# TEST RESULTS OF THE BOOTHBAY NEUSTON NET RELATED TO NET LENGTH, DIURNAL PERIOD, AND OTHER VARIABLES[1]

by

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## Abstract

Two models of the Boothbay neuston net were field-tested under various experimental conditions to determine relative catching ability, ease of handling, and specimen damage for ichthyoplankton. The 4.9 m (16-ft) neuston net was superior in ease of handling and caught slightly more, but not significantly more specimens than the 8.5 m (28 ft) net. Catches for many species varied significantly between day and night. Damage to specimens increased with increased towing speed.

## Introduction

The Boothbay neuston net is becoming a standard gear for collection of ichthyoplankton found at the surface. Sherman and Lewis (1967) reported using this gear for collection of lobster larvae. Personnel participating in Cooperative Investigations of the Carribean and Adjacent Regions (CICAR) activities have prepared a "Guide for Sampling the Early Development Stages of Pelagic Fish during CICAR Operations" which describes the use of the neuston net (FAO 1970). The neuston sampler net initially adopted as the standard for the Marine Resources Monitoring, Assessment and Prediction Program (MARMAP) was a pipe frame 2 meters wide by one meter deep with a 8.5 m long net (see Fig. 1). [1]Because little was known concerning the use of this gear, an experiment was designed to test the operating characteristics of two types of frame and two lengths of net. The frames used in the test were galvanized pipe and aluminum pipe. The nets were a 0.947 mm Nitex mesh. Lengths were 4.9 m and 8.5 m with ratios of mouth to open mesh aperture areas of 1:6 and 1:11, respectively (see Fig. 2). Specific areas of interest were ease of handling, relative catching ability of nets under different conditions of speed and light, and damage to ichthyoplankton.

The neuston test was conducted during 9-15 July 1973 utilizing the R/V Dolphin.

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[1]MARMAP is now using a 0.5 x 1 m neuston net.

Figure 1. Standard Boothbay neuston net 1 x 2 m with pipe frame.

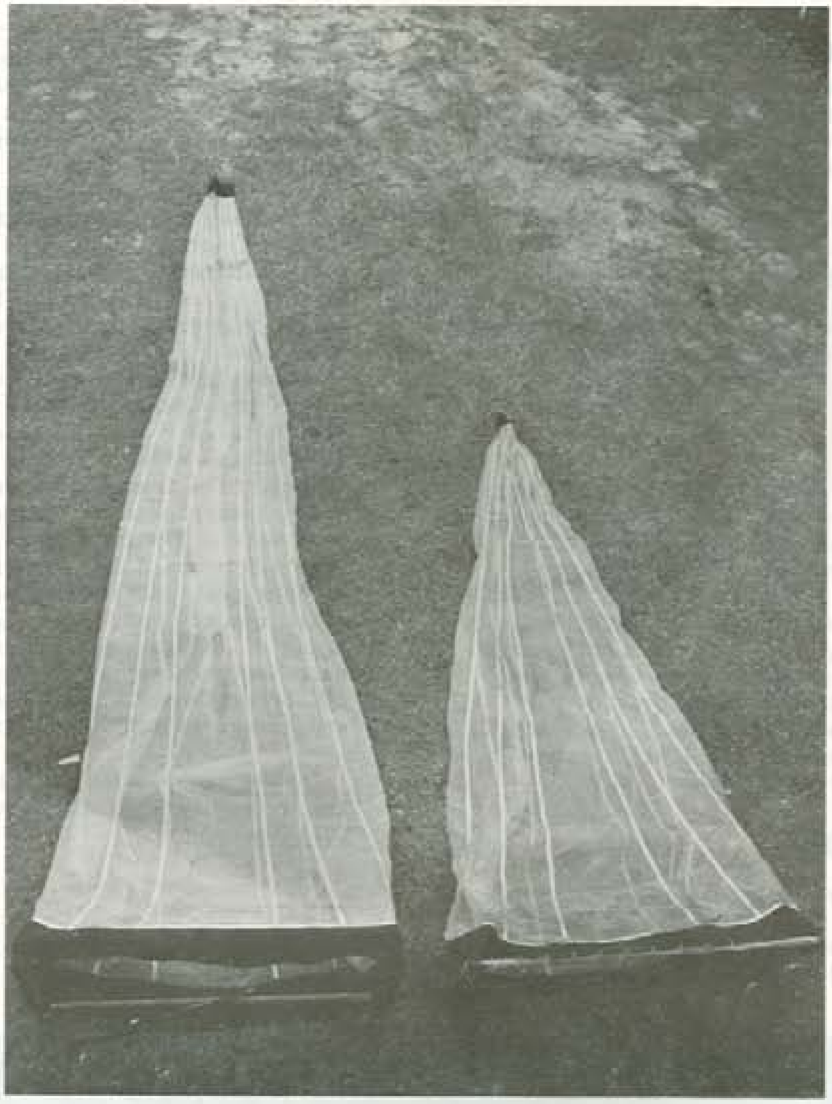

Figure 2. Standard Boothbay neuston nets 1 x 2 m pipe frame, 8.5 m and 4.9 m lengths.

## Materials and Methods

Test Area and Cruise Plan

The cruise was divided into calibration, search, and intensive testing phases.

After a moderate concentration of ichthyoplankton (100 to 500 specimens/tow) had been located during the search phase, an area of approximately 8 km $^2$ (see Fig. 3) was chosen for intensive sampling. During a 25 hour period (14-15 July 1973) 48 neuston samples were obtained. Twenty-four daylight tows were made between 1107 and 1627 EST and 24 night tows between 2206 and 0432 EST (see Table 1).

Although several collections were taken utilizing an aluminum frame, the main neuston gear experiment was conducted only with the galvanized pipe frame.

Towing Procedures

The neuston net was towed from a boom extending out 3 meters from the starboard side of the R/V Dolphin, and the ship was ordered in an arc radius of one nautical mile or less to starboard to keep the net mouth out of the ship's wake.

Bridles of equal length were used on both net sizes at towing speeds of 2 and 3 m/sec, but the outboard bridle was lengthened 18 cm at 1 m/sec to prevent the outboard frame from diving. Bridle wires were 0.64 cm wire cable.

Each pair of main bridles (with a thimble eye at each end) were 7.50 to 8.25 m long. The trailing end of each was shackeled to a double-eyed upper and lower bridle arm, which were shackeled to the upper and lower welded eye on each vertical arm of the frame. The best working combination used was a shorter upper bridle (103 cm long) and a longer lower bridle (113 cm long). Use of equal length upper and lower bridles (108 cm) did not keep the frame alignment vertical.

The net was launched as follows: the frame was balanced on the rail with one

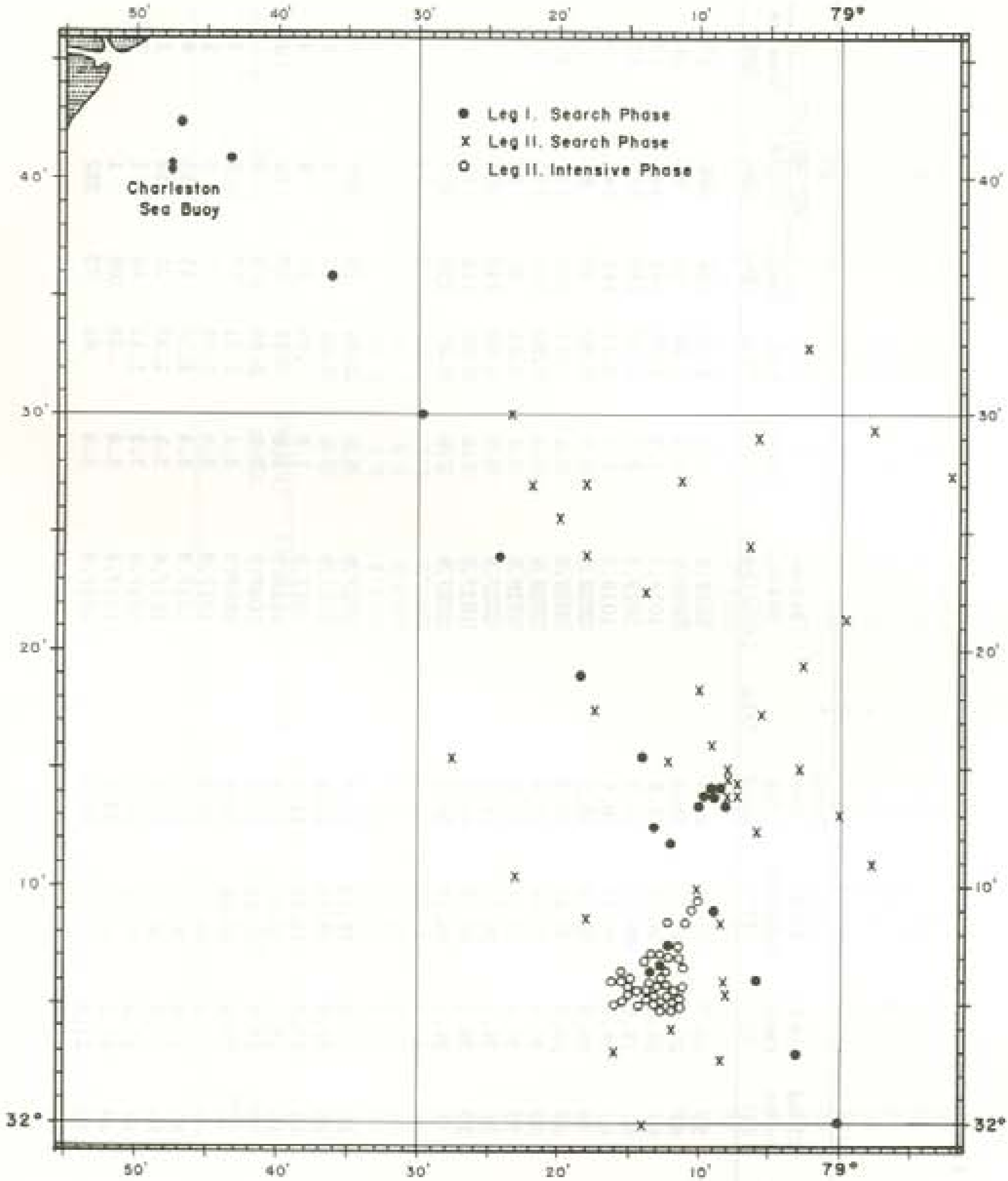


Figure 3. Station locations of R/V Dolphin showing search and intensive phases of neuston gear experiment.

handler on each vertical arm. The tied-off cod end was cast over and trailed. The frame was shoved over the side after a safety line was secured. With the ship running at desired speed, the tow line was played out rapidly (average 29 seconds) to the predetermined distance. After 10-minutes towing time, the net was capstaned in as fast as possible (average 32 seconds). The 3 times, bottom-beam in water to start of tow, tow, end of tow to bottom beam out of water, were recorded with a stopwatch.

The inside and outside of the net were washed down at the end of each tow with a seawater hose.

Towing Speed

The experiment called for towing speeds of 1, 2, and 3 m/sec. Vessel speed was determined by the use of a chip log (wooden block 5 x 10 cm x 30 cm long), which was thrown over from the bow and timed with a stop watch in its drift along a known distance of the ship's length. Table 1 shows that estimated actual speed varied considerably from attempted due primarily to direction of tow in relation to direction and intensity of wind and swell.

Specimen Handling and Processing

After each tow, the catch was drained through a 0.85 mm mesh sieve and the preserved in 5% buffered formalin.

Each catch was examined for presence and amount of sargassum, manatee grass, and coelenterates; estimated wet volume of total catch; and numbers of selected genera

Table 1.—Covariates used in neuston gear experiment.

| Time period | Tow | Time of tow (EST) | Bottom Depth (m) | Wind vel. (knots) | Sea state Beaufort scale | Air temp. (C) | Cloud cover (%) | Surf. temp. (C) | Surf. salinity PPT | Total tow time (min) | Rain | Barom. press. (millibar) | Speed (knots) | Rel. vol. | WET WEIGHT Coel. (gm) | Sargas. (gm) | Manatee (gm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day 1 | 073 | 1339 | 68 | 1 | 2 | 30.0 | 50 | 29.7 | 36.18 | 11.3 | | 1019.6 | 5.0 | 2.68 | 166 | 264 | 573 |
| Day 1 | 074 | 1355 | 68 | 1 | 2 | 30.0 | 60 | 29.7 | 36.18 | 11.4 | | 1019.6 | 5.0 | 2.87 | 97 | 97 | 162 |
| Day 1 | 075 | 1409 | 68 | 1 | 2 | 30.0 | 60 | 29.6 | 36.18 | 10.9 | | 1019.3 | 3.3 | 1.79 | 141 | 141 | 155 |
| Day 1 | 076 | 1425 | 68 | 1 | 2 | 30.0 | 60 | 29.6 | 36.17 | 11.2 | | 1019.3 | 3.3 | 1.47 | 270 | 270 | 171 |
| Day 1 | 077 | 1442 | 68 | 1 | 2 | 30.0 | 60 | 29.6 | 36.17 | 10.5 | | 1019.3 | 1.6 | 0.81 | 247 | 247 | 76 |
| Day 1 | 078 | 1456 | 68 | 5 | 2 | 31.0 | 70 | 29.5 | 36.16 | 10.5 | | 1019.3 | 1.6 | 0.80 | 88 | 88 | 65 |
| Day 1 | 079 | 1511 | 68 | 5 | 2 | 31.0 | 60 | 29.5 | 36.16 | 11.4 | | 1019.3 | 5.1 | 2.81 | 159 | 159 | 102 |
| Day 1 | 080 | 1527 | 68 | 5 | 2 | 30.0 | 50 | 29.4 | 36.16 | 11.4 | | 1018.9 | 5.1 | 2.90 | 137 | 137 | 76 |
| Day 1 | 081 | 1543 | 68 | 4 | 2 | 30.0 | 30 | 29.4 | 36.16 | 11.1 | | 1018.6 | 3.1 | 1.41 | 29 | 29 | 9 |
| Day 1 | 082 | 1558 | 68 | 5 | 2 | 31.0 | 15 | 29.3 | 36.17 | 11.1 | | 1017.9 | 3.1 | 1.48 | 213 | 213 | 3 |
| Day 1 | 083 | 1613 | 68 | 7 | 2 | 31.0 | 10 | 29.2 | 36.17 | 10.5 | | 1017.9 | 1.6 | 0.86 | 118 | 118 | 77 |
| Day 1 | 084 | 1627 | 68 | 7 | 2 | 31.0 | 5 | 29.2 | 36.17 | 10.5 | | 1017.9 | 1.6 | 0.81 | 253 | 253 | 2 |
| Night 1 | 088 | 2206 | 73 | 14 | 2 | 29.0 | 40 | 27.8 | 35.92 | 11.4 | | 1017.9 | 5.6 | 2.74 | 23 | 128 | 13 |
| Night 1 | 089 | 2221 | 73 | 16 | 2 | 29.0 | 40 | 27.8 | 35.96 | 11.4 | | 1017.9 | 5.6 | 2.96 | 113 | 3 | 19 |
| Night 1 | 090 | 2236 | 73 | 14 | 2 | 29.0 | 40 | 27.7 | 35.99 | 11.3 | | 1017.9 | 1.8 | .75 | 23 | 8 | 31 |
| Night 1 | 091 | 2252 | 73 | 12 | 2 | 29.0 | 40 | 27.7 | 36.02 | 11.2 | | 1017.9 | 1.8 | .57 | 17 | 14 | 15 |
| Night 1 | 092 | 2309 | 73 | 15 | 2 | 28.5 | 50 | 27.7 | 36.05 | 10.5 | | 1017.9 | 2.1 | 1.19 | 125 | 1 | 2 |
| Night 1 | 093 | 2323 | 73 | 15 | 2 | 28.5 | 70 | 27.6 | 36.08 | 10.5 | | 1017.0 | 2.1 | 1.21 | 57 | 2 | 37 |
| Night 1 | 094 | 2346 | 73 | 15 | 2 | 28.5 | 80 | 27.6 | 36.11 | 11.3 | | 1017.9 | 5.4 | 2.51 | 22 | 0 | 15 |
| Night 1 | 095 | 0002 | 75 | 15 | 3 | 28.5 | 80 | 27.6 | 36.11 | 11.3 | | 1017.9 | 5.4 | 2.34 | 45 | 135 | 40 |
| Night 1 | 096 | 0017 | 75 | 20 | 3 | 28.5 | 80 | 27.6 | 36.11 | 11.1 | | 1017.6 | 3.1 | 1.33 | 21 | 54 | 23 |
| Night 1 | 097 | 0032 | 75 | 18 | 3 | 28.5 | 80 | 27.6 | 36.12 | 11.2 | | 1017.6 | 3.1 | 1.11 | 40 | 1 | 33 |
| Night 1 | 098 | 0047 | 75 | 18 | 3 | 28.5 | 80 | 27.5 | 36.12 | 10.5 | | 1017.6 | 1.4 | .55 | 105 | 1 | 5 |
| Night 1 | 099 | 0103 | 75 | 17 | 3 | 28.5 | 80 | 27.5 | 36.12 | 10.5 | | 1017.6 | 1.4 | .61 | 73 | 352 | 35 |

Table 1.— Continued.

| Time period | Tow | Time of tow (EST) | Bottom Depth (m) | Wind vel. (knots) | Sea state Beaufort scale | Air temp. (C) | Cloud cover (%) | Surf. temp. (C) | Surf. salinity PPT | Total tow time (min) | Rain | Barom. press. (millibar) | Speed (knots) | Rel. vol. | WET WEIGHT Coel. (gm) | WET WEIGHT Sargas. (gm) | WET WEIGHT Manatee (gm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Night 2 | 100 | 0120 | 86 | 16 | 3 | 28.5 | 80 | 27.6 | 36.12 | 11.4 | | 1017.6 | 5.3 | 2.83 | 41 | 38 | 44 |
| Night 2 | 101 | 0136 | 88 | 20 | 3 | 28.5 | 70 | 27.6 | 36.12 | 11.4 | | 1017.2 | 5.3 | 3.02 | 12 | 4 | 47 |
| Night 2 | 102 | 0151 | 88 | 20 | 3 | 28.5 | 60 | 27.6 | 36.13 | 11.1 | | 1017.2 | 3.9 | 2.10 | 0 | 0 | 57 |
| Night 2 | 103 | 0206 | 88 | 17 | 2 | 28.5 | 60 | 27.6 | 36.13 | 11.2 | | 1017.2 | 3.9 | 1.72 | 0 | 0 | 65 |
| Night 2 | 104 | 0223 | 88 | 20 | 3 | 28.2 | 60 | 27.5 | 36.14 | 10.5 | | 1017.2 | 2.6 | 1.33 | 10 | 8 | 16 |
| Night 2 | 105 | 0239 | 84 | 15 | 3 | 28.5 | 60 | 27.5 | 36.14 | 10.6 | | 1017.2 | 2.6 | 1.31 | 86 | 6 | 10 |
| Night 2 | 106 | 0317 | 80 | 16 | 3 | 28.6 | 60 | 27.5 | 36.15 | 11.4 | | 1017.2 | 4.4 | 2.45 | 2 | 1 | 17 |
| Night 2 | 107 | 0325 | 80 | 15 | 3 | 28.6 | 60 | 27.5 | 36.13 | 11.4 | | 1017.2 | 4.4 | 2.53 | 45 | 4 | 25 |
| Night 2 | 108 | 0340 | 80 | 15 | 3 | 28.8 | 60 | 27.5 | 36.11 | 11.2 | | 1017.2 | 2.7 | 1.20 | 47 | 4 | 25 |
| Night 2 | 109 | 0356 | 80 | 16 | 3 | 28.5 | 70 | 27.6 | 36.09 | 11.2 | | 1016.5 | 2.7 | 1.27 | 130 | 17 | 2 |
| Night 2 | 110 | 0410 | 88 | 13 | 3 | 28.8 | 70 | 27.6 | 36.06 | 10.5 | | 1016.5 | 1.5 | 0.80 | 85 | 0 | 0 |
| Night 2 | 111 | 0432 | 93 | 17 | 3 | 28.8 | 50 | 27.6 | 36.04 | 11.1 | | 1016.5 | 1.5 | 0.77 | 23 | 0 | 0 |
| Day 2 | 114 | 1107 | 86 | 18 | 4 | 29.0 | 60 | 27.6 | 36.10 | 11.4 | | 1017.2 | 3.7 | 1.79 | 29 | 143 | 4 |
| Day 2 | 115 | 1138 | 86 | 18 | 4 | 29.0 | 60 | 27.6 | 36.10 | 11.4 | | 1017.2 | 3.7 | 1.94 | 10 | 20 | 19 |
| Day 2 | 116 | 1156 | 86 | 15 | 4 | 29.0 | 70 | 27.7 | 36.10 | 11.2 | | 1017.2 | 1.7 | 0.68 | 7 | 20 | 3 |
| Day 2 | 117 | 1212 | 86 | 20 | 4 | 30.1 | 60 | 27.7 | 36.11 | 11.2 | | 1017.2 | 1.7 | 0.51 | 15 | 158 | 10 |
| Day 2 | 118 | 1227 | 86 | 20 | 4 | 30.5 | 70 | 27.8 | 36.11 | 10.4 | | 1017.2 | 2.0 | 1.14 | 0 | 54 | 3 |
| Day 2 | 119 | 1246 | 82 | 18 | 4 | 30.5 | 80 | 27.8 | 36.12 | 10.6 | | 1017.2 | 2.0 | 1.16 | 9 | 16 | 16 |
| Day 2 | 120 | 1321 | 70 | 20 | 4 | 28.8 | 80 | 27.9 | 36.12 | 11.4 | + | 1016.9 | 3.5 | 1.65 | 18 | 80± | 5 |
| Day 2 | 121 | 1335 | 70 | 25 | 4 | 28.9 | 85 | 27.9 | 36.11 | 11.4 | + | 1016.9 | 3.5 | 1.53 | 23 | 137 | 3 |
| Day 2 | 122 | 1351 | 70 | 25 | 4 | 29.5 | 90 | 27.9 | 36.09 | 11.2 | + | 1016.9 | 2.6 | 1.10 | 19 | 31 | 10 |
| Day 2 | 123 | 1405 | 70 | 20 | 4 | 29.5 | 90 | 27.9 | 36.08 | 11.2 | | 1016.5 | 2.6 | 0.92 | 15 | 75 | 11 |
| Day 2 | 124 | 1420 | 70 | 18 | 4 | 29.5 | 90 | 27.9 | 36.07 | 10.6 | | 1016.5 | 1.3 | 0.52 | 14 | 162 | 6 |
| Day 2 | 125 | 1433 | 70 | 20 | 4 | 29.6 | 80 | 27.9 | 36.06 | 10.5 | | 1016.5 | 1.3 | 0.57 | 51 | 59 | 6 |

of larval and juvenile fish, principally Coryphaena, Caranx, Decapterus, Seriola, and Istiophorus.

Laboratory Procedures for Sorting Ichthyoplankton

All neuston samples were returned to the Marine Resources Research Institute (MRRI) where sorting of samples was conducted. Fish eggs, larvae, and juveniles were separated from the sample by sorting the entire sample under a 4X magnifying glass. Initial separation of fish larvae from samples was double-checked by having randomly picked samples re-examined. This revealed that the initial sort removed about 95% of all fish larvae.

In addition to the analysis of ichthyofauna, sargassum weed (Sargassum spp.), manatee grass (Syringodium sp.?), and jellyfish were separated from each sample and weighed. These measurements were made to determine relationships between the presence of floating flora, coelenterates, and the presence or absence of ichthyoplankton. Grasses and weeds were blotted with paper towels, allowed to stand for 5 minutes, and then weighed.

Ichthyoplankton Identification

All individuals that were of particular interest to MARMAP surveys or whose characters allowed ready identification were identified to species. Otherwise, specimens were identified by genera or family, and in two cases only by fish order.

Lengths were measured as fork length in forked tail species and total lengths in all others. Lengths were taken from single specimens or from the largest and smallest specimen of each identified species (or other taxon) at each station.

Lengths were taken from all specimens of the silver driftfish, Psenes maculatus, and Hemiramphidae because these were used to evaluate towing characteristics concerning ranges in size of catches.

Experimental Design and Methods

Qualitative aspects of the experiment were (1) ease of handling of the two lengths of nets on a pipe frame, (2) ease of handling of the 8.5 m net on aluminum and pipe frames, and (3) damage to specimens, particularly at different speeds. Analysis of variance (ANOVA) and analysis of covariance provided information concerning effect of light conditions upon catches of selected groups of ichthyoplankton, catching ability of the 8.5 m vs the 4.9 m net, and effects of various covariates upon the catch of ichthyoplankton. Covariates in the experiment were time of tow, depth, wind velocity, sea state, air temperature, cloud cover, surface water temperature, surface water salinity, total tow duration including setting and retrieval times rainfall, barometric pressure, relative volume of tow, towing speed, wet weight of sargassum weed, wet weight of manatee grass, and wet weight of coelentrates collected in each tow. These data are summarized in Table 1.

Time of tow was recorded when the lower beam of the frame entered the water. Other environmental covariates were recorded at the beginning of each tow. Total tow duration was the sum of time expended in setting, towing and retrieving the net. Relative volume of water strained was determined by the formula: Relative Volume Strained = (Speed) (Total tow time) (Average fraction of net in water).

The effect of net size, period 1 or 2, (1 day and 1 night set of tows included in each period) and night vs day were tested using a 3 way ANOVA fixed model which is illustrated below:

$$X_{ijkl} = u + t_i + a_j + b_k + ta_{ij} + tb_{ik}$$

$$+ ab_{jk} + tab_{ijk} + e_{ijkl}$$

$i$ = 1, 2 (nets)
$j$ = 1, 2 (periods)
$k$ = 1, 2 (diurnal periods)
$l$ = 1, 6 (replicates)

Analysis of variance tests were conducted by the Biometry Department of the Medical University of South Carolina utilizing a BMD program. Partial correlation analyses were performed using the BMDO3R program. Partial correlations were calculated one at a time adjusted for the remaining covariates.

# Results

Frame Tests

The purpose of the test was to compare ease of handling and operating efficiency of an aluminum pipe frame with a standard iron pipe frame. The aluminum frame was lighter, but unfortunately was of larger diameter than the iron frame:

| Frame | Weight | Diameter |
|---|---|---|
| iron | 25.4 kg | 52 mm |
| aluminum | 18.6 kg | 72.5 mm |

The outside width to height ratio of the aluminum frame was also greater (2.155 x 1.160 m vs 2.115 x 1.120 m), and the canvas collar of the net had to be strapped to the back of the frame, rather than fitted over the frame as was the case with the iron frame.

Visual comparative observations of operation follow. The aluminum frame was bulkier on deck (with its excessive pipe diameter). It was more difficult to balance on the rail, and tended to dip more into the water on setting. At a towing speed of 1 m/sec, the lighter aluminum frame was more buoyant and rode higher in the water, necessitating play-out of extra towing cable to position it half-submerged. At 2 and 3 m/sec it was only slightly more buoyant than the iron frame, but tended to overreact in pitching and biting into moderately rough waves. The large diameter of the aluminum frames produced relatively large bow waves with the vertical arms (ca 40-50 cm high at 3 m/sec); this may have affected catching ability.

Our experiment with these frames suggested two possible improvements: (1) The bottom beam of a pipe frame should have holes drilled in it to reduce buoyancy (2) Use of a flat solid frame (example, 1.5 cm x 7.5 cm aluminum bar) instead of the tubular one to improve cutting and holding ability and reduce weight and buoyancy. Holes drilled in the back margin would facilitate net lashing; 4 holes drilled into the forward edge would eliminate welding of towing eyes.

Ease of Handling

The 4.9 m net was much easier to handle and secure than the 8.5 m net, especially in high winds and rough seas. The 4.9 m net could be washed down for cleaning and specimen concentration and collection faster and more efficiently.

General Observations

Proper lengths of the towing wrap and bridles used to secure neuston gears are influenced by sea state, towing speed, and vessel characteristics. These may be determined heuristically in order to obtain a desired fishing depth. In addition, the variance about the net's mean fishing depth increases greatly in rough seas. Because of this, it may be appropriate to define a standard neuston tow as one achieved within a certain range of sea conditions.

Neuston nets are excellent collectors of floating weed and associated fauna. This gear also collects floating plastics and tar aggregations. Both of these characteristics contribute to sample handling problems.

Damage to Specimens

Characters used to assess damage were chosen on the basis of their value in identification of fish larvae and their ease of observation (Table 2). Auxis sp. and Gerreidae were chosen because they were neither overly fragile nor handy. A random sample of 50 specimens of Auxis sp. were chosen for selected stations and all specimens of (possibly a single species) Gerreidae for selected stations were examined. Other groups could have been selected, but it was assumed that these were representative of ichthyoplankton in this area and would accurately reflect levels of damage likely to be experienced by other fish larvae.

In general, the level of damage sustained by fish larvae appeared to be directly proportional to towing speed with relatively little damage occurring at speeds between 0.65 and 1.5 m/sec (1.3 to 3.0 knots). Observations in Table 2 also indicated that different species sustained different levels of damage.

The above results suggest that the choice of towing speed must be determined in large part by objectives of a program; particularly, if one species or a selected size range of specimens is sought. For example, if the main objective of a program were to obtain undamaged specimens of slower moving larvae, one would tow at slower speeds. Conversely, if larger or more mobile larvae were sought, one would tow at faster speeds and design gear that would minimize extrusion of larvae.

Escapement

Another consideration concerning towing speed is the size of individuals captured. Table 3 gives the range in total length of fish larvae taken in this experiment. These data do not show any clear relationship between size at capture and towing speed, suggesting that more mobile larvae were able to escape the gear at all speeds employed. This observation was supported by the fact that analysis of covariance tests revealed that only catches of Exocoetidae and Psenes maculatus was affected by towing speed. Thus, it appears that the data were not particularly useful in determining escapement because we did not tow fast enough to capture larger larvae. Nevertheless, when one considers those species-groups that included at least 10 individuals (59), it was apparent that the maximum total length of about 59% (35) was less than 25 mm (Table 3). Moreover, the maximum total length of 24% (14) of the species-groups was between 26 and 50 mm. These observations suggest that larvae at the upper limit of the size range for each species were escaping and that escapement size varies considerably from species to species.

Raw Catch Data

Table 3 gives catch data in decending order of individuals. The 20 most abundant taxa contained 85.57% (9,088) of the total number of specimens. The remaining 92 species-groups contained 14.43% (1,533) of the total individuals. Table 3 also gives the frequency of occurence in number of tows and the general distribution of larvae throughout the area and time

Table 2.– Damage to selected morphometric characteristics of the frigate mackerel, Auxis sp., and of the family Gerreidae collected at various towing speeds by the Boothbay neuston net.

AUXIS SP.

| | | | Eyes Missing | | | | Head | | | | Caudal Fin | | | | | | | | Body | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Left | | Right | | Missing | | Mangled | | All Missing | | 75% Missing | | 25% Missing | | Undamaged | | Anterior Torn | | Posterior Torn | |
| Tow Number | Speed | Sample Size | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| 100 | 5.3 | 50 | 49 | 98 | 50 | 100 | – | – | 25 | 52 | 1 | 2 | 14 | 28 | 34 | 68 | 1 | 2 | 23 | 46 | – | – |
| 106 | 4.4 | 50 | 48 | 96 | 49 | 98 | – | – | 22 | 44 | – | – | 6 | 12 | 44 | 88 | – | – | 21 | 42 | 2 | 4 |
| 107 | 4.4 | 50 | 50 | 100 | 49 | 98 | – | – | 25 | 50 | – | – | 6 | 12 | 32 | 64 | 12 | 24 | 20 | 40 | – | – |
| 108 | 2.7 | 50 | 28 | 56 | 34 | 68 | 1 | 2 | 9 | 18 | 1 | 2 | 4 | 8 | 29 | 58 | 16 | 32 | 5 | 10 | – | – |
| 109 | 2.7 | 50 | 22 | 44 | 22 | 44 | – | – | 10 | 20 | 2 | 4 | – | – | 29 | 58 | 19 | 38 | 5 | 10 | 3 | 6 |
| 110 | 1.5 | 50 | 8 | 16 | 8 | 16 | – | – | 3 | 6 | 1 | 2 | 1 | 2 | 27 | 54 | 19 | 38 | 1 | 2 | 2 | 4 |
| 111 | 1.5 | 50 | 4 | 8 | 5 | 10 | – | – | 9 | 18 | 3 | 6 | 2 | 4 | 24 | 48 | 21 | 42 | 1 | 2 | 2 | 4 |

GERREIDAE

| | | | Eyes Missing | | | | Head | | | | Caudal Fin | | | | | | | | Body | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Left | | Right | | Missing | | Mangled | | All Missing | | 75% Missing | | 25% Missing | | Undamaged | | Anterior Torn | | Posterior Torn | |
| Tow Number | Speed | Sample Size | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| 100 | 5.3 | 8 | 5 | 62 | 5 | 62 | 4 | 50 | – | – | – | – | 2 | 25 | 6 | 75 | – | – | 1 | 12 | – | – |
| 101 | 5.3 | 14 | 4 | 28 | 10 | 70 | – | – | 11 | 77 | 2 | 14 | 7 | 50 | 5 | 35 | – | – | 2 | 14 | – | – |
| 106 | 4.4 | 9 | 1 | 11 | 6 | 66 | – | – | 5 | 55 | – | – | 1 | 11 | 8 | 88 | – | – | 1 | 11 | 1 | 11 |
| 107 | 4.4 | 7 | 1 | 14 | 4 | 56 | – | – | 3 | 42 | – | – | – | – | 7 | 100 | – | – | – | – | – | – |
| 102 | 3.9 | 6 | 1 | 17 | – | – | – | – | – | – | – | – | 3 | 50 | 3 | 50 | – | – | – | – | – | – |
| 103 | 3.9 | 6 | 4 | 66 | – | – | – | – | – | – | – | – | 3 | 50 | 3 | 50 | – | – | – | – | – | – |
| 108 | 2.7 | 5 | 1 | 20 | – | – | – | – | – | – | – | – | – | – | 5 | 100 | – | – | – | – | – | – |
| 109 | 2.7 | 7 | 1 | 14 | 1 | 14 | – | – | – | – | – | – | 3 | 42 | 4 | 56 | – | – | – | – | – | – |
| 104 | 2.6 | 3 | – | – | – | – | – | – | – | – | – | – | – | – | 3 | 100 | – | – | – | – | – | – |
| 105 | 2.6 | 5 | – | – | – | – | – | – | – | – | – | – | – | – | 3 | 60 | – | – | – | – | – | – |
| 110 | 1.5 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | 1 | 100 | – | – | – | – | – | – |
| 111 | 1.5 | 3 | 1 | 33 | – | – | – | – | – | – | – | – | 1 | 33 | 2 | 66 | – | – | – | – | – | – |

Table 3.— Numbers of individuals collected ranked in order of decreasing abundance in intensive phase of neuston experiment (+ = significantly more abundant for day or night, or no significant difference in catch between day and night at 5% level of significance).

| Species group | Total number caught | Number in night catches | Number in day catches | Day | Night | Both | Data too few | Range total length (mm) | Number of tows present | Relative abundance in number of tows present |
|---|---|---|---|---|---|---|---|---|---|---|
| *Auxis* | 3576 | 3573 | 3 | | + | | | 2-16 | 26 | 12 |
| Exocoetidae | 1245 | 700 | 545 | | + | | | 4-83 | 45 | 1 |
| Scombridae | 907 | 906 | 1 | | + | | | 4-15 | 8 | 29 |
| Gerreidae | 513 | 229 | 284 | | | + | | 5-14 | 43 | 2 |
| Tetraodontidae | 409 | 15 | 394 | + | | | | 4-14 | 29 | 9 |
| Mullidae | 348 | 7 | 341 | + | | | | 5-21 | 29 | 9 |
| *Mugil curema* | 230 | 77 | 153 | + | | | | 6-18 | 40 | 4 |
| Priacanthidae | 223 | 222 | 1 | | + | | | 3-30 | 25 | 13 |
| *Coryphaena hippurus* | 217 | 188 | 29 | | + | | | 9-62 | 34 | 5 |
| *Caranx crysos* | 191 | 67 | 124 | + | | | | 7-37 | 42 | 3 |
| Gobiidae | 180 | 179 | 1 | | + | | | 5-14 | 22 | 16 |
| Anguilliformes | 143 | 142 | 1 | | + | | | 6-84 | 24 | 14 |
| Carangidae | 128 | 125 | 3 | | + | | | 3-5 | 21 | 17 |
| *Psenes maculatus* | 125 | 125 | 0 | | + | | | 6-49 | 20 | 18 |
| Hemiramphidae | 124 | 97 | 27 | | + | | | 6-57 | 31 | 7 |
| *Decapterus punctatus* | 118 | 46 | 72 | + | | | | 24-47 | 32 | 6 |
| Fish | 113 | 90 | 23 | | + | | | 3-32 | 23 | 15 |
| *Monacanthus setifer* | 103 | 11 | 92 | + | | | | 9-35 | 30 | 8 |
| Scorpaenidae | 102 | 92 | 10 | | + | | | 3-11 | 29 | 9 |
| Holocentridae | 93 | 93 | 0 | | + | | | 3-17 | 21 | 17 |
| *Caranx* | 91 | 87 | 4 | | + | | | 4-32 | 24 | 14 |
| Synodontidae | 88 | 88 | 0 | | + | | | 5-32 | 18 | 20 |
| *Euthynnus alletteratus* | 67 | 67 | 0 | | + | | | 3-10 | 18 | 20 |
| *Monacanthus hispidus* | 64 | 3 | 61 | + | | | | 14-58 | 22 | 16 |
| *Opisthonema oglinum* | 62 | 55 | 7 | | + | | | 5-15 | 20 | 18 |
| *Istiophorus platypterus* | 59 | 26 | 33 | | | + | | 3-18 | 26 | 12 |
| *Decapterus* | 54 | 53 | 1 | | + | | | 7-11 | 18 | 20 |
| *Coryphaena equisetis* | 54 | 50 | 4 | | + | | | 8-18 | 21 | 17 |

Table 3.— Continued.

| Species group | Total number caught | Number in night catches | Number in day catches | Day | Night | Both | Data too few | Range total length (mm) | Number of tows present | Relative abundance in number of tows present |
|---|---|---|---|---|---|---|---|---|---|---|
| *Aluterus* | 49 | 6 | 43 | + | | | | 1-105 | 17 | 21 |
| *Trachinotus falcatus* | 48 | 31 | 17 | | + | | | 7-18 | 19 | 19 |
| Balistidae | 46 | 21 | 25 | | | + | | 3-12 | 23 | 15 |
| Pomacentridae | 46 | 29 | 17 | | | + | | 5-20 | 28 | 10 |
| Labridae | 44 | 43 | 1 | | + | | | 5-18 | 18 | 20 |
| *Scomberomorus cavalla* | 41 | 39 | 2 | | + | | | 5-10 | 18 | 20 |
| Serranidae | 40 | 40 | 0 | | + | | | 3-16 | 15 | 23 |
| Cynoglossidae | 39 | 39 | 0 | | + | | | 5-16 | 16 | 22 |
| *Kyphosus* | 39 | 15 | 24 | | | + | | 7-21 | 18 | 20 |
| *Selar crumenopthalmus* | 38 | 18 | 20 | | | + | | 6-69 | 15 | 23 |
| *Bothus* | 34 | 33 | 1 | | + | | | 3-22 | 16 | 22 |
| *Canthigaster* | 33 | 31 | 2 | | + | | | 3-17 | 14 | 24 |
| *Monacanthus* | 33 | 3 | 30 | | | | + | 8-30 | 11 | 26 |
| *Dactylopterus volitans* | 30 | 3 | 30 | | | | + | 8-30 | 11 | 26 |
| *Seriola* | 26 | 4 | 22 | | | | + | 5-18 | 14 | 24 |
| *Seriola rivoliana* | 25 | 0 | 25 | | | | + | 14-43 | 9 | 28 |
| *Caranx hippos* | 23 | 21 | 2 | | + | | | 6-32 | 14 | 24 |
| Syngnathidae | 22 | 19 | 3 | | + | | | 7-69 | 15 | 23 |
| Apogonidae | 22 | 22 | 0 | | | | + | 4-10 | 12 | 25 |
| *Rachycentron canadum* | 19 | 19 | 0 | | | | + | 6-13 | 11 | 26 |
| *Balistes capriscus* | 18 | 5 | 13 | | | | + | 7-43 | 10 | 27 |
| Belonidae | 17 | 8 | 9 | | | | + | 7-78 | 7 | 30 |
| Bothidae | 17 | 17 | 0 | | | | + | 4-15 | 6 | 31 |
| *Trachurus lathami* | 15 | 15 | 0 | | | | + | 4-13 | 2 | 35 |
| *Thunnus* | 14 | 11 | 3 | | | | + | 5-10 | 4 | 33 |
| *Megalops atlanticus* | 14 | 14 | 0 | | | | + | 18-66 | 2 | 35 |
| *Coryphaena* | 13 | 12 | 1 | | | | + | 5-9 | 9 | 28 |
| *Syacium* | 13 | 13 | 0 | | | | + | 2-30 | 7 | 30 |
| *Thunnus atlanticus* | 11 | 9 | 2 | | | | + | 5-10 | 11 | 26 |

Table 3.— Continued.

| Species group | Total number caught | Number in night catches | Number in day catches | Day | Night | Both | Data too few | Range total length (mm) | Number of tows present | Relative abundance in number of tows present |
|---|---|---|---|---|---|---|---|---|---|---|
| Trachinotus carolinus | 10 | 9 | 1 | | | | + | 7-14 | 7 | 30 |
| Sphyraenidae | 10 | 1 | 9 | | | | + | 11-21 | 4 | 33 |
| Grammistidae | 7 | 7 | 0 | | | | + | 7-18 | 7 | 30 |
| Cubiceps athenae | 7 | 7 | 0 | | | | + | 15-34 | 6 | 31 |
| Gonostomatidae | 7 | 6 | 1 | | | | + | 5-12 | 4 | 33 |
| Blennidae | 7 | 7 | 0 | | | | + | 6-10 | 3 | 34 |
| Ostraciidae | 6 | 4 | 2 | | | | + | 4-12 | 6 | 31 |
| Hippocampus | 6 | 5 | 1 | | | | + | 6-64 | 5 | 32 |
| Lobotes surinamensis | 5 | 4 | 1 | | | | + | 8-18 | 5 | 32 |
| Gymnachirus melas | 5 | 5 | 0 | | | | + | 6-7 | 5 | 32 |
| Perciformes | 5 | 3 | 2 | | | | + | 3-12 | 3 | 34 |
| Echeneidae | 5 | 5 | 0 | | | | + | 6-11 | 3 | 34 |
| Mugilidae | 5 | 4 | 1 | | | | + | 7-12 | 2 | 35 |
| Pleuronectiformes | 5 | 5 | 0 | | | | + | 5-7 | 1 | 36 |
| Alectis ciliaris | 4 | 4 | 0 | | | | + | 6-16 | 4 | 33 |
| Seriola fasciata | 4 | 1 | 3 | | | | + | 15-29 | 4 | 33 |
| Centropristes striata | 4 | 4 | 0 | | | | + | 5-7 | 3 | 34 |
| Sciaenidae | 4 | 4 | 0 | | | | + | 4-8 | 1 | 36 |
| Caranyx latus | 4 | 1 | 3 | | | | + | 22-27 | 3 | 34 |
| Myctophidae | 3 | 1 | 2 | | | | + | 6-11 | 3 | 34 |
| Elagatis bipinnulata | 3 | 2 | 1 | | | | + | 5-11 | 3 | 34 |
| Cyclopsetta fimbriata | 3 | 3 | 0 | | | | + | 4-22 | 3 | 34 |
| Sphyraena | 3 | 1 | 2 | | | | + | 13-23 | 2 | 35 |
| Aluterus scriptus | 3 | 3 | 0 | | | | + | 7-48 | 2 | 35 |
| Elopidae | 2 | 2 | 0 | | | | + | 18-20 | 2 | 35 |
| Harengula pensacolae | 2 | 1 | 1 | | | | + | 11-13 | 2 | 35 |
| Fistulariidae | 2 | 2 | 0 | | | | + | 53-60 | 2 | 35 |
| Mugil | 2 | 0 | 2 | | | | + | 8 | 2 | 35 |
| Callionymidae | 2 | 2 | 0 | | | | + | 5-8 | 2 | 35 |
| Thunnus albacares | 2 | 2 | 0 | | | | + | 7-8 | 2 | 35 |

## Diurnal Differences in Catch

Catches for many species varied significantly between day and night periods. Although data were too few classify the period of highest abundance for 70 species-groups, 26 groups demonstrated significant variation in the number caught during daylight and nocturnal hours. Catches of six groups did not differ from day to night (Table 3).

## Analysis of Variance and Covariance Tests

The first analysis of variance test was the fixed, three way ANOVA previously mentioned. The design variables were net size, night vs day and period 1 or 2. Initially, transformed data (using small number transformation) were analyzed. Subsequent analysis indicated that the assumption of normality was not being violated. Therefore, untransformed data were utilized in all succeeding analyses.

The results suggested that day vs night, period 1 or 2, and the period-day vs night interaction significantly affected results of the anlysis (Table 4). Note that the net size did not significantly affect catches of the respective species-groups.

Next, analyses of covariance were conducted (see Table 1 for values of covariates). Covariates were tested one at a time vs catches of each species-group in each tow. Results are shown in Table 5. Because a number of covariates did not appear to influence catches, the model was collapsed to include only those covariates that appeared either to affect catches significantly or were of particular biological interest. These were surface temperature, surface salinity, total tow duration, barometric pressure, speed, relative volume strained, wet weights of coelenterates, manatee grass, and sargassum weed. Results are shown in Table 6. Relative volume of tows and weight of coelenterates did not appear to be related to catches and will not be discussed further. Barometric pressure appeared to significantly affect the catch of Exocoetidae. This may be a spurious correlation or it may reflect a chain of meterological events affecting availability of light; hence, catches. The other covariates appeared to influence catches in two or more species-groups and these relationships will be discussed later.

When the main treatment effects (period 1 or 2, days vs night, and their interaction) were adjusted for covariates, they did not appear to significantly affect catches of larvae (Table 6). This was in contrast to the results of the initial ANOVA test conducted without covariates. This appeared reasonable for the period and the interaction effect but unreasonable for the day vs night effect because (1) an extensive literature exists documenting the effect of light conditions upon vertical movement of plankton including fish larvae and (2) Chi-Square analyses demonstrated distinct differences in catches of many species-groups between day and night. These results indicated that the assumption of independence of covariates and design variable had been violated. Therefore, the covariate model appeared invalid and alternative statistical methods were indicated.

Next, analyses of variance tests for individual covariates adjusted for other covariates were performed. Several covariates did vary significantly between day and night but not between the other 2 main treatment effects (Table 7). This was not unexpected for surface temperature. In fact, according to our interpretation, this explains why the surface temperature appeared to influence catches significantly. In essence, changes in light conditions, not correlated surface temperatures, were

Table 4.— Results of three-way analysis of variance (fixed model) on catches of 24 selected species-groups taken in the intensive phase of the neuston gear experiment (+ is significant at 5% level).

| Species-group | Net size | Period | Day vs night | Net size-period interaction | Net size-day vs night interaction | Period-day vs night interaction | Net size-period-day vs night interaction |
|---|---|---|---|---|---|---|---|
| *Opisthonema oglinum* | + | + | + | + | + | + | + |
| Anguilliformes | | + | + | | | + | |
| Hemiramphidae | + | | + | | | | |
| Exocoetidae | | | | | | | |
| Holocentridae | | | + | | | | |
| *Mugil curema* | | | + | | | | |
| Priacanthidae | | | + | | | | |
| *Caranx crysos* | | | | | | | |
| *Trachinotus falcatus* | | | | | | | |
| *Coryphaena equisetis* | | + | + | | | + | |
| *Coryphaena hippurus* | | + | | | | + | |
| Gerreidae | | + | | | | | |
| Mullidae | | + | + | | | + | |
| Pomacentridae | + | + | | | | | |
| *Auxis* | | + | + | | | + | |
| *Istiophorus platypterus* | | + | | | | | |
| *Psenes maculatus* | | + | + | | | + | |
| Gobiidae | | | + | | | | |
| Scorpaenidae | | | + | + | | | + |
| Balistidae | | + | | | | + | |
| *Monacanthus hispidus* | | | + | | | | |
| *Monacanthus setifer* | | + | + | | | | |
| Tetraodontidae | | | + | | | | |
| Total numbers | | | + | | | + | |

Table 3.— Continued.

| Species group | Total number caught | Number in night catches | Number in day catches | Day | Night | Both | Data too few | Range total length (mm) | Number of tows present | Relative abundance in number of tows present |
|---|---|---|---|---|---|---|---|---|---|---|
| Brevoortia patronus | 2 | 2 | 0 | | | | + | 7-8 | 1 | 36 |
| Engraulidae | 2 | 2 | 0 | | | | + | 6 | 1 | 36 |
| Katsuwonus pelamis | 2 | 2 | 0 | | | | + | 5 | 1 | 36 |
| Rajiformes | 1 | 1 | 0 | | | | + | 8 | 1 | 36 |
| Anchoa | 1 | 1 | 0 | | | | + | 10 | 1 | 36 |
| Beloniformes | 1 | 0 | 1 | | | | + | 7 | 1 | 36 |
| Euleptorhamphus velox | 1 | 0 | 1 | | | | + | 33 | 1 | 36 |
| Bregmacerotidae | 1 | 1 | 0 | | | | + | 7 | 1 | 36 |
| Mugiliformes | 1 | 0 | 1 | | | | + | 5 | 1 | 36 |
| Remora remora | 1 | 0 | 1 | | | | + | 33 | 1 | 36 |
| Rachycentron | 1 | 1 | 0 | | | | + | 5 | 1 | 36 |
| Selene vomer | 1 | 1 | 0 | | | | + | 38 | 1 | 36 |
| Trachinotus | 1 | 1 | 0 | | | | + | 5 | 1 | 36 |
| Chaetodipterus faber | 1 | 0 | 1 | | | | + | 5 | 1 | 36 |
| Holacanthus | 1 | 1 | 0 | | | | + | 10 | 1 | 36 |
| Acanthocybium solanderi | 1 | 1 | 0 | | | | + | 7 | 1 | 36 |
| Xiphias gladius | 1 | 0 | 1 | | | | + | 5 | 1 | 36 |
| Psenes cyanophrys | 1 | 1 | 0 | | | | + | 45 | 1 | 36 |
| Psenes pellucidus | 1 | 1 | 0 | | | | + | 19 | 1 | 36 |
| Canthidermis | 1 | 1 | 0 | | | | + | 16 | 1 | 36 |
| Canthidermis maculatus | 1 | 1 | 0 | | | | + | 21 | 1 | 36 |
| Canthidermis sufflamen | 1 | 1 | 0 | | | | + | 21 | 1 | 36 |
| Monacanthus | 1 | 0 | 1 | | | | + | 21 | 1 | 36 |
| Monacanthus ciliatus | 1 | 0 | 1 | | | | + | 17 | 1 | 36 |
| Decapterus macarellus ? | 1 | 1 | 0 | | | | + | 11 | 1 | 36 |

Table 5. Results of analysis of covariance tests, one covariate at a time vs catches of 24 selected species-groups (+ is significant at 5% level).

| Species-group | Time of tow | Depth | Wind vel. | Sea state | Air temp. | Cloud cover | Surf temp. | Surf sal. | Total tow time | Rain | Barom. press. | Speed | Rel. vol. | Coel. | Wet weight Mana-tee | Sarg-assum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Opisthonema oglinum* | | | | | | | | | | | | + | + | | | |
| Anguilliformes | | | | | | | | | | | | | | | | |
| Hemiramphidae | | | | | | | | | + | | | + | | | | |
| Exocoetidae | | | | | | | | | + | | + | + | | | | |
| Holocentridae | | | | | | | | | + | | | + | + | + | | + |
| *Mugil curema* | | | | | + | | | | + | + | | + | | | | |
| Priacanthidae | + | | | | | | | + | | | | | | | | |
| *Caranx crysos* | | | | | | | + | | | | + | | | | | |
| *Trachinotus falcatus* | | | | | | | | | + | | + | + | | | | + |
| *Coryphaena equisetis* | | | | | | | | | + | | | + | | | | |
| *Coryphaena hippurus* | | | | | | | | | + | | | + | | | | + |
| Gerreidae | | | | | | | + | | + | | + | + | | | | |
| Mullidae | | | | | | | | | + | | | + | | | | |
| Pomacentridae | | | | | | | + | + | | | | | | | | |
| *Auxis* | + | | | | | | | | | | | + | + | | | |
| *Istiophorus platypterus* | | | | | | | + | | + | | | + | | | + | |
| *Psenes maculatus* | | | | | | | | + | | | | + | | | | |
| Gobiidae | | | | | | | | | | | | | + | | | |
| Scorpaenidae | | | | | | | | | + | | + | + | + | | | |
| Balistidae | | | | | | + | + | | + | | | + | | | | |
| *Monacanthus hispidus* | | | | | | | | | + | | | + | | | | + |
| *Monacanthus setifer* | | | | | | | | | | | + | | | | | |
| Tetraodontidae | | | | | + | | + | | + | | + | + | | | | |
| Total numbers | + | | | | + | | | | | | | | + | | | |

Table 6.— Results of analysis of covariance tests upon selected covariates adjusted for the main treatment effects period, day vs night and the period-day vs night interaction (+ is significant at the 5% level).

| Species-group | Period | day vs night | Period day vs night | Surf temp. | Surf sal. | Total tow time | Barom. press. | Speed | Rel. vol. | Coel. | Wet weight Mana-tee | Sarg-assum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Opisthonema oglinum* | | | | | | | | | | | | |
| Anguilliformes | | + | | + | | | | | | | | |
| Hemiramphidae | + | | | | | | | | | | | |
| Exocoetidae | | | | | | | + | + | | | + | |
| Holocentridae | | | | + | | | | | | | | |
| *Mugil curema* | | | | | | + | | | | | | |
| Priacanthidae | | + | | + | + | | | | | | | + |
| *Caranx crysos* | | | | | | | | | | | | |
| *Trachinotus falcatus* | | | | | | | | | | | | |
| *Coryphaena equisetis* | | | | + | | | | | | | | |
| *Coryphaena hippurus* | | | | + | | | | | | | | + |
| Gerreidae | | | | | | + | | | | | | |
| Mullidae | | | | + | | + | | | | | | |
| Pomacentridae | | | | | + | | | | | | | |
| *Auxis* | | | | + | | | | | | | | |
| *Istiophorus platypterus* | | | | | | | | | | | + | |
| *Psenes maculatus* | | | | + | + | + | | + | | | | |
| Gobiidae | | | | + | + | | | | | | | + |
| Scorpaenidae | | | | + | | | | | | | | |
| Balistidae | | | | | | | | | | | | |
| *Monacanthus hispidus* | | | | + | | | | | | | | + |
| *Monacanthus setifer* | | | | | | | | | | | | + |
| Tetraodontidae | | | | + | | + | | | | | + | |
| Total numbers | | | | + | | | | | | | | |

probably responsible for significant results observed in Tables 5 and 6. Similarly, an examination of the data suggested that although barometric pressure did change over the experiment, it did so independently of the experimental design and for that reason was not considered a causative agent in the analysis. Conversely, the fact that the covariates total tow duration, speed, and relative volume strained did not vary significantly meant that the execution of the experiment was satisfactorily accomplished with a minimum of bias. Finally, observed changes in wet weights of manatee grass and coelenterates were not unexpected and did serve to provide information for testing correlations of these factors with catches of ichthyoplankton.

Partial Correlation Analyses

As mentioned earlier it appeared that catches of some species-groups were affected significantly by light conditons and other covariates. For that reason conditions (day vs night) were treated as a covariate together with other appropriate covariates which were given in Table 6. Partial correlation analyses were conducted, and the results are given in Table 8. Significant relationships are discussed below.

Total tow time had a positive correlation for one species and 3 family groups. These 4 groups were composed of late larval and early juvenile stages. The greater catches with increased tow time suggests that they were more ubiquitious and uniformly distributed over the surface at this stage of their epipelagic development than were other groups tested.

Catches of two groups were positively correlated with speed. This was expected for Ecocoetidae because some fairly large juveniles were taken and we know that these can avoid slow moving nets. Conversely, we can not explain increased catches of *Psenes maculatus* with speed because we know very little concerning thier habits.

Diurnal period had positive correlation with two groups. The bigeyes (Priancanthidae) were caught in all of the 24 night tows, and a single specimen was taken in one day tow. The eels (Anguilliformes) were caught in 23 of the night tows, and a single specimen was taken in a day tow.

Correlations of catches with surface temperature must be considered in relation to a probable causative agent; namely, changes in diurnal periods. Thus, because surface temperature are lower at night, we interpret negative correlations to indicate that catches increased at night. Conversely, a positive correlation meant that catches were greatest during daylight hours. We do not fully understand why certain species were caught under particular light conditions, but our results indicate that investigators, who analyze ichthyoplankton survey data, should attempt to account for any effect upon catches induced by light conditions or phenomenon associated with changes in light condition.

Catches of the planehead filefish, *Monacanthus hispidus*, pygmy filefish, *Monacanthus setifer*, and dolphin, *Coryphaena hippurus*, increased with concentrations of sargassum weed. The filefishes may be color coded to Sargassum and as pelagic juveniles are well known to use this habitat. The modest correlation of *Coryphaena hippurus* (and the lack of correlation of its cogener, *C. equisetis* with Sargassum is an interesting phenomenon, but any real significance is unknown to us.

Table 7.— Results of analysis of variance tests on selected covariates adjusted for other covariates for the main treatment effects of period, day vs night, and the period-day vs night interaction (+ is significant at 5% level).

| Covariate | Period | Day vs night | Period-day vs night interaction |
|---|---|---|---|
| Surface temperature | | + | |
| Surface salinity | | | |
| Total tow time | | | |
| Barometric pressure | | + | |
| Speed | | | |
| Relative volume | | | |
| Wet weight sargassum | | | |
| Wet weight mantee | | + | |
| Wet weight coelenterates | | + | |

Table 8.— Partial correlation analyses for selected species-groups in neuston gear experiment.

| Species-group | Total tow time | Speed | Diurnal period | Surface temperature | Sargassum weed | Manatee grass |
|---|---|---|---|---|---|---|
| *Opisthonema oglinum* | | | | | | |
| Anguilliformes | | | ++ | | | |
| Hemiramphidae | | | | | | |
| Exocoetidae | | +++ | | | | -- |
| Holocentridae | | | | -- | | |
| *Mugil curema* | ++ | | | | | |
| Priacanthidae | | | ++ | | | |
| *Caranx crysos* | | | | | | |
| *Trachinotus falcatus* | | | | | | |
| *Coryphaena equisetis* | | | | -- | | |
| *Coryphaena hippurus* | | | | -- | + | |
| Gerridae | ++ | | | | | |
| Mullidae | ++ | | | +++ | | |
| Pomacentridae | | | | | | |
| *Auxis* | | | | -- | | |
| *Istiophorus platypterus* | | | | | | |
| *Psenes maculatus* | - | ++ | | - | | |
| Gobiidae | | | | -- | | |
| Scorpaenidae | | | | - | | |
| Balistidae | | | | | | |
| *Monacanthus hispidus* | | | | ++ | ++ | |
| *Monacanthus setifer* | | | | | ++ | |
| Tetraodontidae | ++ | | | ++ | | ++ |
| Total numbers | | | | | | |

Partial correlation coefficient code.

+ = 0.00 to 0.33
++ = 0.34 to 0.66
+++ = 0.67 to 1.00

- = -0.01 to -0.33
-- = -0.34 to -0.66
--- = -0.67 to -1.00

The presence of manatee grass during the survey was most unusual. It occurred as dead, bleached, broken bits (ca 2 to 25 mm long), in wind-collected rafts about 0.5 to 3 $m^2$ area. The grass appeared in the same general area as did sargassum weed, but appeared to form discrete pods. Catches of puffers, Tetradontidae, were positively correlated with density of manatee grass. The white opaque pods of manatee grass may have provided covering habitat for the globular, white-bellied puffers.

The negative correlation of Exocoetidae with mantee grass suggests an avoidance reaction. It is possible that manatee grass may impede the mobility of Exocoetidae and may offset their body-fin camouflage which might make them more vulnerable to predation.

# Discussion and Conclusion

This experiment was constructed primarily to test the effectiveness of the 4.9 and 8.5 m Boothbay neuston nets concerning (1) ease of handling, (2) catching ability under varying tow speeds and light conditions, and (3) conditions of specimens after capture.

The 4.9 m net was clearly superior to the 8.5 m net in both ease of handling and processing of specimens after capture. The 4.9 m net is obviously less expensive to purchase and maintain. We recommend its adoption as a standard gear item, and suggest a comparison of the 4.9 m net with a shorter version (4 m or 3 m), and a net design with more bag and less taper.

There was no significant difference in the catching ability of the two nets, although the 4.9 m net actually caught more specimens during the test.

There did not appear to be any significant difference in condition of specimens after capture between nets. However, ease of processing samples from the 4.9 m net may reduce damage somewhat.

Damage to specimens appeared to increase with increasing speed and the level of damage sustained varied between species-groups.

Damage to specimens increased, as expected, with greater towing speed. Speeds of 1 m/sec produced minimal damage, and specimen damage to speeds of 2 m/sec was modest. Even at 3 m/sec damage was not so severe that great difficulty was experienced in identifying torn or broken specimens. We recommend 2 additional experiments, one to determine maximum net speed possible within limits of safety and regular gear behavior related to gross specimen damage to a point of unidentifiability, and a second experiment to quantify the relationships of towing speed and towing time duration with total volume of water sampled. We subjectively recommend a routine towing procedure of 3 m/sec for 10 minutes.

Chi-Square analyses indicated that the catches of 36 species-groups were affected by changes in diurnal period. Catches of 28 increased at night, whereas collections of 8 were greater during daylight hours.

Analyses of covariance indicated that a number of factors including total tow time, towing speed, diurnal period, surface temperature, sargassum weed, and manatee grass were correlated with catches of ichthyoplankton. In addition, the effect of surface temperature appeared to be an apparent effect actually produced by light or other conditions, not by observed changes in temperature. Thus, a negative correlation meant that catches increased at night; whereas, a positive correlation indicated greater catches during daylight hours.

The results of the neuston gear experiment indicate that (1) the 4.9 m net is the preferred net for routine surveys, (2) acceptable towing speeds lie between 1 and 3 m/sec, and (3) choice of sampling hours should take into account variation in catches associated with changes in light conditions.

# References

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Appendix Table 1.— Values of partial correlation coefficients with confidence limits, P = .95.[a]

| Species-group | Covariate | $r^2$ | Confidence limits [a] |
|---|---|---|---|
| Anguilliformes | Diurnal periods | 0.63 | .47, .78 |
| Exocoetidae | Speed | 0.68 | .50, .79 |
| | Manatee | -0.34 | -.80, -.56 |
| Holocentridae | Surf temp. | -0.44 | -.21, -.58 |
| Mugil curema | Total tow time | 0.62 | .42, .77 |
| Priacanthidae | Diurnal period | 0.64 | .45, .78 |
| Coryphaena equisetis | Surf temp. | -0.35 | -.08, -.50 |
| Coryphaena hippurus | Surf temp. | -0.37 | -.22, -.66 |
| | Sargassum | 0.33 | .06, .55 |
| Gerridae | Total tow time | 0.45 | .20,, .64 |
| Mullidae | Surf temp. | 0.71 | .56, .82 |
| | Total tow time | 0.42 | .16, .62 |
| Pomacentridae | | | |
| Auxis | Surf temp. | -0.43 | -.18, -.63 |
| Istiophorus platypterus | | | |
| Psenes maculatus | Surf temp. | -0.33 | -.05, -.54 |
| | Total tow time | -0.30 | -.02, -.52 |
| | Speed | 0.48 | .21, .65 |
| Gobiidae | Surf temp. | -0.49 | -.24, -.67 |
| Scorpaenidae | Surf temp. | -0.33 | -.08, -.56 |
| Monacanthus hispidus | Surf temp. | 0.51 | .29, .69 |
| | Sargassum | 0.47 | .20, .65 |
| Monacanthus setifer | Sargassum | 0.58 | .32, .71 |
| Tetradontidae | Surf temp. | 0.47 | .20, .64 |
| | Total tow time | 0.49 | .24, .68 |
| | Manatee | 0.54 | .32, .71 |

[a] Calculated from Table A.11A of Steel & Torrie (1960).