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A COMPARISON OF THE CATCH FROM TWO TYPES OF SHRIMP NETS OFF SOUTH CAROLINA, USA

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by

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ABSTRACT

Comparative mensuration of a two-seam net and a tongue trawl was completed by examining changes in dimensions with depth and tow direction. The two-seam net had a width of 16.1 m and was estimated to extend 2.1 m vertically at the center of the headrope. The horizontal spread of the tongue trawl was 13.5 m with a vertical spread of 4.2 m at center. Small, statistically consistent differences in openings (< 0.5 m) occurred with depth and direction, but the only factor believed to be influencing changes in catch (kg/hectare) with depth (10 fold increase in shallow water) was the distribution of animals with depth, independent of towing characteristics.

Differences in biomass (kg/tow, kg/hectare, and ratio of kg of taxon/hectare:kg of shrimp/hectare) between the two-seam and tongue trawl were documented for eight major taxa. Major differences in total catch occurred between years primarily because of changes in the catch of miscellaneous invertebrates and shrimp. Significant differences in the lengths of seven priority species occurred between the two gears. These differences were greater than 1 cm in spot (larger in tongue), Atlantic croaker (larger in two-seam), and Spanish mackerel (larger in tongue). Ratio of biomass to shrimp biomass was statistically different between the two gears only for king mackerel (higher in tongue). Mean value of ratios of fish to shrimp biomass was 21.01:1 for the two-seam net and 41.20 for tongue trawl. Comparisons with recalculated ratios from published data using a standard methodology indicated a potential increase in the ratio over time and the need to validate the technique of subsampling heterogenous trawl samples. Finfish by-catch in both gears was dominated by sciaenids (44% of all fish). Neither gear collected any red drum, spotted seatrout, snappers,

nor groupers. Catches of Spanish and king mackerel were documented and warrant further investigation to evaluate the effects on local populations.

INTRODUCTION

Since the early 1900's, the shrimp fishery in South Carolina has utilized trawling in nearshore coastal waters as its major means of harvesting shrimp. Bottom trawling also catches multiple fish and invertebrate species in addition to the targeted shrimp. In the Atlantic Coastal region of the United States, the incidental catch of mixed species, collectively referred to as "by-catch", has been the subject of numerous studies (Anderson 1968, Lunz et al. 1951, Keiser 1977, Brown et al. 1979, Low et al. 1982). Estimates of the magnitude of the by-catch have ranged from 54.4 kg/hr (120 lb/hr, Knowlton 1972) to 548.4 kg/hr (1209 lb/hr, Rothmayr 1965). Comparisons of the by-catch of fishes to the shrimp catch have resulted in the reporting of a fish to shrimp ratio ranging by tow from 0.30:1 (Keiser 1976) to 49,500:1 (Keiser 1977). Similar catch ratios have been reported for the Gulf of Mexico (Bryan et al. 1982).

Recently, increased interest in the species composition and magnitude of finfish in the by-catch has received considerable attention, particularly in the Gulf of Mexico. Gutherz and Pellegrin (1988) estimated that approximately 4.5 x 10^6 juvenile red snapper were harvested over a 10 year period, and concluded that the impact of juvenile mortalities by shrimp trawling on the population was probably minimal. However, Powers et al. (1987) estimated a 90% increase in the yield of red snapper in the Gulf could result from reduction in shrimp by-catch. Marshall (1990) and Williams (1990) stressed concern over increasing mortality of recreational finfish as by-catch in the trawler fishery.

Within the last 10 years, trawling for shrimp in the Atlantic waters off the southeastern United States has employed two different types of nets. For brown shrimp (Penaeus aztecus), most shrimpers have used a traditional two-seam net with a relatively small vertical opening (~2 m). For catching white shrimp (Penaeus setiferus), various nets (falcon, tongue, mongoose, or fly), designed for increased vertical opening and overhanging headrope, have been developed and fished. Previous estimates of by-catch in this region were based on catches primarily with low opening two-seam nets.

The purpose of this report is to: 1) briefly describe the performance characteristics of the two-seam and tongue nets, 2) summarize the magnitude and species composition of the by-catch from the two types of trawls, 3) test for statistical differences in by-catch between these nets during the brown and white shrimp season, and 4) statistically compare catches of shrimp and by-catch among the nets employed in this study with other observations by on-board observers and with studies from other areas.

METHODS

Area Sampled

The majority of the comparative trawling were in three local shrimping grounds; two areas north of the Charleston North Jetty to Charleston Harbor and the area off Stono Inlet (Fig 1). In the Charleston area, research trawling was concentrated primarily north of the North Jetty along the beach north toward Dewees Inlet, and immediately north along the North Jetty. Off the Stono River, trawling was conducted both north and south of the sea buoy. Four tows were made off the North Edisto River. All tows were made in and amongst the operating shrimp fleet or where the fleet had been fishing, often with shrimpers pulling both inshore and offshore of the research vessel.

Gear Description

The two nets trawled for the comparison of finfish and shrimp catches were a 26.5 m tongue (Falcon) net and a 26.5 m two-seam net, both constructed by Beaufort Marine Supply of Bluffton, S.C. The nets were towed simultaneously with the two-seam net on port side and the tongue trawl on starboard side. Both nets were constructed of No. 15 nylon thread with 4.8-cm stretch mesh in the top, bottom, wings, first, and second tail bags and of No. 30 nylon thread with 4.2-cm stretch mesh in the cod ends.

The 27.2 m footrope of the tongue net had loops of progressively decreasing sized chain (three loops of 1.0-cm chain, ten loops of 0.8-cm chain, ten loops of 0.6-cm chain, five loops of 0.5-cm chain, and two additional loops of 0.6-cm chain) on each side of the middle. A 0.9 m chain extension was between the center of the footrope and the tickler chain. The length of the tickler chain, attached between the doors, was kept approximately 1.2 m shorter than the footrope to drag 0.9 m ahead of the footrope. The 26.6 m headrope of the tongue net had one large (60-cm) Norwegian float attached to the top center of the net and two 22.3-cm styrofoam floats, each located ¼ of the distance from each end of the 22.3 m of net webbing. When stretched lengthwise, the tongue trawl measured 17.2 m from center of footrope to end of the cod end. The cod end of the tongue trawl was protected with a layer of chaffing gear.

The 29.2 m footrope of the two-seam net had loops of progressively decreasing sized chain (twelve loops of 0.8-cm chain, ten loops of 0.6-cm chain, then three additional loops of 0.6-cm chain) on each side of the middle, with one loop of 0.6-cm chain in the middle of the footrope. A 1.0 m chain extension was between the center of the footrope and tickler chain. The 26.7 m headrope of the two-seam net had three 22.3-cm styrofoam floats positioned at about ¼-distances (~ 6 m) along the 22.5 m of headrope webbing. When stretched on the ground, the two-seam net measured approximately 13.5 m in length between the center of the footrope and the cod end. The cod end on the two-seam trawl was protected with a layer of heavy scallop mesh.

Net Mensuration

Measurements of the width and height of each net in actual towing configuration were transmitted from SCANMAR[1] Hydroacoustic Transponders attached to the net wings and headrope to an underwater hydrophone near the ship and digitally displayed to the nearest 0.1 m. During special net mensuration cruises, nets were towed exactly as during normal trawling operations by the same vessel (R/V Lady Lisa) that was used in the catch comparison. Multiple measurements (usually >10) were obtained during several tows (usually ≥ 3) with each net on the inshore and then the offshore side of the vessel (altered by changing vessel's heading to reciprocal courses), in each of two depth zones (4.0- 5.5 m; 12.8- 14.6 m). The width of the net opening was determined as the distance between two transponders at each end of wing webbing on the headrope. Net height was determined by a transponder in the center of the headrope measuring distance above bottom. Total catch of each net deployed during mensuration was either weighed or estimated from the volume.

Differences in measurements were evaluated statistically. Homogeneity of variance was tested using the F-max test. Because gear malfunctions, vessel limitations, and inclement weather hampered full completion of all cells in this nested ANOVA design and because of heterogeneity of variances, comparisons between depth zones and vessel direction were evaluated with Kruskal-Wallis non-parametric tests. Mean net dimensions were used in

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[1]. Use of trade name does not imply endorsement.

calculations of catch standardized by area swept and by volume of water strained.

Trawling

Trawling was conducted from the R/V Lady Lisa, a 23m shrimp trawler at approximately 1.29 m/sec (2.5 kt at 1200 RPM). Towing bridles, measuring 91 m at the trawling block, were typically fully deployed. Both nets were towed simultaneously for 20 minutes with the two-seam net consistently fished from the port outrigger while the tongue net was towed from the starboard outrigger. When maneuverability among commercial vessels allowed, alternate trawl tows were made in opposite directions , primarily, along shore. Tows were conducted in the local shrimping grounds among operating boats, typically with shrimpers both inshore and offshore, or in the very near proximity to a single boat. Many commercial fishing operations stopped late in the day, especially during the white shrimp season of 1990, and, occasionally, several tows were conducted after departure of most of the fleet but where vessels had operated earlier in the day. All tows were made between one hour after sunrise and one hour before sunset.

Sampling during the brown shrimp season was conducted between June 26 and July 13 in 1989 and between June 25 and August 16 in 1990 (Table 1). Sampling during the white shrimp season was conducted between August 27 and September 14, 1990. All trawling for catch comparisons was in water depths between 12-37m.

Priority finfish and shrimp (Table 2) were identified, counted, and weighed by species, and all or a valid subsample (following Grosslein 1969) were measured to the nearest centimeter total length or fork length. All other finfish and invertebrates were identified to the lowest possible taxonomic group for a complete species inventory but weighed by aggregate groupings (i.e., other finfish, miscellaneous invertebrates, etc.).

Comparisons of catch between the tongue and two-seam nets were conducted on data standardized as catch by tow, catch by area swept, and fish:shrimp ratio. Results of trawl mensuration were used to determine the mean dimensions of the opening of each trawl. The vessel speed, estimated by chip log as 1.29 m/s (2.5 kt), was used to estimate the distance along the bottom. In addition to the calculation of total weight (kg) per tow, weight per hectare of bottom area swept and weight per 10,000 m^3 of water filtered were estimated for each priority species or group from these measurements. The ratio of weight (kg/hectare) to shrimp weight (kg/hectare) for eight taxonomic groups was calculated for each tow to estimate relative by-catch magnitude. These groups were: total catch, all invertebrates, priority shrimp, all fish, priority fish, other fish, Spanish mackerel, and king mackerel.

Catch data were tested for homogeneity of variance (F-max test) and normality (using Shapiro-Wilk statistic). When assumptions of homogeneity and normality were met, comparisons were evaluated with analysis of variance or, in the case of gear comparisons, paired t-tests. A (log x+1) transformation was used to normalize the data for comparison. Kruskal-Wallis (or Wilcoxon for paired) non-parametric tests were used when the assumptions of normality and homogeneity of variance were not met. Data were tested statistically for differences in catch by gear (PF=port two-seam trawl or ST=starboard tongue trawl), year (1989 or 1990), week (1 through 6) and season (brown = brown shrimp or white = white shrimp).

RESULTS

Trawl Mensuration

The trawl mensuration was completed on 27 tows: 12 tows with the tongue (106 measurements) and 15 tows with the two-seam net (156 measurements). Several data sets were incomplete because of vessel limitations and repeated equipment malfunction within the limitations of time, problems occurred. Catches of nine paired tows were not measured nor estimated, although the mensuration data for these were valid. No measurements were obtained on the tongue trawl from the offshore side of the vessel when towing in shallow water.

Dimensions of the mouth opening stabilized within an initial 2.0-min. period after the trawls were set. For each net, average net dimensions varied 0.5 m or less between depth zones and on different shoreward-sides of the vessel. The tongue trawl averaged 13.5 m wide and 4.2 m high during trawling (Table 3). The average width of the two-seam net was 16.1 m, while height determination on this was somewhat problematic. The height sensor of the SCANMAR system was not designed to resolve distances very close to the height transponder. During calibration of the instrument, this distance was determined to be ~2.3 m. Anomalous readings occurred on all but 11 of the 176 attempted height measurements on the two-seam net and were eliminated from the analyses. Height of the headrope center on the two-seam net was estimated to be 2.1 m based on the average of the 11 accepted readings and the 1.7 m distance between the headrope and footrope at the ends of the wings.

Using the above dimensions and the speed of the vessel, the tongue trawl sampled 2.1 hectares per tow filtering a total of 65,700 m^3 per tow while the two-seam sampled 2.5 hectares per tow sampling 46,000 m^3 per tow. Analysis of variance and/or Kruskal-Wallis tests on measurements pooled by net indicated that the height and width of the tongue net were significantly different from those of the two-seam net (Table 4). For the tongue trawl, small (< 0.5 m), but consistently significant differences were found in height and width between depth zones, but no differences were found in net dimensions nor catch based on side toward shore during the tow. For the two-seam trawl, valid tests were completed only for width and showed no differences between depth zones and small (< 0.5 m) significant differences based on the shoreward side. Tests on catch during trawl mensuration evaluate these differences in dimensions indicated that there was a significant difference in catch between depth zones regardless of the trawl type with all shallow tows averaging 92.5 kg/tow and all deep tows averaging 9.2 kg/tow. Considering each trawl separately, this difference with depth was the only significant difference observed in catch during mensuration.

General Catch

A total of 182 species, including 96 species of fish, were collected during this survey, 162 species occurring in the two-seam and 154 occurring in the tongue trawl (Appendix 1). The total cumulative catch weighed 15,830.25 kg from these 282 trawls. Trawl tows were made in depths from 12-27 m. The majority of the catch was composed of non-priority invertebrates (Fig. 6). Priority shrimp (503.65 kg) comprised 3.2% of total catch and priority fish (2,242.71 kg) made up 14.2% (Table 5). Mean catch, expressed as kg/tow and kg/hectare of bottom trawled was greater in the tongue than the two-seam trawl for all major groups except all fish and priority fish. The catch of the two-seam net was greater in biomass per volume of water sampled for all groups than the tongue net.

Collections of priority species were dominated in both biomass and number per tow by Atlantic croaker (Micropogonias undulatus), spot (Leiostomus xanthurus), brown shrimp (Penaeus aztecus), southern whiting (Menticirrhus americanus), white shrimp (Penaeus setiferus), and blue crab (Callinectes sapidus) (Table 6). Bluefish (Pomatomus saltatrix) were also common in catches, but very few summer flounder (Paralichthys dentatus) and southern flounder (Paralichthys lethostigma) were taken. Total brown shrimp catch during the two brown shrimp seasons sampled in 1989 and 1990 was 16,089 shrimp weighing 347.57 kg while white shrimp taken during the one white shrimp season sampled (1990 only) totaled 9,662 shrimp at 215.96 kg. Pink shrimp (Penaeus duorarum) occurred relatively infrequently (2,917 shrimp at 28.76 kg). Overall, 22 of the 282 tows (7.8%) did not collect any of the priority shrimp species. A total of 3,996 Spanish mackerel (Scomberomorus maculatus) weighing 94.98 kg and 289 king mackerel (S. cavalla) weighing 15.81 kg were taken during the 282 tows. Four priority species groups were not taken during this survey (Table 6): Cynoscion nebulosus (spotted seatrout), Sciaenops ocellatus (red drum), any Epinephilinae (groupers), nor any Lutjanidae (snappers).

Catch differed with season. Mean catch by area swept (kg/hectare) was higher during the white shrimp season for total catch (Fig. 7), all invertebrates (Fig. 7), and priority shrimp (Fig. 8) than during either brown shrimp seasons. The mean catch of total finfish (Fig. 8) and priority finfish (Fig. 9) was higher in 1990 than in 1989. Small changes occurred in the mean catch of other fish (Fig. 9) with higher means in the 1990 white shrimp season. Both mackerel species occurred in all three sampling periods with highest mean catches in the 1989 brown shrimp season (Fig. 10).

Catch Comparisons

Catch data were not normally distributed and variances were not homogeneous, even after transformation (log x + 1) of the data. Catches (kg/tow and kg/hectare) of all major groups by week and year were significantly different (Table 9). Trawls during week 4 collected significantly higher catches (kg/hectare) of all groups except the two mackerels. Highest catches of Spanish mackerel occurred during week 2 while catches were highest for king mackerel during week 6. Catches in 1990 were significantly higher for all groups except Spanish mackerel which were significantly higher in 1989. Catches for all major groups except priority fishes and Spanish mackerel were significantly higher during the white shrimp season.

There were no significant differences between the tongue and two-seam net in catch (kg/hectare) of the priority fish, other fish, Spanish mackerel, or king mackerel, but total catch, invertebrate catch, and shrimp catch were significantly higher in the tongue trawl.

Paired t-test verified significantly higher catches in the tongue trawl than the two-seam net for total catch, invertebrates, and shrimp during the 1990 white shrimp season, for total catch and invertebrates during the 1989 brown shrimp season, and for invertebrates and other fish during the 1990 brown shrimp season.

Of the 13 priority species collected statistically significant differences in length of individuals (ranging from 0.33 - 1.60 cm) caught by the two nets were found for seven species (Table 7). For Atlantic croaker (Fig. 11), spot (Fig. 11) and Spanish mackerel (Fig. 12), this difference in mean length was more than one centimeter. Lengths of Atlantic croaker, brown shrimp (Fig. 13) and southern whiting (not illustrated) were statistically larger in the two-seam trawl. Specimens of Spanish mackerel, spot, blue crabs, and weakfish had statistically greater lengths in the tongue trawl. No statistical differences were found in the distribution of lengths among gears for king mackerel (Fig. 12), pink and white shrimp (Fig 13), bluefish and summer and southern flounder.

The ratio of catch (kg/hectare) for each major group to catch of priority shrimp varied with gear, year, and season (Table 8). This ratio was most variable during the 1989 brown shrimp season for all seven groups. The mean ratio for each of the seven groups was considerably higher in the tongue trawls during this season. For all fish and priority fish during the 1990 white shrimp season, greater variability and larger mean ratios in the catches from the two-seam net. Generally, mean ratios of most groups were highest in 1989 brown shrimp season, intermediate in 1990 brown shrimp season, and least in the 1990 white shrimp season.

The majority of the catches in each gear had ratios of fish to shrimp biomass (kg/tow) less than 10 (Fig. 14). Ratios for thirteen tows with the two-seam trawl and nine with the tongue could not be calculated because the tows caught no shrimp. The mean ratio for the two-seam trawl was 21.01 (range 0.26-332.72); the mean ratio for the tongue was 41.20 (range 0.49-2,021.08). Distribution of only ratios less than 20 indicated that the majority of ratios were less than 5 (Fig. 15). Shrimp biomass exceeded fish biomass (ratios < 1) in 16.42% of the two-seam and 16.67% of the starboard tongue trawls.

No statistical differences between the two gears existed in the ratios for any of the taxonomic groups except for king mackerel (Table 9). The ratio of the catch of king mackerel to shrimp catch was statistically greater in the two-seam trawl than in the tongue trawl. Statistically highest ratios for all groups occurred in 1989, except for king mackerel which exhibited no statistical differences in ratios between the two years. Highest ratios for all groups but the mackerels occurred in week one (week 2 highest for Spanish; week 6 for kings). Catches with highest ratios for fish, priority fish, other fish, and Spanish mackerel occurred during the brown shrimp season, while ratios of king mackerel were highest during the white shrimp season. The ratios of total and invertebrate catch to shrimp biomass were not significantly different between seasons.

DISCUSSION

Trawl Mensuration

Because of the great difference in drag between the two net types, a considerable amount of left rudder had to be applied to maintain the desired course, the rudder angles varying depending on heading, relative wind direction and velocity, and relative current. The effect that rudder angle may have had on the towing characteristics of the net or catch were not quantified in our study. However, the end result of this effect was addressed during trawl mensuration by comparing net measurements and catch with varying direction.

Despite efforts to maintain standard nets of each net type, changes in net configuration occurred with continual fishing. The most important change may have been the stretching of the tickler chain which was corrected periodically. The variation in length of tickler chain was considered of little importance when distributed over the large number of collections under various fishing and environmental conditions.

An approximation for the horizontal opening of a shrimp net (0.6 times the length of the headrope, Roe 1969) has been used by several authors in expansion of catch data to catch per area swept (Wenner et al. 1979, Websters et al. 1989). Our trawl mensuration indicated good agreement with the two-seam net that opened 0.61 times the headrope length. The tongue trawl yielded a factor of 0.51, indicating that a more appropriate factor for tongue trawls may be 0.5. Both nets reached full fishing configuration very shortly (2 min.) after full deployment.

The small (<0.5 m) but statistically consistent differences in net dimensions based on side toward shore during tows with the two-seam net were not reflected in differences in catch. This observation supports the conclusion that the side of the vessel that the net is on during the tow is not a factor influencing the catch.

Significant differences in catch with depth occurred in both nets during mensuration. There were no (for two-seam) or only slight (<0.5 m for tongue) differences in net dimensions between depth zones. Differences in biomass and species diversity with depth are documented for this region (Strusaker 69; Webster et al. 1990; Boylan et al. 1990). Thus, it is our conclusion that the order of magnitude difference in total catch between depths reflects a real distributional difference in the biota and not the minor difference in net dimensions.

General Catch

The total of 96 taxa of fish and 86 of all other taxonomic groups collected in this study from depths of 12-27 m off South Carolina was similar to that found by other studies in this region. Wenner et al. (1979, 1980) found 74-94 species of fish in summer tows from 9 to 27 m throughout the SAB during 1974 and 1975. Anderson (1968) found a total of 98 taxa of fish throughout the inshore waters of the South Atlantic Bight but had identified several groups only the generic level (Anchoa spp., Eucinostomus spp., Prionotus spp.). Webster et al. (1989) reported a total of 90 species of fish and decapods from inshore depths (5-9 m) during summer. The dominant taxa reported in the past (Anderson 1968, Wenner and Sedberry 1989) from catches by similar gear were among those dominant priority species in the current study (spot, croaker).

In the current study, four priority taxa were not taken - red drum (Sciaenops ocellata), spotted seatrout (Cynoscion nebulosus), snappers (Lutjanidae), and groupers (Epinephelinae). Several past studies using shrimp trawls in similar areas collected these taxa, but very infrequently and in low numbers (27 red-drum, Low et al. 1982; spotted sea trout, few in Wenner and Sedberry 1989; 278 in Anderson 1968; snappers, Wenner and Sedberry 1989, Webster et al. 1989, Boylan et al. 1990). Off Texas, red snapper occur in shrimp trawls among the top 25 species collected in the by-catch and catches may be impacting the population (Bryan et al. 1982). Powers et al. (1987) estimated the yield of red snapper could increase by 90% in the Gulf if the by-catch were eliminated. There is no evidence to support a similar concern for these four taxa off South Carolina at the present time.

Biomass (kg/hectare) estimates were similar to other estimates from the southeastern coast of the United States. Total catch was 20.86 kg/hectare for the two-seam trawl and 31.05 kg/hectare from the tongue trawl. Webster et al. 1989 and Brylan et al. 1990 both using tongue trawls throughout the same depths (9-27m), found similar estimates, 29.7 kg/hectare and 22.7 kg/hectare respectively. In texas, however, Bryan et al. 1982 reported total catches of 51..0-103.6 kg/hectare. Wenner et al. 1980 reported total catch ranging 20.25 - 73.35 kg/tow with a 3/4 Yankee trawl, in 9-27 m throughout the SAB. Their estimates being similar to our estimates of 49.19 kg/tow in the two-seam and 63.08 kg/tow in the tongue trawl off Charleston.

Mean densities of fish were 3.40 kg/hectare (or 20.40 kg/tow) for tongue trawl and 3.61 kg/hectare (or 21.66 kg/tow) Higher catches of fishes have been reported from throughout the shallow water (< 27m) of the SAB, 12.21 kg/hectare (Wenner & Sedberry 1989) and 36-362 kg/hr (Low et al. 1982). In waters off Georgia, Knowlton (1972) caught fishes at rates of 128.8 lb/hr, comparing with our rates of 44.97 - 47.75 lb of fish/hr.

Wenner and Wenner (1989) collected 220.3 kg of priority shrimp in 303 tows over the entire year, yielding density estimates of 0.324 kg/hectare. Our estimates of 0.76 or 0.94 kg from June to September are understandably higher than their yearly estimate in that our estimate was based only on sampling during the shrimping season.

Catch Comparison

It is understandable that both the tongue net and two-seam net caught similar quantities of benthic fish species, which made up most of the priority fish and other fish categories. Although the two-seam net covered 16% greater area of the bottom per tow than the tongue net, both nets covered similar areas (2.1 and 2.5 hectares respectively). The tongue net caught less priority finfish than the two-seam net in 1990. The fact that the tongue net caught more shrimp than the two-seam net during white shrimp season confirmed the shrimp fishermen's choice of tongue style nets for the white shrimp, which tend to move high in the water column. There is however, a doubling of the fish to shrimp ratio in catches by the tongue trawl. The large catches of invertebrates and the correlated "total catch" of the tongue net reflects the large volume strained and high incidence of jelly fish within the water columns during several seasons. The extra fishing height of the tongue net contributed to significantly higher catches of Spanish mackerel during all seasons and king mackerel during the 1989 brown shrimp season. Catch of these species could indicate a benthic or near bottom swimming behavior of the small mackerel during daylight periods.

This study was not designed to compare the sizes of shrimp and fish to past years data, but comparisons can be made if restricted to similar sampling techniques and times. With a few exceptions lengths of priority species collected were similar to sizes reported from similar areas, years, and seasons. Spot collected in this study ($\bar{x}$ = 10.9cm TL in two-seam, - 11.98 cm TL in tongue) were more than 3 cm smaller than the summer average of 16-17 cm for the SAB (Wenner and Sedberry 1989) or the yearly average of 15 cm (Webster et al. 1989). Also croaker were approximately 2 cm shorter than average lengths for each gear used (14.2 vs 16 by Webster et al. 1989 for tongue trawl; 15.8 vs 17 for two-seam trawl by Wenner and Sedberry 1989). Smaller differences were noted in the average length of brown shrimp (11.4 cm herein) compared to other reports (Boylan et al. 1990, 12.8 for summer, 13.1 for South Carolina) without data on the entire season for these animals, these differences may represent artifacts of sampling in time or space or simply a minor seasonal shift in occurrence during this study.

Evidence indicating actual changes in the utilization of habitats by different life history stages has previously been reported for inshore waters for spot and croaker (Stender and Martore 1990). The data herein could be consistent with either a slight seasonal or a new utilization of the area but does not represent a sufficient sampling season to resolve which is more likely. Lengths of Spanish and king mackerel, whiting, bluefish, white and pink shrimp, and blue crabs were similar to lengths from other reports (Webster et al. 1989, Wenner and Sedberry 1989, Boylan et al. 1990).

The calculation of a fish to shrimp ratio provided a useful index for summarizing and comparing the relative changes in catch of fish and shrimp. However, comparisons with similar ratios in the literature have indicated that considerable caution must be used in evaluating fish to shrimp ratios. In the past the ratio has been calculated in different ways. Keiser (1976) used a log transformation for the calculation of a mean ratio (1.98) and 95% confidence limits (0.22-17.84). Wolff (1972) presented fish and shrimp weights by individual trawl, but used the ratio of the yearly sum of fish weight to the yearly sum of shrimp weight to express his "average" fish to shrimp ratio (5.38). The use of summed weights to determine the ratio was also used by Low et al. (1990, max ratio = 2.23 off South Carolina) and Whitaker et al. (1989, overall ratios of 0.5 for inside Calibogue Sound).

Keiser (1977) used the median ratio of 2.58 for May - August and 1.20 for September - December. Pellagrin (1982) utilized a true mean of individual ratios reporting ratios ranging from 4.2 - 15.9 for Gulf of Mexico. Bryan et al. (1982) calculated the mean but used a ratio to the biomass of commercial sized shrimp (≥112 cm TL). Although calculated quite differently, all of these ratios are referred to as the mean fish:shrimp ratio. Initial comparison with our 21.01 ratio for the two-seam net (or 41.20 for tongue trawl) would suggest our data to be anomalously high; however, recalculations of the reported ratios based on the original data for each tow yield different conclusions (Table 10). In general, there is considerable variability in this ratio, particularly in comparing the current study with corrected data from much earlier works (Latham 1951; Roelfs 1951). Eldridge et al. (1974) gave data indicating high landings of shrimp during the years of the two earlier studies. Differences with the current study may reflect changes in the relative occurrence of shrimp in the catches.

Comparisons of current findings with previous South Carolina studies (Keiser 1976, Low et al. 90) indicate much higher ratios, more tows without shrimp, fewer tows with more shrimp than fish, a greater percentage of tows with ratios more than 20, and a larger maximum ratio. A major difference rests in the methodology of processing the catch in these studies. Previously, both studies subsampled the entire catch with a washtub or bushel basket versus the complete workup of the catch in the current study. Such a subsampling technique underestimates some species (i.e., crabs, Keiser, 1976, p.37). Data from Wolff (1972) indicated a reduced ratio (9.7 vs 22.43) when only large trawlers from offshore were surveyed by the subsampling method. Observations during this study, as well as Keiser (1976) and Low et al. (1990) raise doubts concerning the validity of this subsampling technique. It is also noted that both previous studies were based on vessel observers on board shrimpers. There could be differences in the rigging of gear as towing methodology that could contribute to this difference. However, through past consultation with shrimpers, net maker Tony Lettich of Beaufort Marine Supply, and communication with cooperating shrimpers, these differences are thought to be minimal. Shrimpers often tow for approximately 2-4 hours, while our trawls fished only 20 minutes. Observations with underwater video cameras indicate that many fish are herded by the mouth of the trawls and caught at the time of hauling. Frequent hauling of the nets may increase the percentage of these fishes relative to the density of shrimp on the bottom, particularly for brown shrimp, which appear to concentrate more on the bottom than white shrimp. A combination, therefore, of actual distributional differences and possible differences in methodology are thought to account for most of the variability in ratios.

Catches of Spanish and king mackerel, have been documented in the past. Anderson (1968) collected 132 Spanish mackerel from 907.5 hours of trawling throughout the SAB. Knowlton (1972) reported catches of Spanish mackerel off Georgia from April - September totaling 395 lb. (< 0.5% of total catch). Keiser (1976) collected 135 king mackerel weighing 4.0 kg and 1,065 Spanish mackerel weighing 49.2 kg (together < 1.5% of total weight) in 294 tows. More mackerel were collected in the current survey, totaling 3,996 Spanish mackerel weighing 94.98 kg and 289 king mackerel weighing 29.39 kg in 282 tows. Density of mackerels found by Boylan et al. (1990) Spanish 0.2 kg/hectare, king 0.08 kg/hectare) were similar to the overall concentrations in the present study (Spanish 0.15 kg/hectare; king 0.04 kg/hectare). Low et al. (1990) found Spanish and king mackerels together comprised 0.58 % of the total catch and 2.22 % of the fishes collected. The mackerels were more prevalent in this study, comprising 0.79 % of the total catch and 5.55 % of the fishes. It is not known how these fluctuations in numbers and biomass relate to changes in the population in the SAB. However, the magnitude of the catch of mackerels, and, particularly, its potential recent increase warrant further study.

ACKNOWLEDGEMENTS

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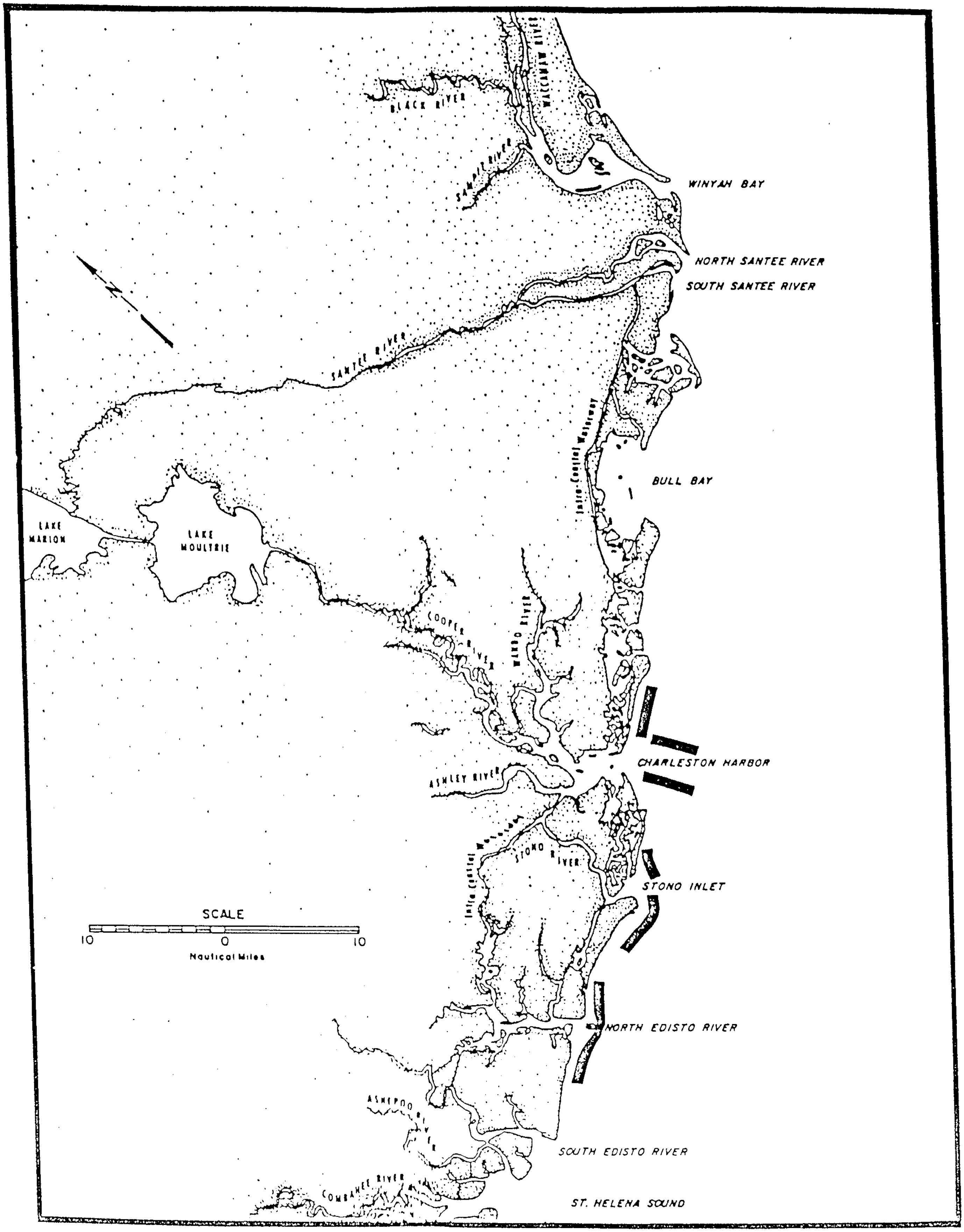
Fig. 1. Locations of trawl paths during trawl mensuration and catch comparisons.



BLACK RIVER
WACCAMAW RIVER
SAMPIT RIVER
WINYAH BAY
NORTH SANTEE RIVER
SOUTH SANTEE RIVER
N
SANTEE RIVER
Intra-Coastal Waterway
BULL BAY
LAKE MARION
LAKE MOULTRIE
WANDO RIVER
COOPER RIVER
CHARLESTON HARBOR
ASHLEY RIVER
STONO RIVER
STONO INLET
SCALE
10
0
10
Nautical Miles
NORTH EDISTO RIVER
ASHEPOO RIVER
SOUTH EDISTO RIVER
COMBAHEE RIVER
ST. HELENA SOUND

Fig. 2. Schematic representation of the tongue trawl. Numbers with 'm' represent distances in meters, plain numbers indicate number of meshes along seam, and numbers in parentheses represent slope in meshes.

Starboard Tongue

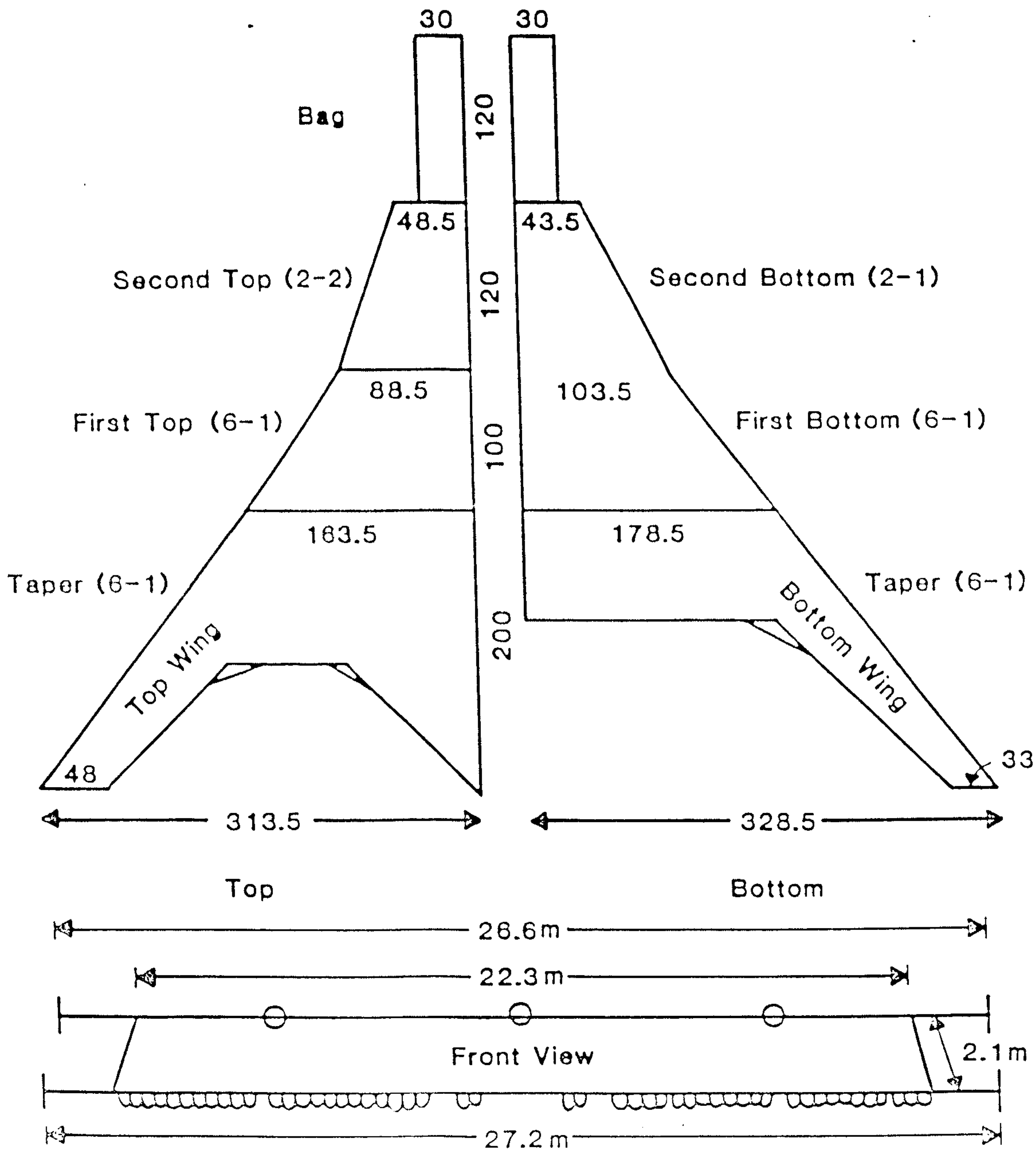


Fig. 3. Schematic representation of the two-seam trawl. Numbers with 'm' represent distances in meters, plain numbers indicate number of meshes along seam, and numbers in parentheses represent slope in meshes.

Port Flat

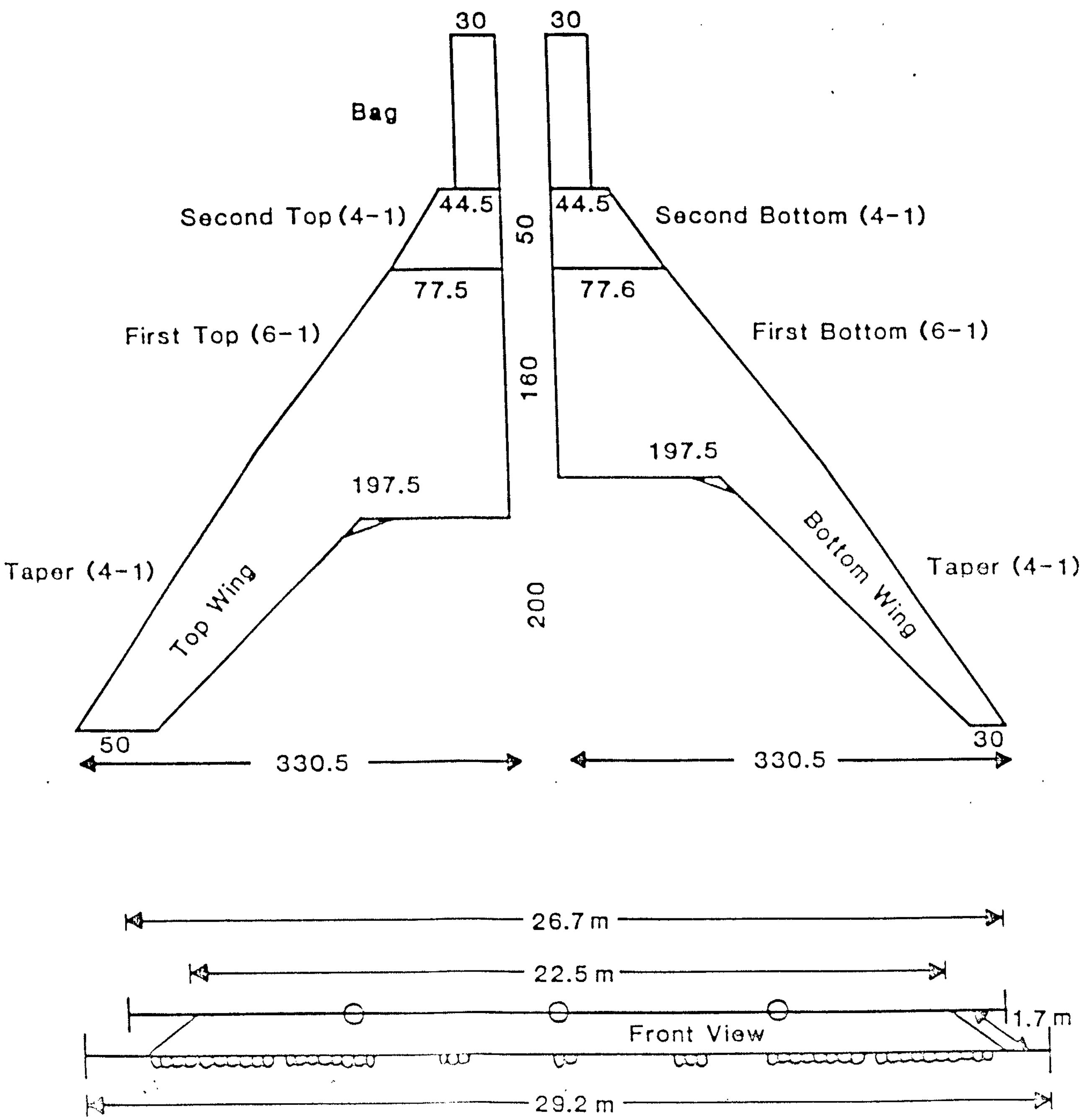

30
30
Bag
Second Top (4-1)
44.5
44.5
Second Bottom (4-1)
50
77.5
77.6
First Top (6-1)
First Bottom (6-1)
180
197.5
197.5
Taper (4-1)
Top Wing
200
Bottom Wing
Taper (4-1)
50
30
330.5
330.5
26.7 m
22.5 m
1.7 m
Front View
29.2 m

Fig. 4. Diagrammatic sketch of the tongue trawl during tow based on results of mensuration.

Starboard Tongue

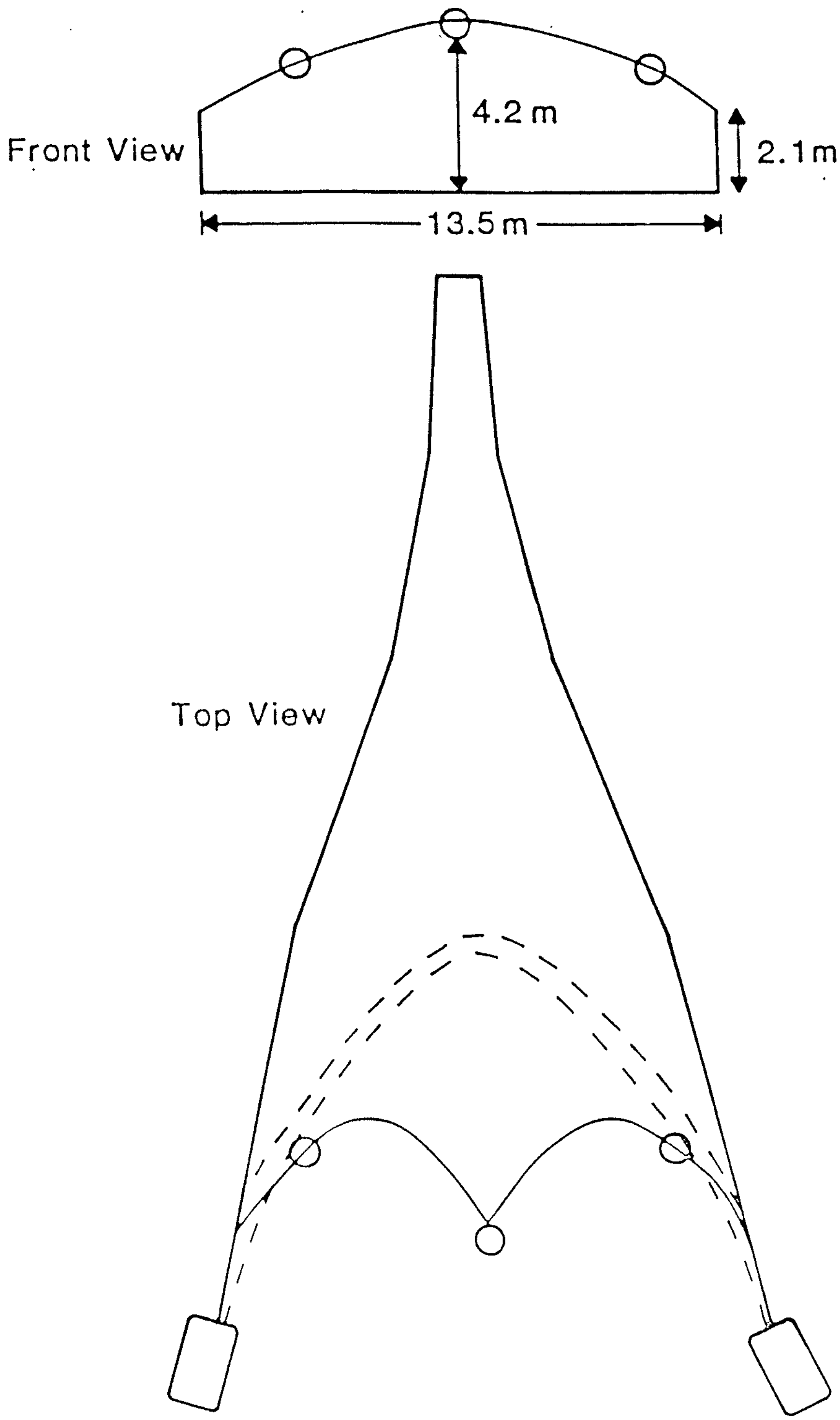


Fig. 5. Diagrammatic sketch of the two-seam trawl during tow based on results of mensuration.

Port Two-Seam

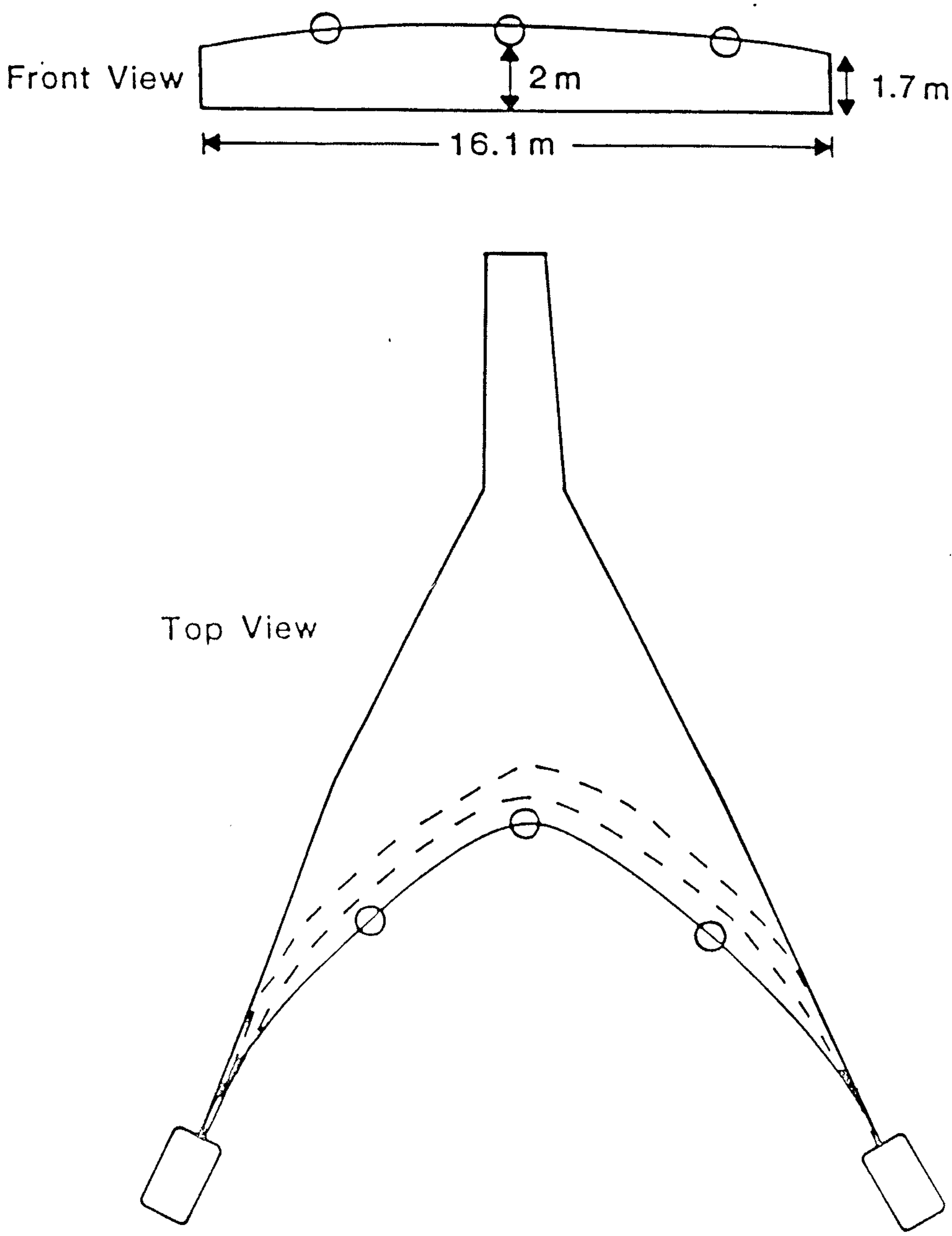


Fig. 6. Overall biomass per tow for each major taxonomic group giving mean (-), standard error (:::), standard deviation (¯), and range (|) in kg/tow.

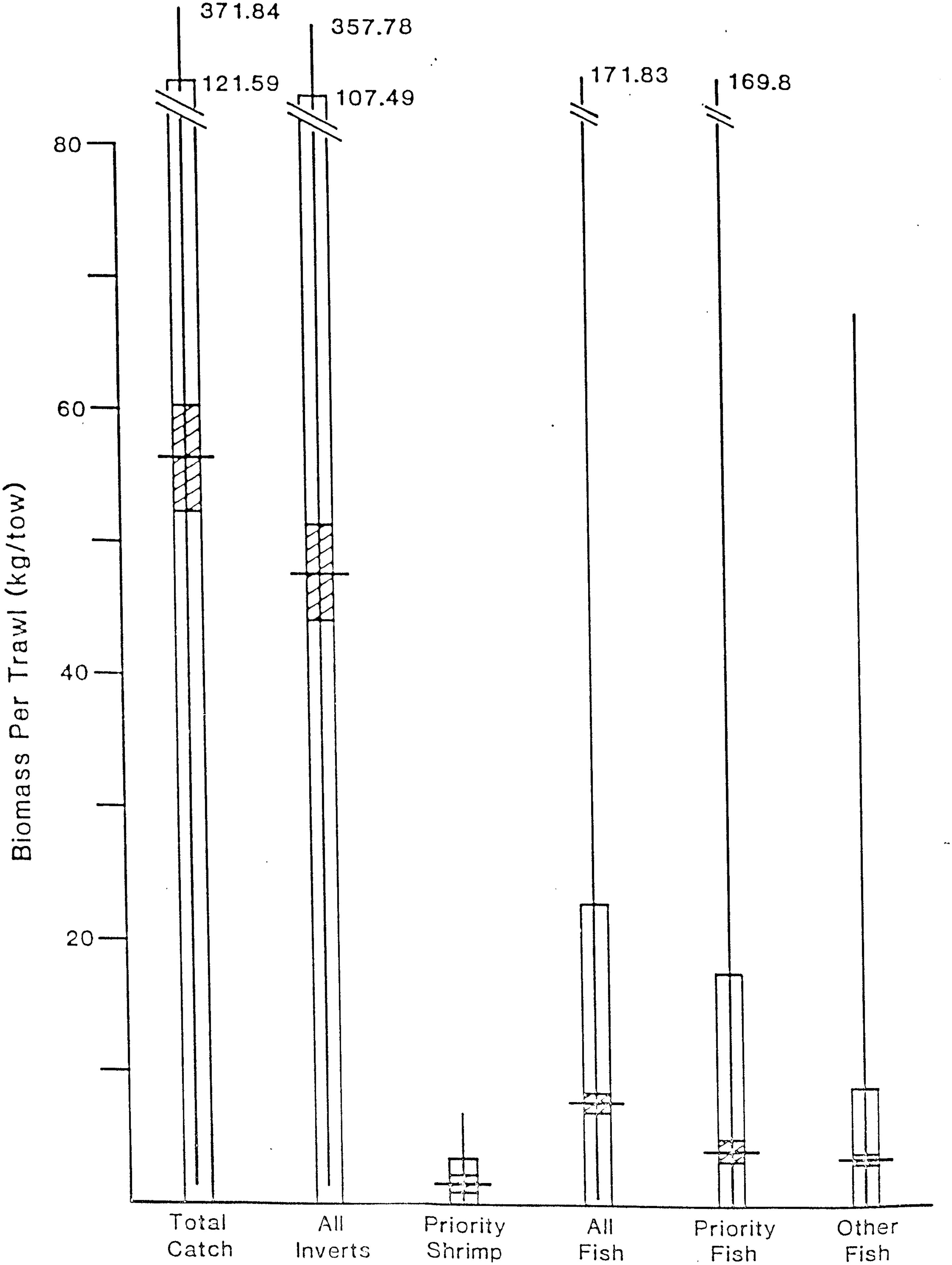
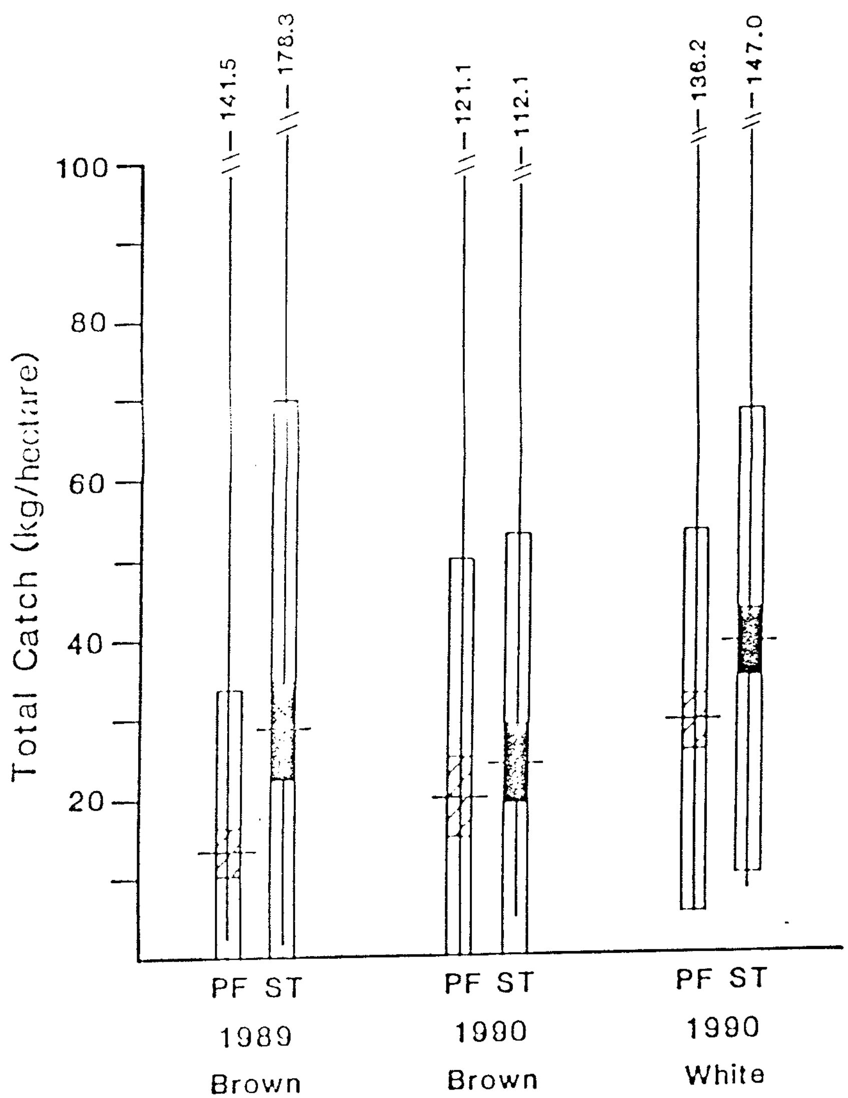

371.84
121.59
357.78
107.49
171.83
169.8
80
60
40
20
Biomass Per Trawl (kg/tow)
Total Catch
All Inverts
Priority Shrimp
All Fish
Priority Fish
Other Fish

Fig. 7. Total and invertebrate catch per hectare by gear, year, and shrimp season giving mean (-), standard error (::: for two-seam, ▩ for tongue), standard deviation (¯), and range (|) in kg/hectare.


Total Catch (kg/hectare)
100
80
60
40
20
141.5
178.3
121.1
112.1
136.2
147.0
PF ST
1989
Brown
PF ST
1990
Brown
PF ST
1990
White

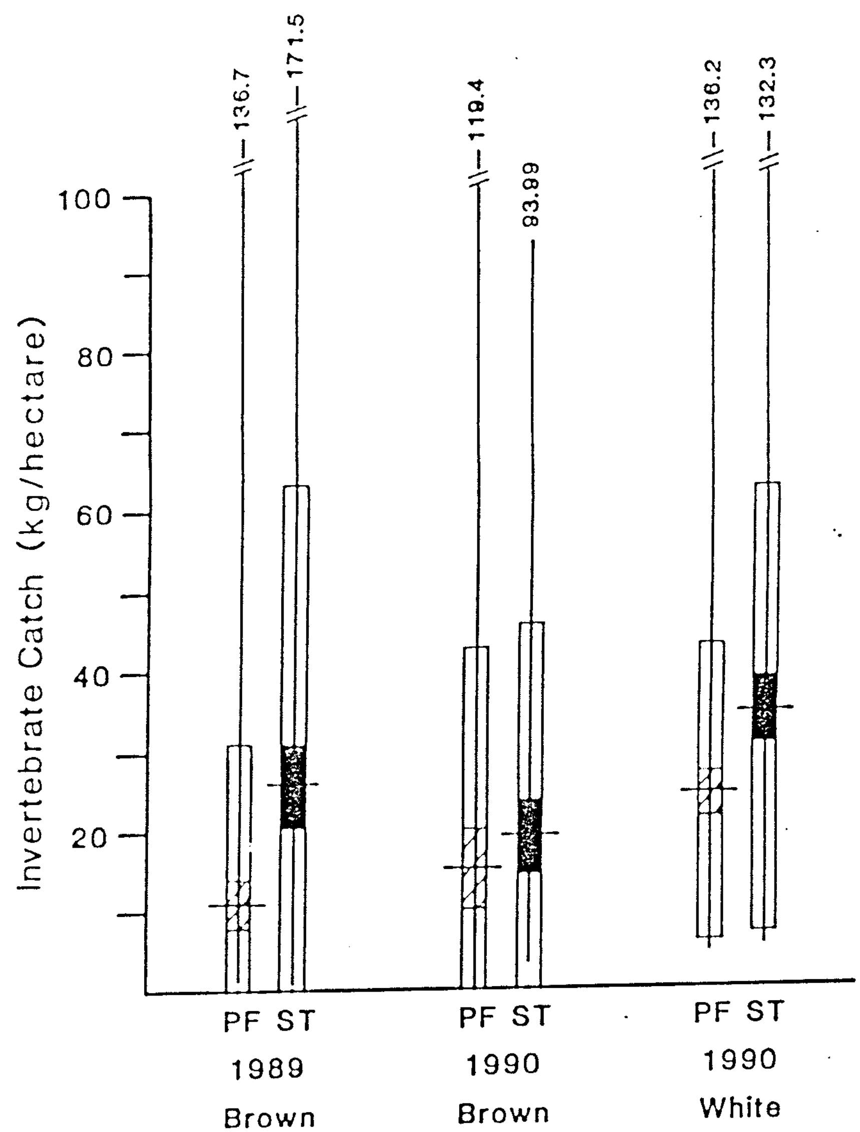
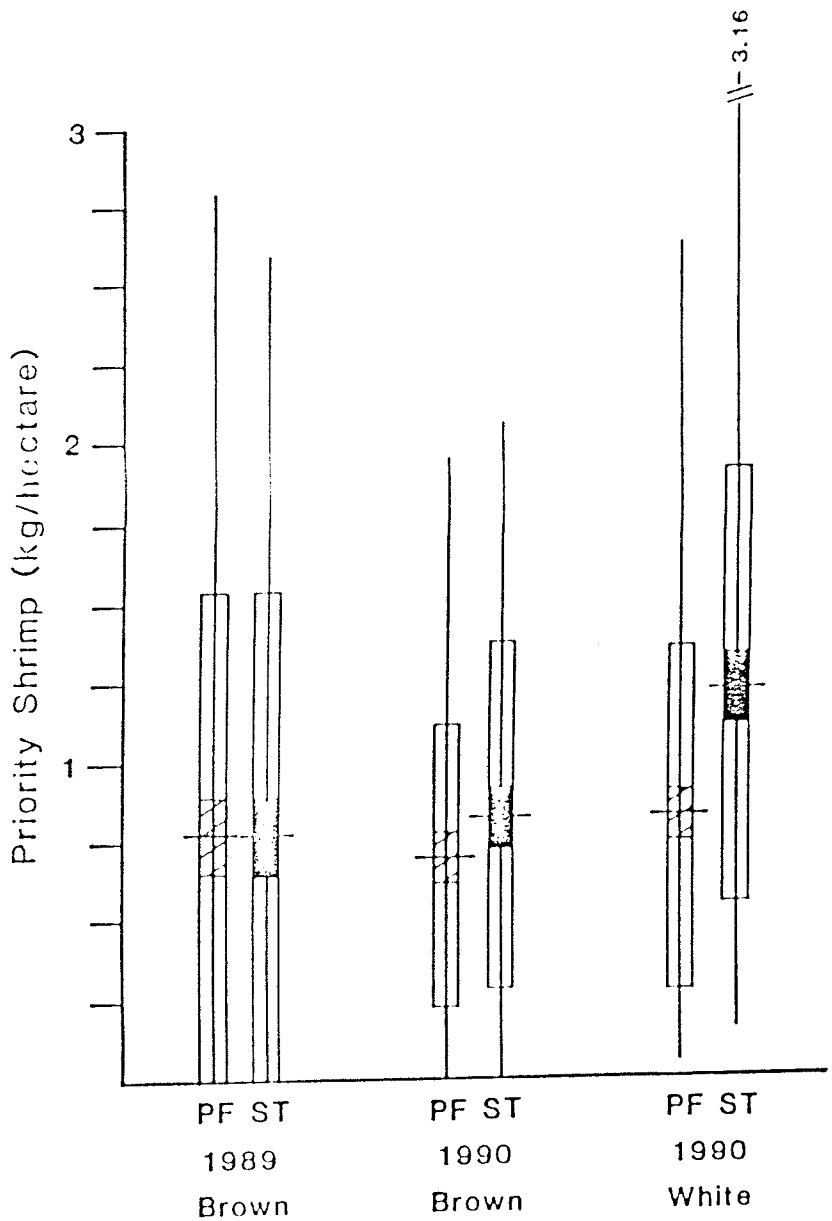
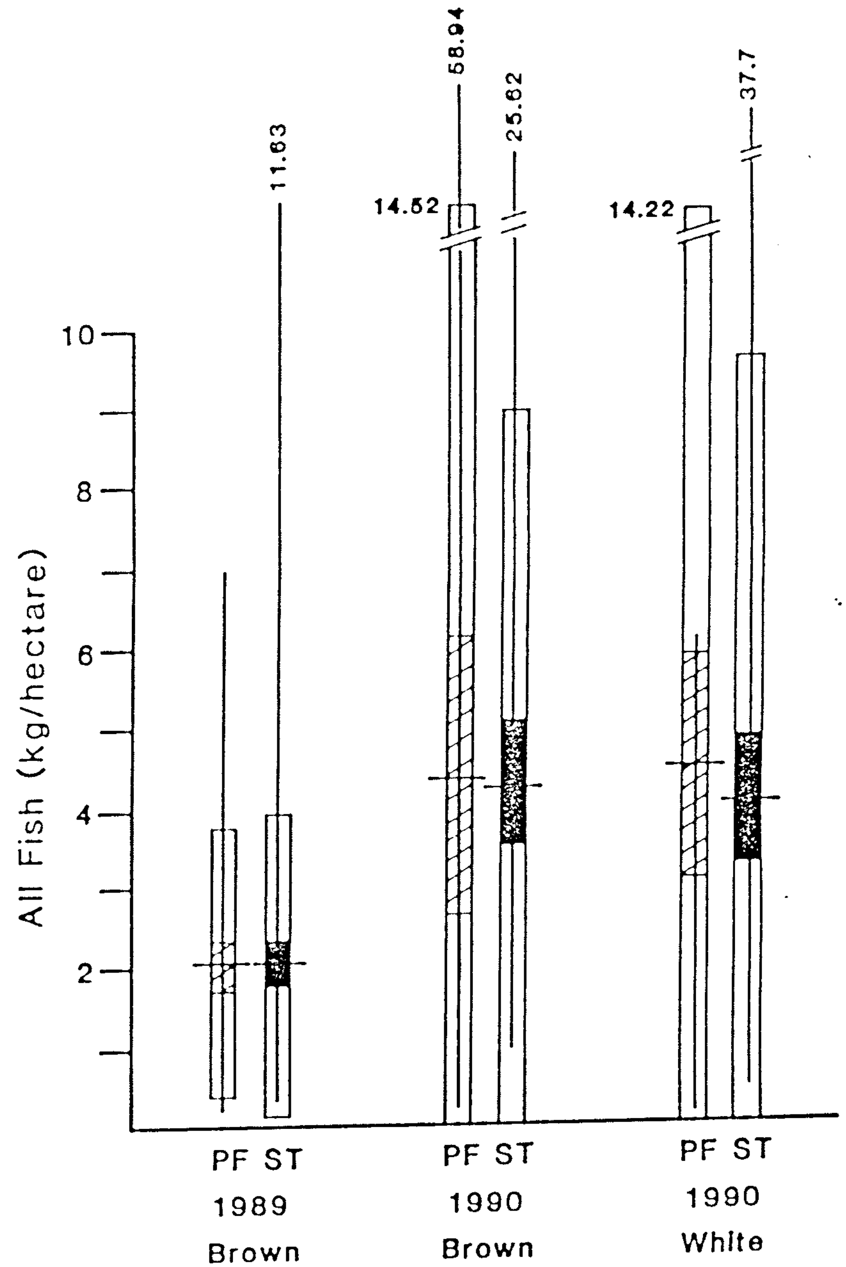

Invertebrate Catch (kg/hectare)
100
80
60
40
20
136.7
171.5
119.4
93.99
136.2
132.3
PF ST
1989
Brown
PF ST
1990
Brown
PF ST
1990
White

Fig. 8. Catch per hectare of priority shrimp and all fish by gear, year, and shrimp season giving mean (-), Standard error (::: for two-seam, ▩ for tongue), standard deviation (□), and range (|) in kg/hectare.

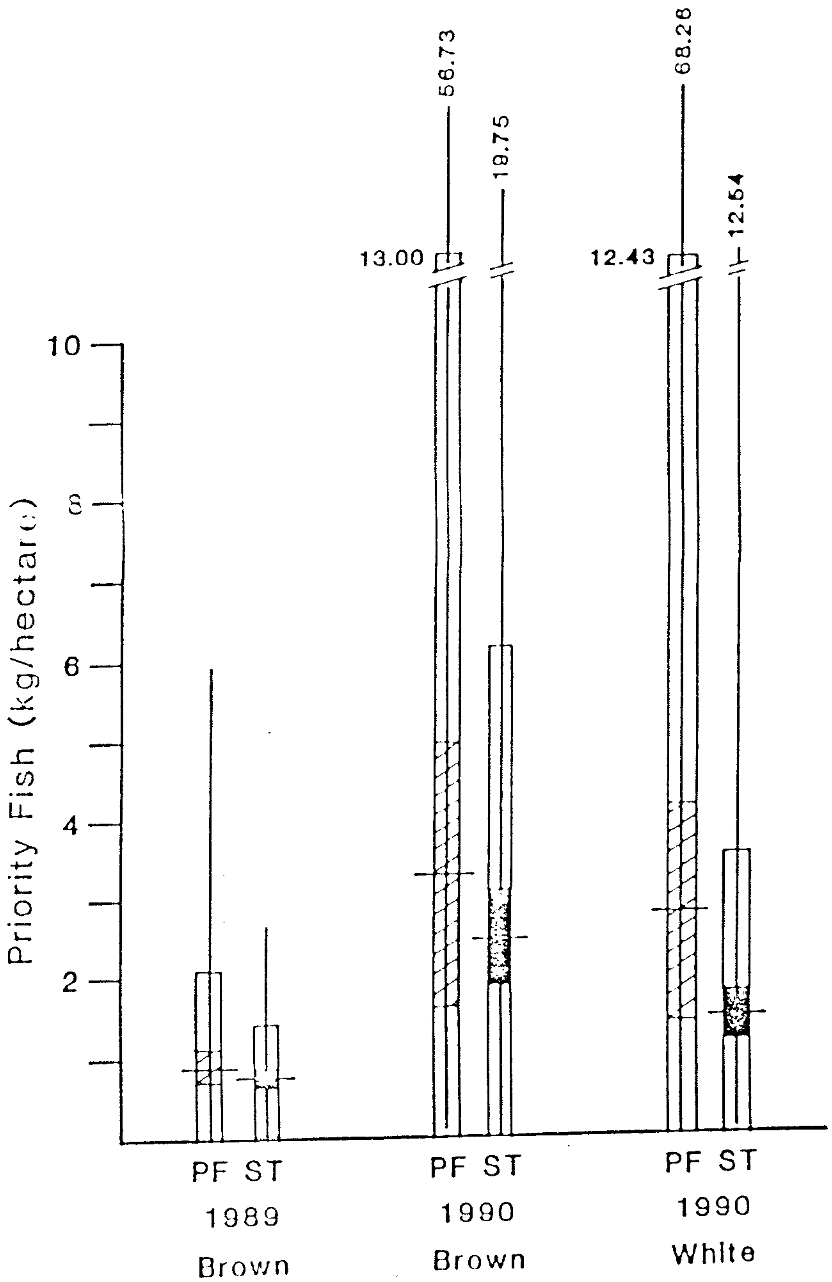


Priority Shrimp (kg/hectare)
3
2
1
3.16
PF ST
1989
Brown
PF ST
1990
Brown
PF ST
1990
White



All Fish (kg/hectare)
10
8
6
4
2
11.63
14.52
58.94
25.62
14.22
37.7
PF ST
1989
Brown
PF ST
1990
Brown
PF ST
1990
White

Fig. 9. Catch per hectare of priority fish and other fish by gear, year, and shrimp season giving mean (-), Standard error (∷ for two-seam, ▒ for tongue), standard deviation (□), and range (|) in kg/hectare.


Priority Fish (kg/hectare)
10
8
6
4
2
13.00
56.73
19.75
12.43
68.26
12.54
PF ST
1989
Brown
PF ST
1990
Brown
PF ST
1990
White

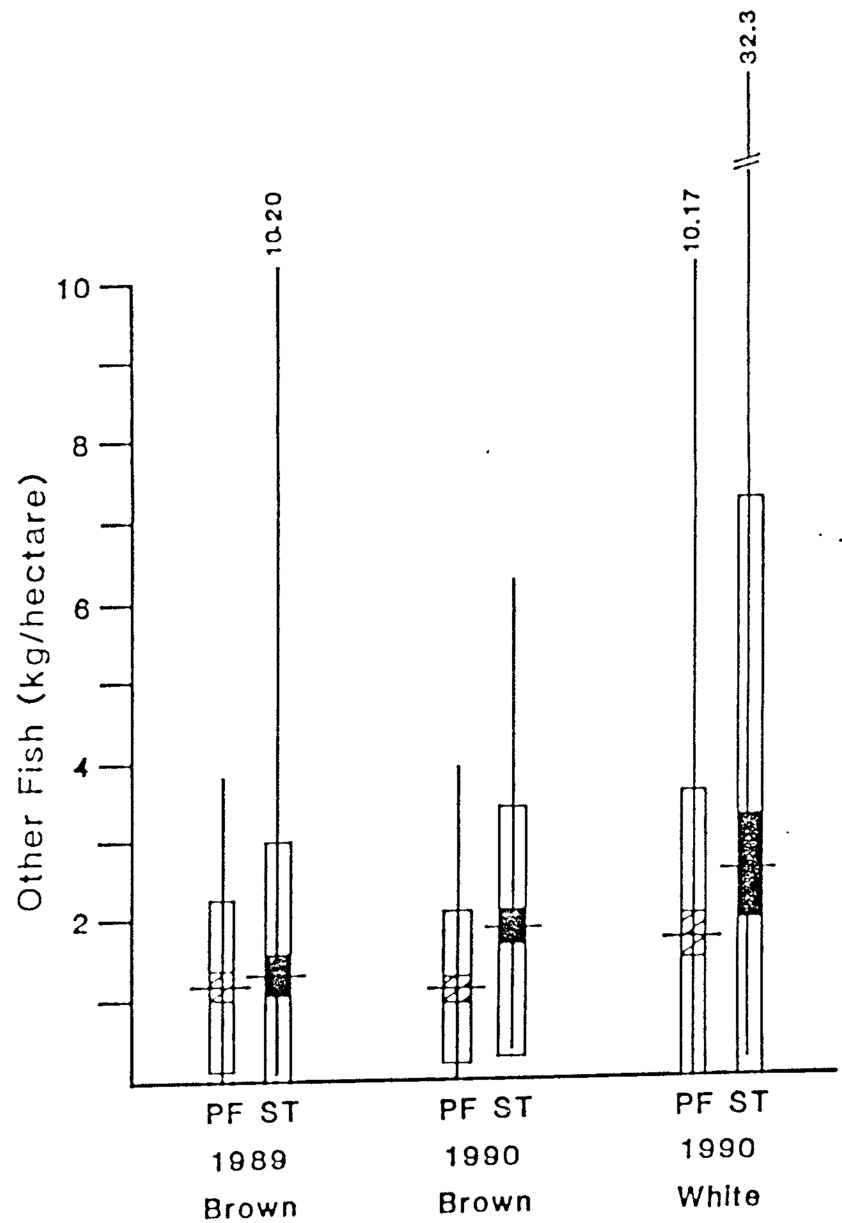
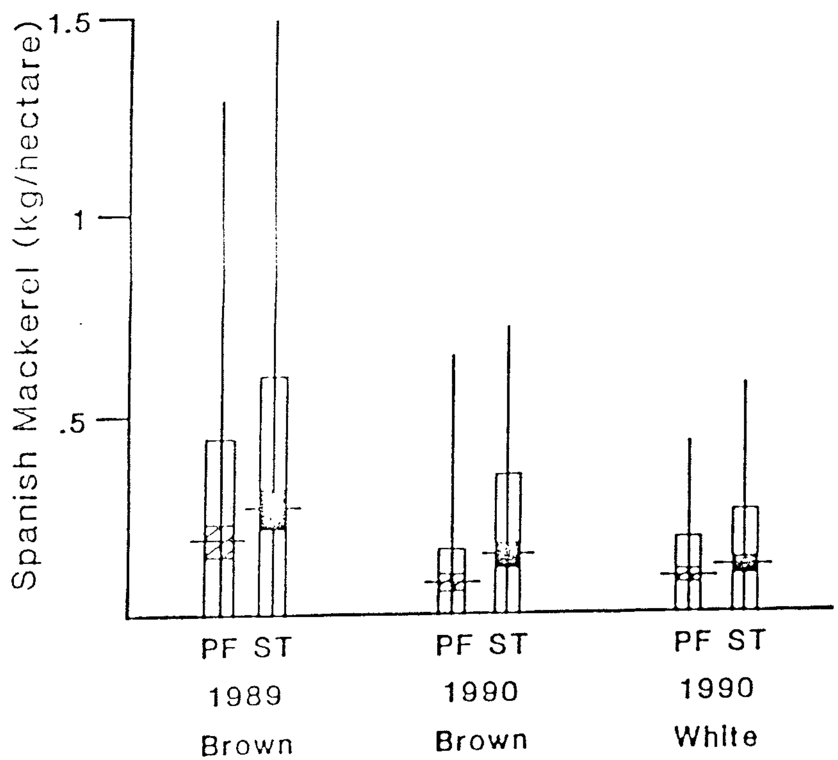

Other Fish (kg/hectare)
10
8
6
4
2
10.20
10.17
32.3
PF ST
1989
Brown
PF ST
1990
Brown
PF ST
1990
White

Fig. 10. Catch per hectare of Spanish and king mackerel by gear, year, and shrimp season giving mean (-), Standard error (::: for two-seam, ▩ for tongue), standard deviation (□), and range (|) in kg/hectare.


Spanish Mackerel (kg/hectare)
1.5
1
.5
PF ST
1989
Brown
PF ST
1990
Brown
PF ST
1990
White

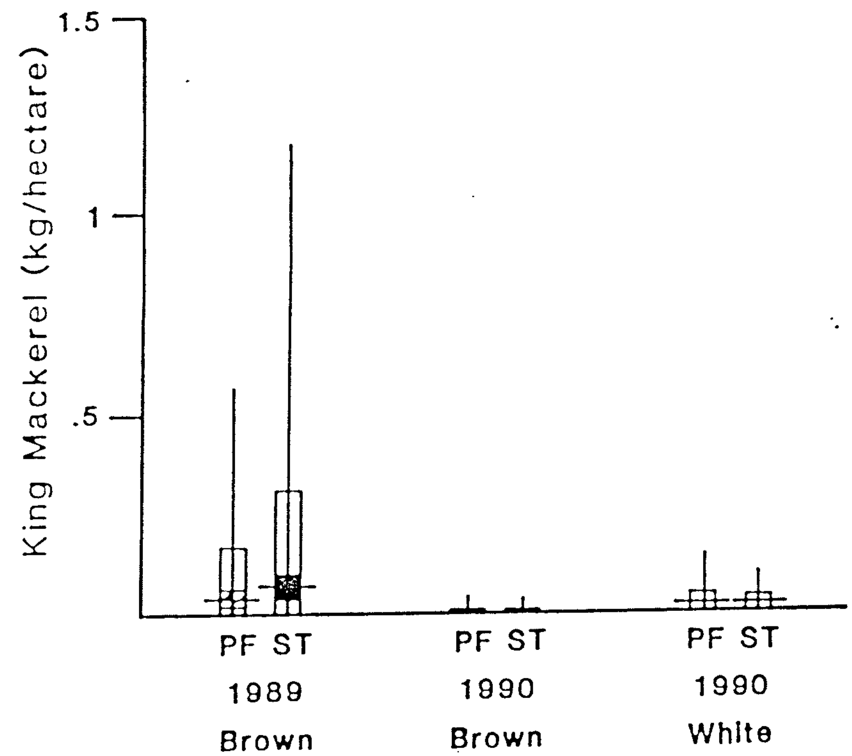

King Mackerel (kg/hectare)
1.5
1
.5
PF ST
1989
Brown
PF ST
1990
Brown
PF ST
1990
White

Fig. 11. Length frequency histogram for Atlantic croaker (Micropogonias undulatus) and spot (Leiostomus xanthurus). Shaded data is from two-seam trawl; unshaded is from tongue trawl.

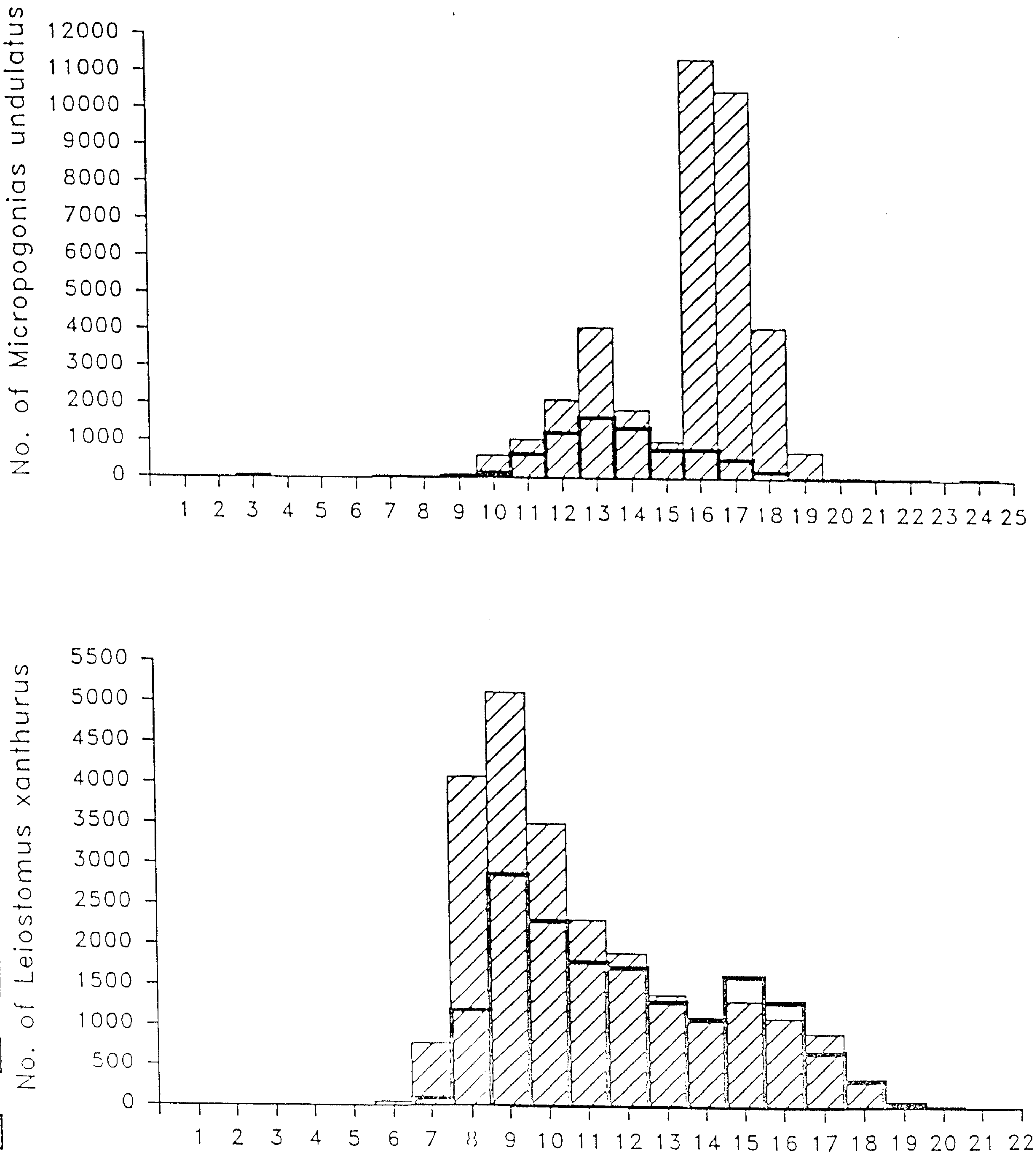
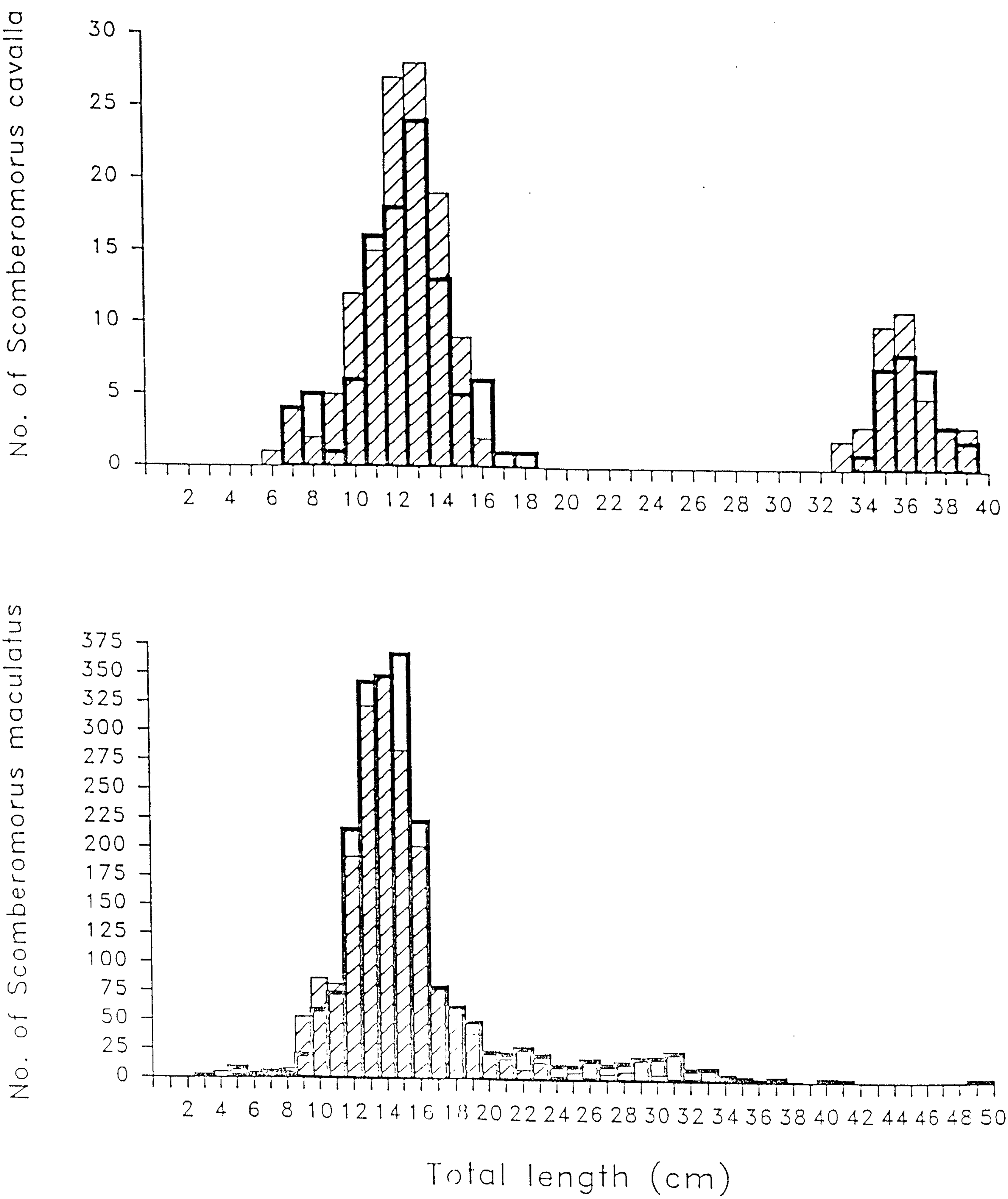
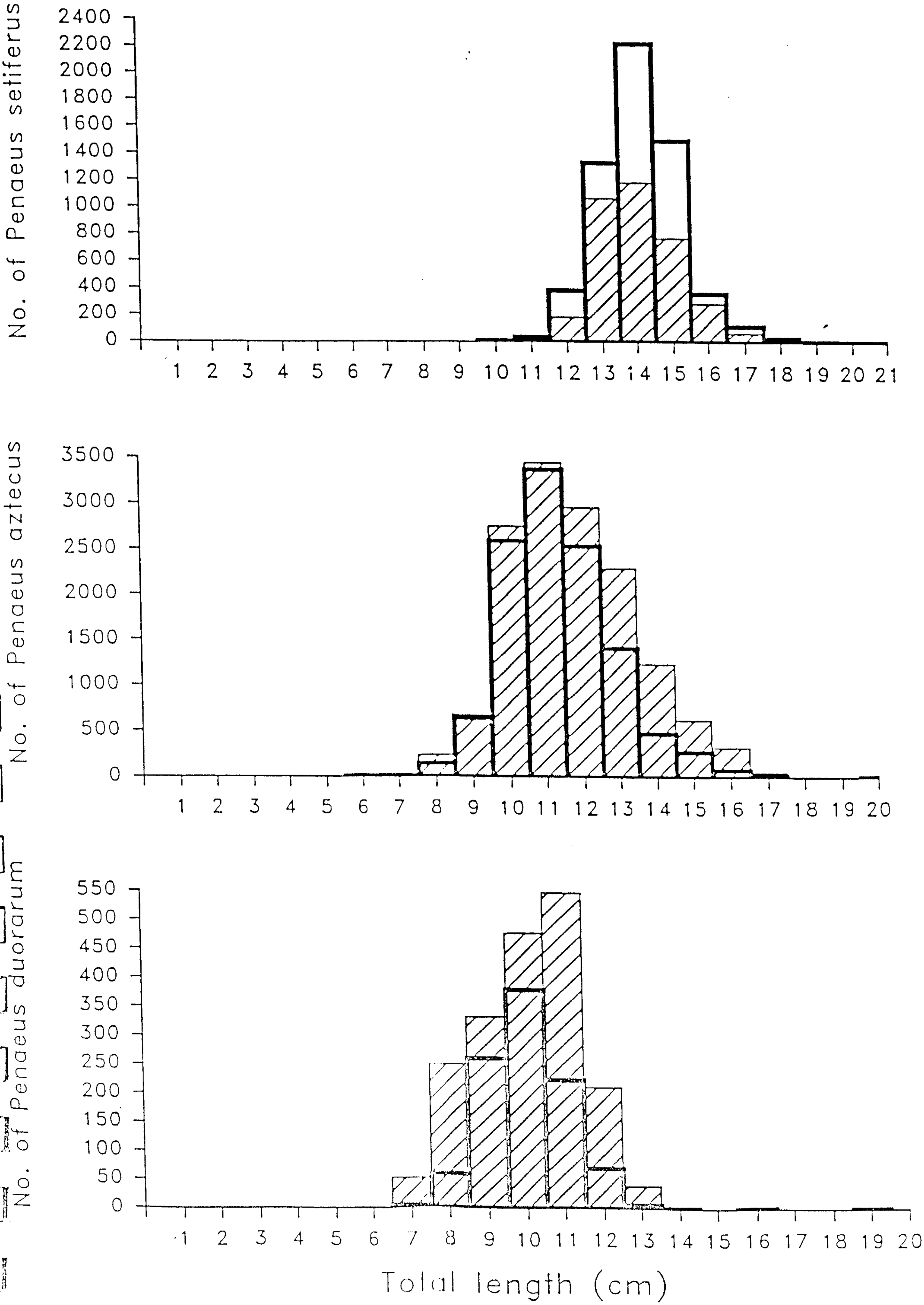

No. of Micropogonias undulatus
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
No. of Leiostomus xanthurus
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Total length (cm)

Fig. 12. Length frequency histogram for Spanish (Scomberomorus maculatus) and king (Scomberomorus cavalla) mackerel. Shaded data is from two-seam trawl; unshaded is from tongue trawl.



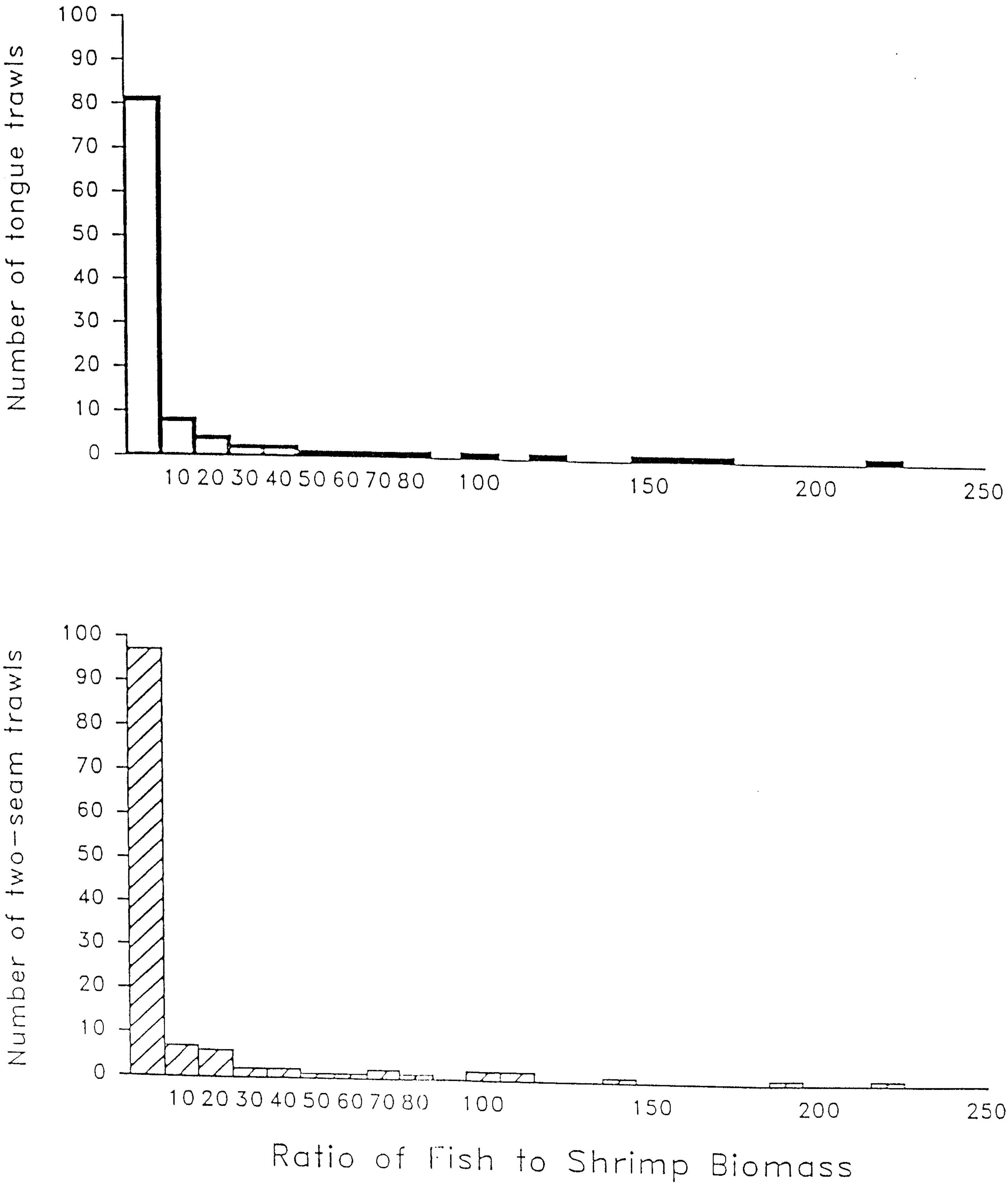
No. of Scomberomorus cavalla
30
25
20
15
10
5
0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
No. of Scomberomorus maculatus
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
Total length (cm)

Fig. 13. Length frequency histogram for white (<u>Penaeus setiferus</u>), brown (<u>Penaeus aztecus</u>), and pink (<u>Penaeus duorarum</u>) shrimp. Shaded data is from two-seam trawl; unshaded is from tongue trawl.



No. of Penaeus setiferus
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
No. of Penaeus aztecus
3500
3000
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
No. of Penaeus duorarum
550
500
450
400
350
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Total length (cm)

Fig. 14. Frequency histogram of ratios of fish to shrimp biomass (kg/hectare) for tongue and two-seam trawl.



Number of tongue trawls
100
90
80
70
60
50
40
30
20
10
0
10 20 30 40 50 60 70 80
100
150
200
250
Number of two-seam trawls
100
90
80
70
60
50
40
30
20
10
0
10 20 30 40 50 60 70 80
100
150
200
250
Ratio of Fish to Shrimp Biomass

Fig. 15. Frequency histogram of only ratios less than 20 of fish to shrimp biomass (kg/hectare) for all trawls and two-seam net (shaded).

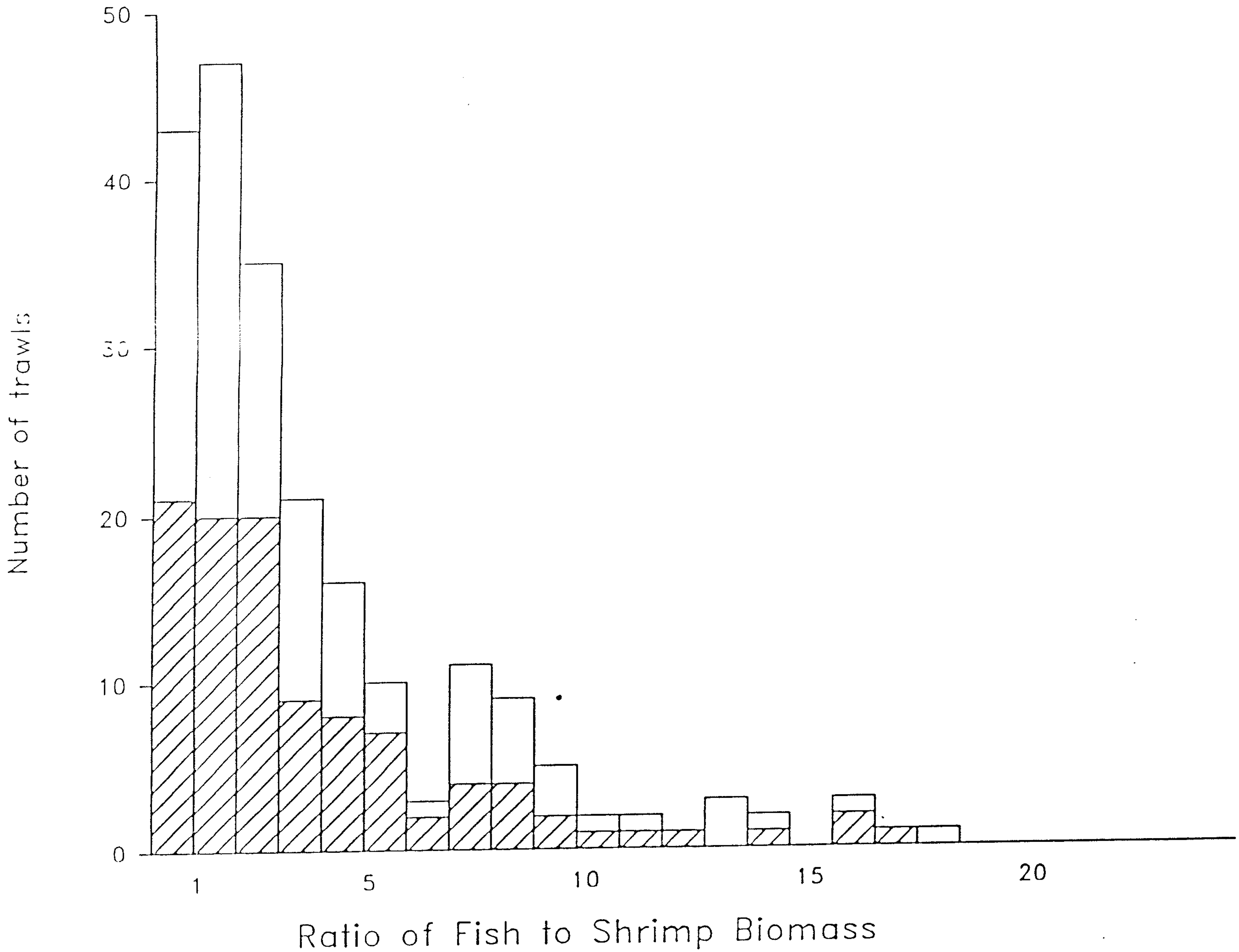

Number of trawls
50
40
30
20
10
0
1
5
10
15
20
Ratio of Fish to Shrimp Biomass

Table 1. Sampling effort for catch comparisons.

Cruise	Day/Month	Year	Season	Week	Total Tows
8901	26-30 June	1989	Brown	1	58
8902	10-13 July	1989	Brown	2	50
9001	25-29 June	1990	Brown	3	62
9002	14-16 August	1990	Brown	4	16
9003	27-30 August	1990	White	5	44
9004	10-14 September	1990	White	6	52
					282

Table 2. Priority species for net comparison

Penaeus setiferus	White shrimp
Penaeus aztecus	Brown shrimp
Penaeus duorarum	Pink Shrimp
Callinectes sapidus	Blue crab
Scomberomorus cavalla	King mackerel
Scomberomorus maculatus	Spanish mackerel
Cynoscion nebulosus	Spotted seatrout
Cynoscion regalis	Weakfish
Leiostomus xanthurus	Spot
Menticirrhus americanus	Southern kingfish
Micropogonias undulatus	Atlantic croaker
Sciaenops ocellatus	Red drum
Pomotomus salatrix	Bluefish
Paralichthys dentatus	Summer flounder
Paralichthys lethosigma	Southern flounder
Epinephelinae	Groupers
Lutjanidae	Snappers

Table 3. Mean distances and catch (± standard deviation) from mensuration of two trawls (number of measurements in parentheses).
* indicates reading questionable because of gear limitations.

Depth	Net:	Port Two-seam		Starboard Tongue	
All	Height (m)	* see text		4.2 ± .5 (104 of 106)	
	Width (m)	16.1 ± .6 (156)		13.5 ± .6 (99 of 106)	
	Catch (kg)	30.2 ± 34.7 (16)		40.3 ± 59.5 (16)	
	Shore:	Inshore side	Offshore side	Inshore side	Offshore side
Shallow	Height (m)	* 2.7 ± .2 (7)	* 2.8 ± .1 (2)	4.2 ± .9 (44)	--------
	Width (m)	16.4 ± .7 (47)	15.9 ± .8 (37)	13.2 ± .7 (40)	--------
	Catch (kg)	88.7 ± 63.1 (1)	70.0 ± 34.6 (4)	105.0 ± 71.9 (4)	136.6 (1)
Deep	Height (m)	* --------	* 2.5 ± 2.5 (4)	4.3 ± .2 (32)	4.3 ± .1 (28)
	Width (m)	16.2 ± 3 (32)	15.9 ± .3 (40)	13.7 ± .5 (31)	13.8 ± .3 (28)
	Catch (kg)	11.0 ± 6.5 (5)	9.9 ± 7.2 (6)	7.5 ± 4.8 (6)	8.6 ± 4.5 (5)

Table 4. Results of statistical tests on trawl mensuration by net, depth, and relative shoreside position. Significant difference is indicated by (*) for P‹0.05, (**) for P‹0.01, and (***) for P‹0.001. Blanks indicates no valid test. [1] indicates result of a paired t-test.

Data Set	Tested Group	Height		Width		Catch	
		Kruskal-Wallis	ANOVA	Kruskal-Wallis	ANOVA	Kruskal-Wallis	t-test
All							
	Gear	***	***	***	***	ND	ND[1]
	Depth Zone					***	***
	Shore Side					ND	ND
Two-seam							
	Depth Zone			ND	ND	**	*
	Shore Side			***	***	ND	ND
Tongue							
(only inshore)	Depth Zone	**		***	***	**	*
(only Shallow)	Shore Side	ND	ND	ND	ND	ND	ND

Table 5. Catch summary with total biomass for each group collected and mean catch expressed as biomass by tow (kg/tow), by area swept (kg/hectare), and by volume (kg/10,000m³)

Group	Total Catch (kg)	Net	By Tow (kg/tow)		By Area (kg/hectare)		By Volume (kg/10,000m³)	
			x̄	S.D.	x̄	S.D.	x̄	S.D.
Total	15,830.25	PF	49.19	±60.36	20.86	±25.18	11.27	±13.61
		ST	63.08	±69.70	31.04	±34.13	9.85	±10.84
Inverterbrates	13,431.84	PF	40.21	±53.49	17.21	±22.25	9.30	±12.03
		ST	55.05	±64.97	27.13	±31.80	8.61	±10.10
Priority Shrimp	503.65	PF	1.72	±1.55	0.76	±0.61	0.41	±0.33
		ST	1.85	±1.53	0.94	±0.71	0.30	±0.23
All Fish	2,242.71	PF	8.88	±19.19	3.61	±8.05	1.95	±4.35
		ST	7.03	±8.99	3.40	±4.42	1.08	±1.40
Priority Fish	1,180.52	PF	5.36	±18.62	2.24	±7.85	1.21	±4.24
		ST	3.02	±4.90	1.47	±2.39	0.47	±0.76
Other Fish	1,162.19	PF	3.52	±3.74	1.36	±1.41	0.73	±0.76
		ST	4.01	±6.38	1.93	±3.13	0.61	±0.99
Spanish Mackerel	94.98	PF	0.30	±0.46	0.12	±0.18	0.07	±0.10
		ST	0.37	±0.50	0.18	±0.25	0.06	±0.48
King Mackerel	29.39	PF	0.12	±0.60	0.02	0.08	0.01	±0.04
		ST	0.09	±0.39	0.03	0.14	0.01	±0.05

Table 6. Catch (biomass and number) and length data by net of priority species.

Species	Net	Weight: Total (kg)	Weight: Mean	Weight: Standard Error	Number: Total	Number: Mean	Length: Min.	Length: Max.	Length: Mean	Length: Standard Error
Penaeus setiferus	PF	80.54	0.57	0.07	3650	25.88	7	20	14.09	.02
	ST	130.93	0.93	0.11	6012	42.64	10	21	14.09	.01
Penaeus aztecus	PF	143.71	1.02	0.12	14554	103.22	6	19	11.91	.02
	ST	120.40	0.85	0.10	11535	81.81	6	20	11.37	.01
Penaeus duorarum	PF	18.98	0.13	0.05	1912	13.56	6	13	10.05	.03
	ST	9.09	0.06	0.01	1005	7.13	7	19	10.01	.04
Callinectes sapidus	PF	52.00	0.37	0.10	919	6.52	6	18	12.78	.06
	ST	43.56	0.31	0.06	520	3.69	7	19	13.35	.09
Scomberomorus cavalla	PF	16.74	0.12	0.05	161	1.14	6	39	17.58	.81
	ST	12.65	0.09	0.03	128	.91	7	39	17.55	.90
Scomberomorus maculatus	PF	43.03	0.31	0.04	1871	13.27	3	38	14.41	.08
	ST	51.95	0.37	0.04	2125	15.07	3	50	15.61	.11
Cynoscion nebulosus	PF	0	0		0	0				
	ST	0	0		0	0				
Cynoscion regalis	PF	37.99	0.27	0.07	1449	10.28	3	36	14.40	.09
	ST	22.63	0.16	0.03	1052	7.46	6	27	14.76	.08
Leiostomus xanthurus	PF	194.38	1.38	0.37	24044	170.52	6	22	10.93	.02
	ST	91.26	0.65	0.13	16455	116.70	7	20	11.98	.02

		Weight			Number		Length			
Species	Net	Total (kg)	Mean	Standard Error	Total	Mean	Min.	Max.	Mean	Standard Error
Menticirrhus americanus	PF	20.86	0.15	0.04	4513	32.01	3	37	15.51	.06
	ST	23.63	0.17	0.03	2501	17.74	3	31	15.18	.08
Micropogonius undulatus	PF	403.05	2.86	1.38	37872	268.60	3	25	15.76	.01
	ST	182.73	1.30	0.39	7621	54.05	7	25	14.16	.03
Sciaenops ocellatus	PF	0	0	0	0	0				
	ST	0	0	0	0	0				
Pomotomus saltatrix	PF	22.00	0.16	0.02	367	2.60	9	28	18.39	.18
	ST	28.31	0.20	0.03	366	2.60	10	27	18.85	.17
Paralichthys dentatus	PF	8.58	0.06	0.01	145	1.03	9	34	17.67	.31
	ST	7.07	0.05	0.01	98	.70	9	32	18.13	.44
Paralichthys lethostigma	PF	8.54	0.06	0.01	40	.28	12	39	25.68	.82
	ST	4.83	0.03	0.01	29	.21	13	33	24.00	.89
All Epinephelinae	PF	0	0	0	0	0				
	ST	0	0	0	0	0				
All Lutjanidae	PF	0	0	0	0	0				
	ST	0	0	0	0	0				

Table 7. Length comparisons between nets among priority species. Significant difference is indicated by (*) for P < 0.05, (**) for P < 0.01, (***) for P < 0.001, and (ND) for no difference.

	Lengths in PF		Lengths in ST		Results from ANOVA
	x̄	S.D.	x̄	S.D.	
Penaeus aztecus	11.91	±1.87	11.37	±1.47	***
Penaeus duorarum	10.05	±1.37	10.01	±1.11	ND
Penaeus setiferus	14.09	±1.26	14.09	±1.16	ND
Callinectes sapidus	12.78	±1.98	13.35	±2.06	***
Scomberomorus cavalla	17.58	±10.24	17.55	±10.20	ND
Scomberomorus maculatus	14.41	±3.44	15.61	±4.96	(Wilcoxon) ***
Cynoscion regalis	14.40	±3.41	14.76	±2.88	**
Leiostomus xanthurus	10.93	±2.84	11.98	±2.84	***
Menticirrhus americanus	15.51	±4.41	15.18	±3.88	**
Micropongonias undulatus	15.76	±2.20	14.16	±2.41	***
Pomatomus saltatrix	18.39	±3.44	18.85	±3.25	ND
Paralichthys dentatus	17.67	±3.79	18.13	±4.35	ND
Paralichthys lethostigma	25.68	±5.27	24.00	±4.81	ND

Table 8. Ratios of biomass per area (kg/hectare) of each group to shrimp biomass by year, season, and gear.

		89 Brown		90 Brown		90 White	
Group	Parameter	PF	ST	PF	ST	PF	ST
	# of tows	45	47	34	36	48	50
Total	mean	291.65	1,899.04	38.28	55.61	47.87	49.38
	std. err.	83.46	941.34	10.85	18.31	6.22	10.72
	median	15.27	37.34	13.17	20.88	31.67	25.40
	25th perc.	6.36	7.31	7.61	10.94	19.67	15.22
	75th perc.	361.15	774.67	54.75	48.68	56.92	55.97
Inverter-brates	mean	238.36	1,688.86	26.34	40.70	41.28	44.80
	std. err.	76.23	909.59	6.91	14.81	5.64	10.25
	median	9.15	36.58	9.27	15.45	26.56	19.15
	25th perc.	5.12	5.92	4.50	7.03	15.19	12.67
	75th perc.	201.98	672.67	34.68	27.92	51.85	50.82
All Fish	mean	43.47	100.54	11.94	14.55	6.67	4.62
	std. err.	11.76	46.14	5.19	6.62	1.72	0.87
	median	2.75	5.80	3.12	4.58	3.09	2.23
	25th perc.	1.00	0.95	1.69	2.93	2.01	1.35
	75th perc.	46.87	55.14	6.85	7.83	5.92	4.00
Priority Fish	mean	8.94	21.28	8.54	8.29	3.96	1.52
	std. err.	2.38	7.64	4.13	4.19	1.64	0.27
	median	1.45	1.24	1.73	2.42	1.43	0.78
	25th perc.	0.27	0.39	0.72	0.62	0.48	0.37
	75th perc.	10.73	13.00	3.43	4.96	2.81	1.63
Other Fish	mean	34.53	79.26	3.40	6.26	2.71	3.11
	std. err.	9.88	40.02	1.39	2.57	0.58	0.76
	median	1.46	1.75	1.29	1.90	1.85	1.13
	25th perc.	0.43	0.44	0.70	1.14	1.10	0.73
	75th perc.	35.29	28.86	2.51	3.24	2.76	2.76
Spanish Mackerel	mean	1.67	6.75	0.26	0.30	0.15	0.16
	std. err.	0.84	3.64	0.10	0.09	0.03	0.04
	median	0.12	0.24	0.03	0.08	0.08	0.06
	25th perc.	0.01	0.03	0.0	0.0	0.0	0.0
	75th perc.	0.49	0.98	0.18	0.36	0.21	0.20
King Mackerel	mean	1.88	5.14	0.003	0.003	0.03	0.02
	std. err.	1.05	2.99	0.001	0.001	0.005	0.005
	median	0.0	0.0	0.0	0.0	0.01	0.008
	25th perc.	0.0	0.0	0.0	0.0	0.0	0.0
	75th perc.	0.0	0.0	0.0	0.0	0.03	0.03

Table 9. Results of Kruskal-Wallis tests for significant differences among classes for each of the eight major groups. Significant difference is indicated by (*) for $P < 0.05$, (**) for $P < 0.01$, (***) for $P < 0.001$, and (ND) for no difference.

Variable	Class	Total Catch	Inverte-brates	Priority Shrimp	All Fish	Priority Fish	Other Fish	Spanish Mackerel	King Mackerel
kg/tow	Gear	*	*	ND	ND	ND	ND	ND	ND
	Year	***	**	***	***	***	**	***	**
	Week	***	***	***	***	***	***	***	***
	Season	***	***	***	**	ND	***	ND	***
kg/hectare	Gear	***	***	*	ND	ND	ND	ND	ND
	Year	***	***	***	***	***	**	***	***
	Week	***	***	***	***	***	***	***	***
	Season	***	***	***	**	ND	**	ND	***
Ratio of kg/hectare to kg/hectare of Shrimp	Gear	ND	ND		ND	ND	ND	ND	*
	Year	*	*		*	*	**	***	ND
	Week	***	***		***	***	***	***	***
	Season	ND	ND		**	***	***	***	**

Table 10. Summary of reported fish to shrimp ratios.

Source	Area	% tows w/o shrimp	% of ratios < 1	Std. dev.	Mean ratio	% of ratios > 20	Minimum ratio	Maximum ratio
Roelofs 1951	NC	0	35.3	1.87	1.99	0	0.38	6.67
Latham 1951	NC	0	0	4.36	6.11	0	2.00	15.00
Wolff 1972	NC	11.1	12.5	45.26	22.43	25.0	0.60	185.90
Holland et al. 1989	NC	0	0	12.31	15.25	27.4	1.78	49.00
Pierce et al. 1989	NC	0	0	4.52	17.46	5.6	11.91	31.44
Keiser 1976	SC	1.4	25.5			3.7	0.30	136.10
Low et al. 1990								
two-seam	SC	0	29.2	1.13	2.06	4.2	0.54	4.33
tongue	SC	0	50.0	12.44	5.03	10.0	0.57	40.41
Current Study								
two-seam	SC	9.2	14.9	52.23	21.01	17.0	0.26	332.72
tongue	SC	6.4	15.6	192.99	41.20	15.6	0.49	2,021.08
Keiser 1977	GA		20.0		5.6	0.11		49,500.0