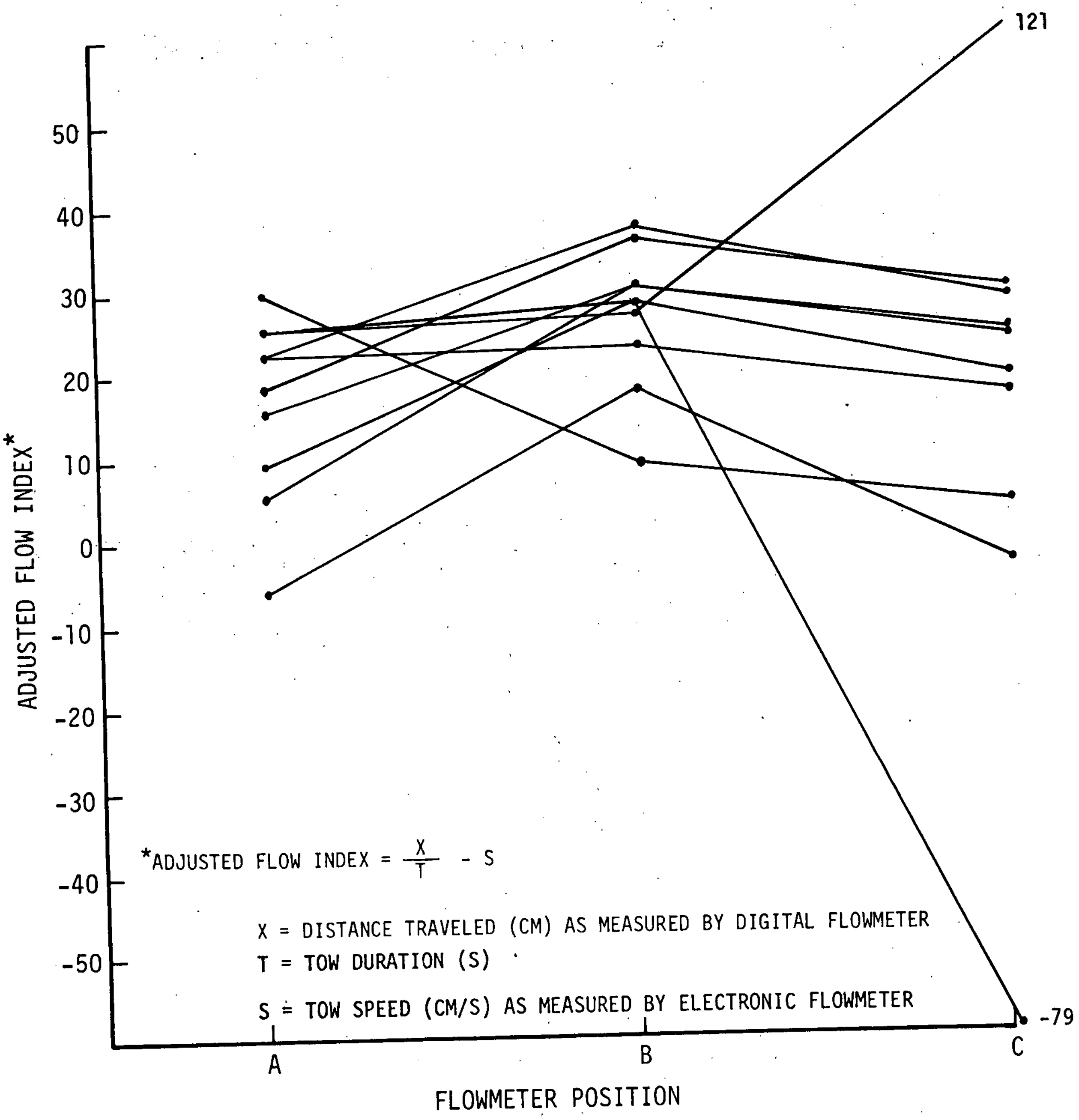


Figure D-16. Flowmeter Profiles for 10.0 Min Tows with 1.0 m^2 Tucker Trawl, 15 September 1975

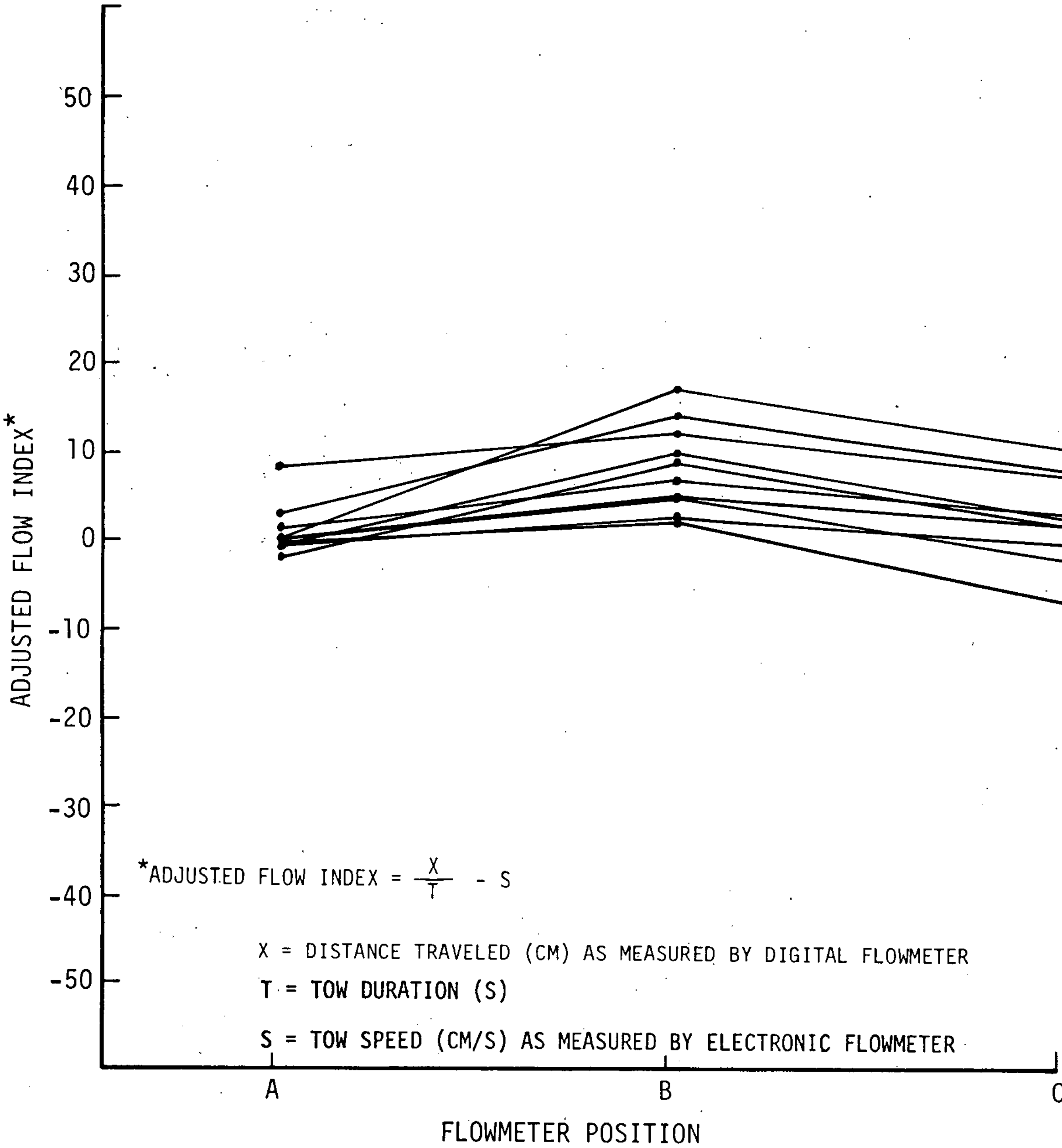


Figure D-17. Flowmeter Profiles for 12.5 Min Tows with 1.0 m^2 Tucker Trawl, 15 September 1975

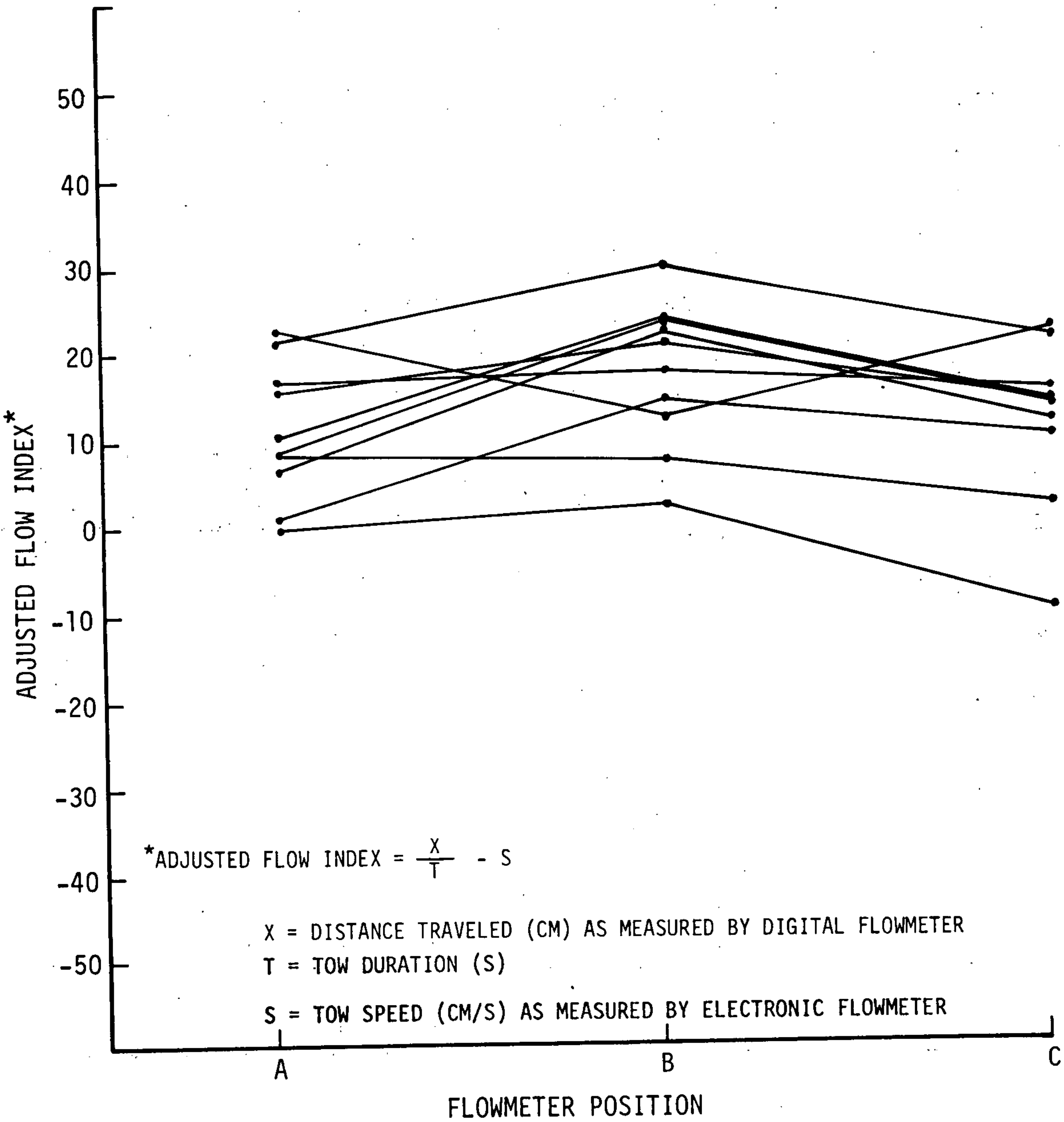


Figure D-18. Flowmeter Profiles for 15.0 Min Tows with 1.0 m^2 Tucker Trawl, 16 Sep

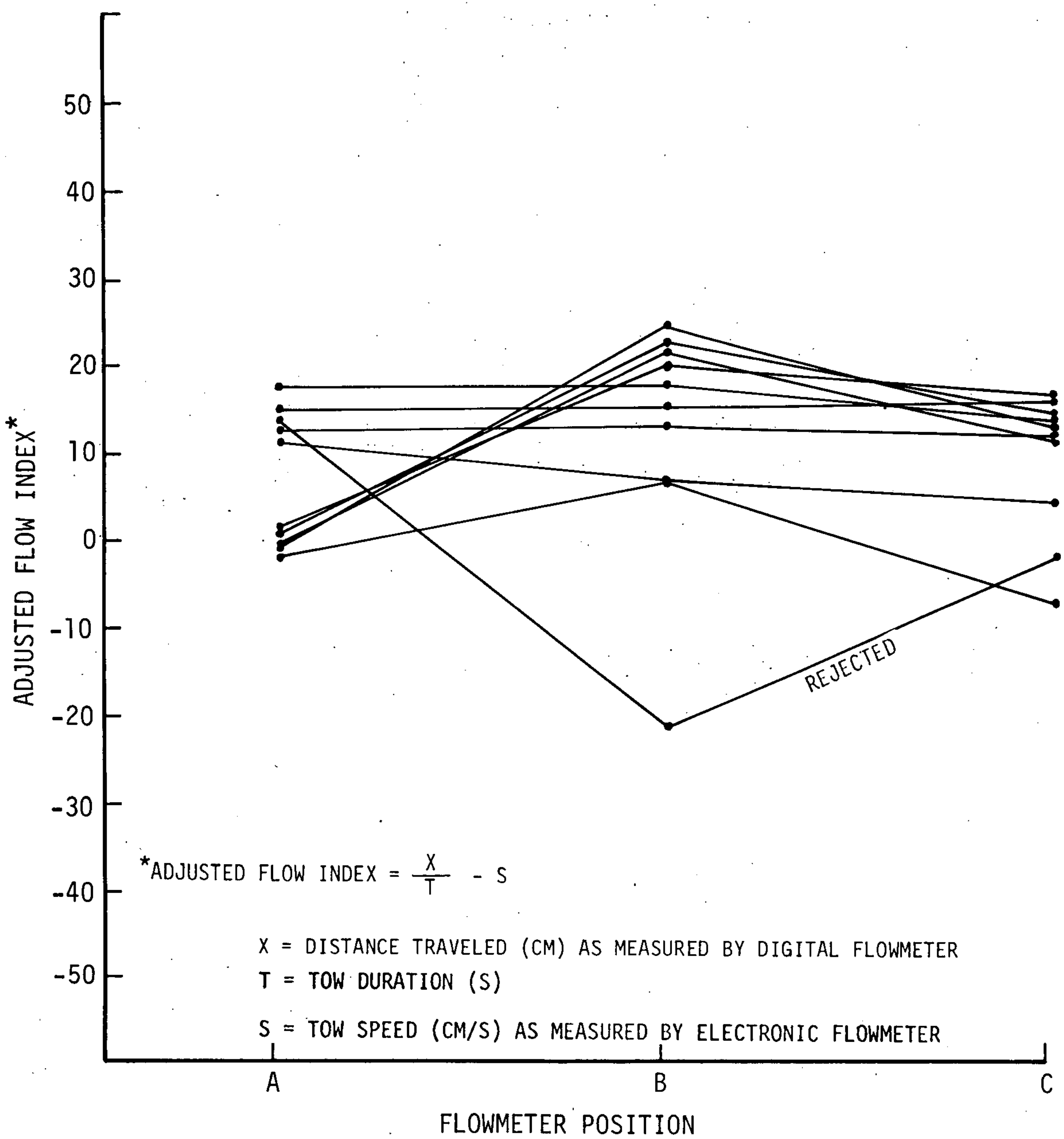


Figure D-19. Flowmeter Profiles for 17.5 Min Tows with 1.0 m^2 Tucker Trawl, 16 September 1975

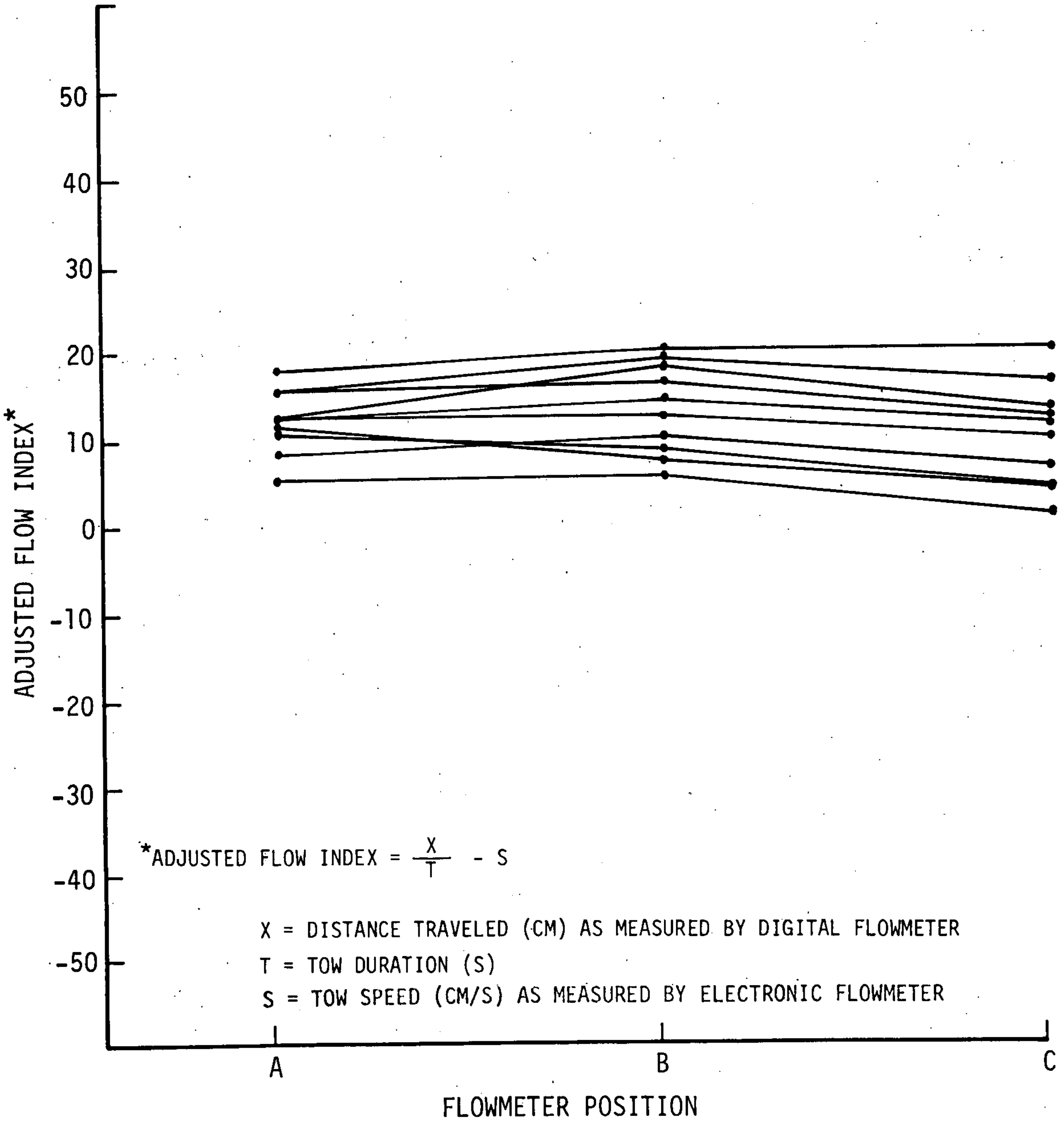


Figure D-20. Flowmeter Profiles for 20.0 Min Tows with 1.0 m^2 Tucker Trawl, 17 September 1975