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PROCEEDINGS OF THE WORKING GROUP ON SHRIMP FISHERIES OF THE NORTHEASTERN SOUTH AMERICA
PANAMA CITY, PANAMA, 23-27 APRIL 1979
REPORT OF THE MEETING
CONTRIBUTIONS

UNITED NATIONS DEVELOPMENT PROGRAMME
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in the Western Central Atlantic

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Contributions

by

A.C. Jones and L. Villegas
Editors

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DEVELOPMENT OF FISHERIES IN THE WESTERN CENTRAL ATLANTIC

The Interregional Project for the Development of Fisheries in the Western Central Atlantic (WECAF), which was initiated in March 1975, entered its second phase on 1 January 1977. Its objectives are to assist in ensuring the full rational utilization of the fishery resources in the Western Central Atlantic through the development of fisheries on under-exploited stocks and the promotion of appropriate management actions for stocks that are heavily exploited. Its activities are coordinated by the Western Central Atlantic Fishery Commission (WECAFC) established by FAO in 1973. The Project is supported by the United Nations Development Programme (UNDP) and the Food and Agriculture Organization of the United Nations as the Executing Agency.

As in the initial phase, two series of documents will be prepared during the second phase of the Project to provide information on activities and/or studies carried out. This document is the twenty eighth of the series WECAF Reports. The other series of documents is entitled WECAF Studies.

W.F. Doucet
Programme Leader

FOREWORD

The Proceedings of the Working Group on Shrimp Fisheries of Northeastern South America has been published under WECAF Reports 27 and 28. WECAF Report 27 includes the report of the Working Group as well as the national reports and Report 28 contains the contributed papers for the meeting.

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SUMMARY

A Working Group to assess the state of exploitation of the shrimp fisheries off Guianas-Brazil, determine suitable management measures and define research needs and priorities was convened in 1979 by the WECAF Project.

The Working Group reviewed the current status of the shrimp resource and fisheries, as requested. Some signs, but not conclusive indications, of overfishing of the stocks were noted. A general conclusion is that the shrimp stocks of this area appear to be about fully utilized but that good management can preserve the present biological and economic viability of the fishery. The Group suggested a number of management goals and regulatory options for consideration by the countries concerned. Achievement of the task of principal concern to the Group, that of providing scientific advice for fishery management, is dependent on improving the available scientific data base. In this regard, the Group made specific recommendations. Implementation of these recommendations will be necessary if further scientific predictions on the status of the stock are required.

Contribution 4.1

United States Shrimp Surveys off the Guianas and Northern Brazil (1972-1976)

by

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1. Summary

The area covered by FRV OREGON II investigations off Guianas and northeastern Brazil (1972-76) and the methods used in collection of shrimp data and associated ecologic data are described.

Detailed charts of the qualitative and quantitative distribution of the commercially important species of penaeids are given for each cruise.

The associated ecologic information consisting of temperature, salinity, bottom type, and depth ranges for each commercial shrimp species are presented and discussed as related to the distribution and occurrence of commercial species of shrimp.

Size composition, sex ratios, and length-weight relationships of commercial species of shrimp are presented and discussed.

The total biomass in shrimp trawls is presented as a mean catch rate per hour according to each 5 fathom interval starting with 5 fathoms and ending with about 45 fathoms. The percentage of commercial shrimp in trawls is also given.

The grain size and the organic matter of the surface sediments of the investigation area are described. The relationship between certain physical and chemical bottom characteristics of the surveyed area and the occurrence of shrimp are discussed.

2. Introduction

We report on the results of five cruises conducted by the Southeast Fisheries Center, Miami, Florida, in connexion with the U.S.A.-Brazil Bilateral Shrimp Agreement, which was signed on 9 May 1972 (Allen, 1973; Jones and Dragovich, 1973). The vessel used was the NOAA OREGON II, a 157 ft ship specially designed for marine biological research (Fig. 4.1.1). The areas surveyed were off the continental shelf off Guyana, Suriname, French Guiana, and Brazil, including the Agreement Area off northern Brazil (Fig. 4.1.2). The dates for the cruises discussed in this paper were 12 June to 7 July 1972 (cruise # 38); 15 January to 28 February 1974 (cruise # 49); 7 January to 18 February 1975 (cruise # 56); 22 April to 3 June 1975 (cruise # 58); and 14 May to 14 June 1976 (cruise # 66, leg 3). The time for each survey did not exceed 20 days; the remaining time was used for travel.

The primary objectives of our surveys were (1) to observe the species and size distribution of shrimp available to the commercial fishery, (2) to carry out reconnaissance studies on the total biomass of associated fauna (primarily fish) found in the trawls with shrimp, and (3) to make concurrent observations on water temperature, salinity, and bottom type. In this paper, we discuss the listed objectives, except for the associated fauna, which will be treated in separate reports. Collette and Rützler (1977) have already described the reef-fish fauna (45 species) over sponge bottoms off the Amazon River, based on data from cruise # 58.

Three species of penaeid shrimp - brown shrimp, Penaeus subtilis, pink spotted or hopper shrimp, P. brasiliensis, and pink shrimp, P. notialis - make up the major part of the commercial catch on the Guianas shrimp grounds and are generally found at depths from 15 to 45 fath or (27.4-82.3 m) (Jones and Dragovich, 1977). White shrimp, P. schmitti, occurs in shallower water (usually at depths from 2 to 20 fath or 3.7 to 36.6 m) than the other three species and makes up a minor part of the catches.

Other shrimp of minor commercial importance are the sea bob, Xiphopenaeus kroyeri, scarlet prawn, Plesiopenaeus edwardsianus, and royal red shrimp, Pleoticus robustus. Sea bob is abundant in shallow water (2-20 fath or 3.7 to 36.6 m) and is fished by local fishermen. Commercial aggregations of scarlet prawn and royal red shrimp occur on the continental slope but are little fished.

The existence of commercially exploitable stocks of shrimp off the Guianas was suspected in 1944 (Whiteleather and Brown, 1945), but large-scale harvesting did not start until years later. The results of surveys by a French modified trawler ORSTOM II off French Guiana during 1954-58 (Durand, 1960), by the FRV OREGON I during 1957 and 1958 in the area between Trinidad and the Amazon River (Bullis and Thompson, 1959), and the research vessel CORVETTE during 1957 in the area off Suriname provided additional information on the shrimp resources of the area (Higman, 1959). The history of the Guianas shrimp fishery was described by Naidu and Boerema (1972) and Jones and Dragovich (1977).

3. Description of the Investigation Area

The coastline of Guyana, Suriname, and French Guiana stretches for about 1 600 km (994 statute mi) between the Orinoco (9°N, 61°W) and Amazon (1°N, 50°W) Rivers. The coastline is transversed by several large rivers - Essequibo, Demerara, Berbice, Corentyne, Coppename, Suriname, Maroni, and Oyapock, which empty into the adjacent Atlantic Ocean. The continental shelf off the Guianas is a rather smooth seafloor which gently slopes toward its break at approximately 55 to 65 fath (100.6 to 118.9 m). A broad belt of sea bottom 12.4 to 24.8 mi (20-40 km) wide extending out to a depth of 10.9 to 13.7 fath (20-25 m) consists of unconsolidated mud (Allersma, 1971). Farther from the coast the coarser type bottom consists chiefly of sand with some mud.

The sediments of the continental shelf between the mouths of the Orinoco and Amazon Rivers form an extensive chenier plain and are deposited as a strip on the northern border of the crystalline basement of the hilly pre-paleozoic Guiana Shield (Nota, 1967). Zanderij-formations (late-tertiary coarse sands and sandy pelites, probably of terrigenous origin), the Coropina formation (late-Pleistocene fine sands and silty pelites of marine origin) and the Demerara formation (Holocene fine sands and pelites of marine and fluvial origin) are the principal differentiations of the chenier plain between the deltas at the Amazon and Orinoco Rivers.

The climate of the Guyana, Suriname, French Guiana and Amazon Region is humid tropical with air temperatures usually between 26° and 28° C. Winds generally blow from between northeast and southeast and are slightly stronger along the eastern part of the coast. In the spring, the winds are chiefly from the northeast and east, and the wind speed averages 6 to 8 m/sec. From July to November the winds are of lesser speed (3 to 4 m/sec) and are usually from an easterly direction. Severe storms are unknown.

Waves and swells follow the wind pattern with heights of about 2 m from December to June and 1 to 1.5 m from July to November. The waves and swells are from the northeast and east.

The Guiana Current, an extension of the South Equatorial Current, (Gibbs, 1970) flows along the coast from east to west with a volume off Cayenne, French Guiana, of roughly 10^7 m^3/sec and a width of about 200 km (Allersma, 1971). The Guiana Current separates from the coast near Cayenne to follow the continental break off Guyana. The maximum velocity of this current (about 1 m/sec off French Guiana and 0.6 m/sec off Guyana) is attained in about April; the velocity is less (0.7 and 0.3 m/sec, respectively) during the second half of the year. Only a weak influence of the Guiana Current is felt over the continental shelf westward from the Maroni River, in contrast to the area farther to the east where the main current hugs the coast. Surface currents over the continental shelf off Suriname show a distinct seaward component while a coastward movement is observed in the lower strata (Eisma, 1967). This implies a certain degree of upwelling at roughly 50 km from the coast. Local currents are greatly influenced by the local wind in the shallow near-shore strip (about 25 km wide).

The tide is semi-diurnal and almost synchronous along the whole of the Guiana Coast. The tidal range is 2 m at the mouth of the Amazon River, decreases 1.5 m at Georgetown and about 0.5 m near Trinidad.

Salinity is less than 35 percent in the near-shore zone, due to river discharge, and also in the main stream of the Guiana Current because it carries water from the Amazon River. Between the near-shore zone and the main stream of the Guiana Current, especially over the middle of the continental shelf off Suriname and Guyana, surface salinities are generally between 35 percent and 36 percent.

The Amazon River supplies the largest amounts of fresh water and of suspended materials to the Current. The river's discharge of 100 000 to 300 000 m^3/sec carries sediments at a rate estimated between 0.25 and 0.9 x 10^7 million tons a year (Allersma, 1971). Other rivers along the coasts of the Guianas are small in comparison to the Amazon. The Essequibo River discharges reach up to about 5 000 m^3/sec. The Orinoco River, in Venezuela, with a flow of 30 000 m^3/sec is downstream of, and has little or no influence upon, the Guiana coast.

The sediment loads of the local rivers are too small to account for the enormous flow of sediment along the coast (Allersma, 1971). Present opinion identifies the Amazon River as the principal source of the sediments. This opinion is strengthened by the homogeinity of the sediments along the entire coast, the absence of similar sediments east of the mouth of the Amazon River, and the quantity being well within the supply of the Amazon River. The average annual deposition of sediment along the Guiana coast by the Amazon equals 80 million t (Allersma, 1971). Further evidence on the origin of marine muds along the Guyana coast is presented by Eisma and Marel (1971) who examined, by X-ray fraction, the mineralogical composition of clay samples from the Amazon Basin and the Guyana coast, including samples collected inland and on the continental shelf. They also determined humus content, specific surface, potassium fixation and noted that muds from the Guyana coast have practically the same composition as those of the Amazon but are very different from the Guyanese soils and river muds.

4. Fishing Gear and Trawling Time

The principal fishing gear in all surveys was 40 ft (12.2 m) four-seam flat trawl fabricated of 2 in (5.1 cm) stretched mesh # 18 twine nylon netting with 1 3/4 in (2.5 - 0.8 cm) mesh cod end. The net was rigged either in the Texas drop chain style (5/16 in [0.8 cm] chain) or in the loop chain style (1/4 in [0.6 cm] chain). In most cases, tickler chains were used. All trawls were towed on a single warp bridle with 8 ft by 40 in (2.4 by 12.2 m) otter doors. The ratio of warp length to water depth was generally from 3:1 to 5:1, depending on the water depth and the towing speed, which was usually 3 knots over the bottom. This gear was used in pairs during most cruises.

A single 70 ft (21.3 m) semi-balloon trawl net with loop chain, mud roller, and standard 10 ft by 40 in (2.4 by 12.2 m) otter doors was used when fishing for scarlet prawns, P. edwardsianus, at 350-450 fath (640 - 823 m) on cruises 49 and 56. Due to limitations in the amount of cable on board, this net could only be fished at a wire ratio of 3:1.

On the basis of the duration of the trawling time, we had two kinds of tows - 1/2 h tow and tows exceeding 1 h to 5 h . To primarily provide qualitative information, 1/2 h to 1 h tows were used most frequently throughout the investigation area. In areas with rough bottom trawling time was less than 30 min. To obtain more representative commercial samples, tows of over 1 h were used as, for example, in the deep-water explorations (over 100 fath or 182.9 m) or during the simulated-type fishing operation. A total of 426 drags were made in the waters of the continental shelf at depths of less than 100 fath (182.9 m) and 31 drags were made in the deep waters exceeding 100 fath (182.9 m).

5. Handling the Catch Aboard the Vessel and Processing the Samples

As soon as the net was brought aboard the vessel, the entire catch was weighed and recorded in pounds. To help sort the organisms, the catch was loaded on a conveyor belt in small portions and samples of invertebrates and fish were removed for taxonomic identifications and morphometric measurements. Commercial species of shrimp were removed from the catch, identified, sexed, counted, and weighed. Twenty-five specimens of each sex of each commercial species of shrimp were saved as a sample if there was an ample quantity in the catch. If the catch had less than 25 specimens of each sex of each species, all specimens were saved. The samples were placed in polyethylene bags, labeled, and frozen. Before work began in the laboratory, the samples were thawed. Total length and carapace length were measured, using Allen's measuring device (Allen, 1963); all measurements were recorded to the nearest millimeter. The total length measurement used in our study is the distance from the tip of the rostrum to the posterior end of the telson, and that of the carapace is the distance from the orbital margin to the midposterodorsal margin of the carapace.

Tail and total weights of 100 specimens (if available) were made of each sex and each species from selected samples. The weights were recorded to the nearest tenth of a gram.

Qualitative records were kept of fishes and invertebrates other than shrimp found in the trawls, but are not reported in this paper.

6. The Distribution of Commercial Species of Shrimp

We examined the qualitative and quantitative aspects of the geographic distribution of shrimp. There were two chief parts to our surveys. In one part the areas were surveyed primarily for geographic distribution of species and in the other part simulated commercial fishing was carried out. Usually fewer shrimp were caught in surveys concerned with the distribution of species than during the simulated production-type fishing. Areawise, we trawled over the continental shelf and continental slope. For the sake of simplicity, fishing the continental shelf for *Penaeus*, and the slope for *P. edwardsianus*, scarlet prawn, will be referred to in this paper as shallow-water and deep-water surveys, respectively.

(a) Geographic Distribution

The occurrence of the principal species of shrimp is presented for each cruise separately (Figs. 4.1.3-4.1.7). Brown, pink-spotted, and white shrimp were found along the entire area from Guyana to the Amazon River. The distribution of pink shrimp extended from the western borders of Guyana to mid French Guiana.

During cruise 38, brown and pink-spotted shrimp were noted from off Georgetown, Guyana to Cabo Orange, French Guiana; pink shrimp were restricted to the area off Guyana and western Suriname; white shrimp were present only off Suriname (Fig. 4.1.3). During cruise 49, brown and pink-spotted shrimp were taken along the entire coast from Georgetown, Guyana to Cayenne, French Guiana; pink shrimp was found only from Georgetown, Guyana to off the mouth of the Maroni River, French Guiana; white shrimp were caught only off Guyana (Fig. 4.1.4). During cruise 56, brown and pink-spotted shrimp were noted at most locations off French Guiana and pink shrimp was present at only a few locations also off the coast of French Guiana (Fig. 4.1.5). The distribution of brown shrimp and pink spotted shrimp during cruise 58 extended from Cayenne to roughly 1° S (Fig. 4.1.6). A single specimen of white shrimp, mature female, was caught off Cape Orange in 18 fath (32.9 m) of water. During cruise 66, brown shrimp were found from Eastern Guyana to Cayenne; pink shrimp were found from the eastern border of Guyana to mid French Guiana, and white shrimp were found off Guyana and French Guiana (Fig. 4.1.7).

In her comprehensive studies of the genus Penaeus in the western Atlantic, Pérez Farfante (1967, 1969) assembled numerous records on geographic occurrences of P. subtilis (formerly P. aztecus subtilis), P. brasiliensis, P. notialis (formerly P. duorarum notialis) and P. schmitti. Our observations on the geographic distribution of the four species agree with those of Pérez Farfante and provide further information on their distribution within the boundaries of the investigation area. In addition to Perez Farfante's studies, reports by Bullis and Thompson (1959), Higman (1959), Durand (1960), and Bashirullah and Lares (1973) deserve special attention.

Bullis and Thompson (1959) made two trawling surveys of the continental shelf between Trinidad and just north of the Amazon, one in the fall of 1957 and the other in late summer of 1958. The fall cruise covered the area between Trinidad and the Amazon and consisted of 71 drags in 10-100 fath (18.3-182.9 m) depths, and 42 drags in 100-400 fath (182.9-731.8 m) depths; the late summer cruise extended from Trinidad to the coastal waters of Cayenne, French Guiana, and produced 163 drags at depths of less than 50 fath (91.4 m). Among commercially important shrimp, Bullis and Thompson listed occurrences of P. brasiliensis (from Venezuela to the Amazon at 16 to 50 fath or 29.3 to 91.4 m); P. subtilis (along the scattered points off the northeastern South American coast at depths 10 to 50 fath or 16.3 to 91.4 m); P. schmitti (at depths 15 to 26 fath or 27.4 to 47.5 m); and three deep-water shrimp: Solenocera vioscai (95 to 160 fath or 173.7-292.6 m), P. robustus (185 to 350 fath or 338.3-640 m), and P. edwardsianus (185 to 400 fath or 338.3-732 m). The results of Higman's (1959) trawling explorations off Suriname (April-October 1957) include P. brasiliensis, P. subtilis, P. schmitti, and Xiphopenaeus kroyeri. Durand (1960) noted the presence of X. kroyeri (10 to 44 m) and P. brasiliensis (35 to <85 m) and of P. subtilis (22 to 73 m) off French Guiana. Bashirullah and Lares (1973) conducted a shrimp trawling survey during April (20 sampling locations) and November (19 sampling locations) over the continental shelf of eastern Venezuela to the western part of French Guiana. The most abundant and widespread Penaeus in their survey was P. brasiliensis. This species occurred off the mouth of the Essequibo River and off Suriname at depths 30 to 90 m with greatest abundance from 30 to 90 m. The distribution of P. notialis was similar to that of P. brasiliensis (30 to 50 m depth). The white shrimp, P. schmitti, was present only off Guyana at two locations (16 and 20 m depth), and the sea bob, X. kroyeri, was prevalent in the nearshore shallow waters of Guyana and Suriname.

Our observations on geographic distribution of P. subtilis, P. brasiliensis, P. notialis, P. schmitti, and X. kroyeri are in agreement with the findings of Bashirullah and Lares (1973). Except for P. notialis, which was not reported by Bullis and Thompson (1959), Higman (1959), and Durand (1960), our observations are also in agreement with their findings.

(b) Quantitative Aspects of Shrimp Distribution

First, we will discuss the penaeids caught at depth ranges not exceeding 45-50 fath (82.3 - 91.4 m), and secondly the scarlet prawn *P. edwardsianus* fished at depths exceeding 100 fath (182.9 m).

Brown shrimp was the dominant species in all shallow-water surveys (Table 4.1.1); pink-spotted shrimp was second (except for cruise 66), followed by pink shrimp and then white shrimp, which was the least abundant species. White shrimp usually occur in shallow water 2-15 fath (1.8-27.4 m). The information obtained on this species was limited since we trawled mostly in water exceeding these depths. Information on brown, pink, and pink-spotted shrimps is of greater dependability since these species occur principally at the depths which were most frequently sampled.

To portray the quantitative distribution of shrimp caught during each survey, we plotted indices of abundance - pounds of heads-on shrimp per hour of trawling for all commercial species combined (Figs. 4.1.8-4.1.12). A distinct patchiness in shrimp concentrations was evident throughout the Guianas-Brazil fishing grounds (Figs. 4.1.8-4.1.12). The degree of patchiness varied considerably from cruise to cruise. The highest catch rate (48 lb per hour) during cruise 38 was off French Guiana; other high catches, but of lesser magnitude, were off French Guiana, Suriname, and Guyana (Fig. 4.1.8). During the same cruise, in 93 percent of the observations, the average catch per hour (cph) varied from 0 to 20 lb (0 to 9.1 kg) (Fig. 4.1.13). During cruise 49 in 85 percent of the regular fishing trawls, catch per hour varied from 0 to 20 lb or 0 to 9.1 kg (Figs. 4.1.9, 4.1.13). During cruise 49, we also conducted simulated fishing for three nights off Suriname and French Guiana, at depths of 22-30 fath (40.2 to 54.9 m). The catch per hour in these areas ranged up to 33 lb (14.9 kg) and averaged 14 lb (6.4 kg). During cruise 56, we trawled only in a relatively small area off French Guiana and the highest catches of shrimp were, as during cruise 49, near the 25 fath (45.7 m) curve (Fig. 4.1.10). During cruise 58, commercial quantities (exceeding 20 lb, 9.1 kg per hour of trawling) of shrimp (almost exclusively brown) were found at several scattered locations extending from Cape Orange to the area south of Belem (Fig. 4.1.11). The most productive grounds during cruise 66 were also south of Cape Orange (Fig. 4.1.12). The quantitative account on the distribution and occurrence of penaeids presented in this report should not be used as guidelines in evaluation of this fishery. A quantitative analysis of the penaeid fishery off the Guianas and northeastern Brazil can be found in publications by Naidu and Boerema (1972) and Jones and Dragovich (1977).

Deep-water explorations were conducted during cruises 49 and 56 in the water overlying the continental slope off Suriname and French Guiana and resulted in good catches of scarlet prawns (Figures 4.1.9 and 4.1.10). We dragged at depths of 350-450 fath (640.4 to 823.3 m) during cruise 49 and 170-400 fath (310.9 to 732 m) during cruise 56. These depths were restricted to steep areas of the continental slope. During cruise 49, ten tows were made, each of three or four-hour duration. The catch per hour of scarlet prawns ranged up to 43 lbs (19.5 kg) and for eight successful tows averaged 31 lbs (14.1 kg) per hour. During cruise 56, the duration of 21 tows was two-four hours. Tows of lesser duration, about one hour, were made while searching for shrimping grounds. The explorations started at 170 fath (310.9 m) where poor catches were recorded and progressed into the deeper waters until consistently good catches of scarlet prawn were located at 360-400 fath (658.7 to 732 m) depths. Values as high as 42 lbs (19.0 kg) per hour of trawling were recorded. The average catch per hour for the final five days of fishing was 25.1 lbs (11.4 kg).

(c) Distribution of Shrimp in Relation to Depth

Brown shrimp were present from 8 to 44 fath (12.8 to 80.5 m); pink-spotted from 15 to 39 fath (27.4 to 71.3 m); pink shrimp from 15 to 34 fath (27.4 to 62.2 m), and white shrimp from 10 to 19 fath (18.3 to 34.7 m) (Fig. 4.1.14). Based on observed depth ranges and on frequency of occurrence at different salinities (Fig. 4.1.15), the adult forms of the three principal species of shrimp (brown, pink, and pink-spotted) may be considered as eulittoral and sublittoral, primarily marine organisms. The white shrimp can be defined as an eulittoral, euryhaline organism. The observed depth ranges of sea bob, even though not presented in Fig. 4.1.14, were from 5 to 19 fath (9.1 to 34.7 m); this species may be considered as an eulittoral, euryhaline species. The scarlet prawn occurred at depths from 360-450 fath (658.7 to 823.3 m) and may be considered as an archibenthic, stenohaline organism.

7. Size Composition and Length Relationships of Shrimp

The sizes of the shrimp and their morphometric relationships were examined for each of the five cruises. The mean size and standard deviations of each shrimp species and sex are presented in Table 4.1.2. The mean size of male shrimp was smaller than for females for all species combined, 142 mm total length compared to 162 mm. For both sexes combined, pink-spotted shrimp were largest (177 mm), brown shrimp smallest (143 mm), and pink shrimp and white shrimp intermediate in size (165 mm and 166 mm, respectively). The largest specimens (170 mm) were collected during cruise 56, and the smallest (131 mm) during cruise 58; average lengths were 157 mm for cruise 49; 145 mm for cruise 38, and 141 mm for cruise 66. Cruise 56 simulated a commercial fishing operation and intentionally sampled only dense concentrations of large shrimp.

To test the significance of differences in size of shrimp in relation to species, sex, and cruise, two analysis of variance tables were prepared (Tables 4.1.3 and 4.1.4). A single analysis of variance table would have required estimating several missing values, since pink and white shrimp were not collected on all cruises. Because the average sizes of shrimp were based on unequal sample sizes, it was decided to treat the data in two tables, which tended to minimize sample size differences.

The first analysis of variance table (Table 4.1.3) compared average sizes of male and female pink-spotted and brown shrimp for five cruises and showed significant differences between species, cruises, and sexes, and a significant interaction between species and sex. Pink-spotted shrimp were significantly larger than brown shrimp, male shrimp were significantly smaller than female shrimp, and the average sizes between cruises were significantly different. The difference between male shrimp of the two species was smaller than the difference between female shrimp.

The second analysis of variance table (Table 4.1.4) compared average sizes of male and female shrimp of all four species for three cruises. Significant differences were between species and sex and significant interactions were between species and cruise and between species and sex. The results are consistent with those in Table 4.1.3. Cruises 56 and 58 were omitted in this table because pink shrimp and white shrimp were not collected on these cruises.

To study the length-weight relationship of brown and pink-spotted shrimp, regression coefficients of total weight on total length were calculated by least squares of a natural logarithmic transformation (Table 4.1.5). The resulting equations are given separately for males and females, since analysis of covariance indicated significant differences between the sexes. For brown shrimp adjusted means were different between the sexes, and for pink-spotted shrimp both adjusted means and slopes were different between the sexes.

Nomura and Filho (1968) found no significant differences in the length-weight relationship between the sexes of brown shrimp and pink-spotted shrimp. They obtained a regression relationship of

$$\log W = -5.356 + 3.124 \log L \ (r = 1.00)$$

The coefficient 3.124 is intermediate between the values 3.10 and 3.15 obtained for males and females, respectively, in our study.

Regression coefficients of carapace length on total length of brown and pink-spotted shrimp were also calculated by least squares (Table 4.1.5). The correlations between carapace length and total length varied from 0.91 to 0.98. Low values of the correlation coefficient may have resulted from different techniques of measurement used by the different persons who made the measurements or from shrimp with broken rostrums whose full lengths would not have been included in the total length measurement. Measurements from a single cruise showed as much variation as measurements from all cruises combined. Our regression coefficients of 0.23 to 0.30 were less than found by Nomura and Filho (1968) for male (0.37) and female (0.41) brown shrimp. Correlation coefficients of their samples (0.99 and 1.00) were higher than ours, even though their sample size was smaller (270 males and 296 females).

Regression coefficients of tail weight on total weight of brown shrimp and pink-spotted shrimp were calculated by least squares (Table 4.1.5). For brown shrimp, the regression coefficients were 0.59 for males and 0.61 for females. Our values are close to the 0.59 values obtained for each sex by

Nomura and Filho. We cannot explain the differences in intercept values, except for possible differences in weighing techniques, e.g., differential drying of the specimens before weighing.

8. Total Biomass in Shrimp Trawls

Large quantities of fish, crustacea, and other invertebrates are caught in the shrimp trawl fishery (Peterkin, 1977). Except for a few choice specimens (chiefly of snapper, grouper, and lobster) which are kept, the entire catch, other than shrimp, is usually thrown overboard. This by-catch or biomass if saved could be used as a source of needed protein.

To estimate how many of these fish, crustacea, and other invertebrates were discarded during the reported surveys, we calculated the number of hours fished, catch per hour and total biomass for each cruise for each 5 fath interval, starting with 5 fath (9.1 m) and ending with 45 fath (82.3 m) Table 4.1.6). In total, 253 trawls produced 106 789 lbs (48 438 kg) of biomass with an hourly average catch rate of 418.1 lbs (189.6 kg). Study of bathymetric fluctuations of total catch indicated quantitative variations between different depths, existence of geographic variations, and variations for the same depth between two different cruises (Table 4.1.6).

The highest catch rates of total biomass were made during cruises 66 and 58 in the shallow coastal waters influenced by Amazon discharge; during the remaining three cruises the catch rates were much lower. The extremely high catch rate (1 457 lbs/h or 660.9 kg/h) at a depth of 40 fath (73.2 m) for cruise 58 (Table 4.1.6) is not a true representation of biomass in terms of fish and crustaceans since practically entire catches were made up of sponges, corals, and gorgonians.

Rathjen, Yesaki, and Hsu (1969) in their paper on the trawl fishing potential off northeastern South America reported on the total biomass catch. They used data from an 85 ft shrimp trawler, COQUETTE, collected during 1962, 1963, 1964, and 1965, and calculated the hourly average catch rates for the four years of trawling off the coasts of Guyana, Suriname, and French Guiana according to seven depth categories. Their hourly average catch rates were 527.15, 452.48, 493.91, 73.70, 151.54, and 104.10 lbs (or 239.1, 205.2, 224.0, 33.4, 66.7, and 47.2 kg) for 5, 10, 15, 20, 25, 30, and 35 fath (9.1, 18.3, 27.4, 36.6, 45.7, 54.9 and 64.0 m), respectively. Their maximum catches were from 10 to 15 fath; at greater depths the values were of much lesser magnitude and fluctuated irregularly. They also observed variations in catch rates for the same depths from year to year. In some instances these variations between the different years were on the order of two to three magnitudes.

The data on biomass showed a lack of a consistent progressive decline in catch rates in the offshore direction, as observed by Rathjen, Yesaki, and Hsu (1969). Highest catch rates of biomass in our study were in an area between 10 and 25 fath (18.3 and 45.7 m). Our catch rates were comparable to the values observed by Rathjen, Yesaki, and Hsu only up to about 20 fath (36.6 m). High catch rates near the river mouths were observed in both studies by us and by Rathjen, Yesaki, and Hsu. These authors noted a direct relationship between the high biomass off Suriname and the periods of peak discharge of the Suriname River.

The percentage of shrimp caught by commercial fishermen off the Guianas usually represents 8 to 10 percent of the total live catch (Peterkin, 1977). For the most part, the percentage of shrimp in our trawls was below that of commercial fishermen.

Trawls on cruises 38, 49, 58, and 66 were, for the most part, of 1/2 h and 1 h duration. The low catches of penaeid shrimp during these cruises (2 to 4 percent of the total biomass) may be partially explained by the fact that 1/2 h or 1 h of trawling is not sufficient for the gear to start fishing properly. The entire cruise 56 was devoted to simulated fishing and the average time for the 27 commercial type tows was 2.5 hours per tow. On the whole, the total quantity of shrimp caught during cruise 56 was much higher than during the other four cruises and represented 8.2 percent of the total biomass caught. The frequency of occurrence of the catches in the commercial category (20 lb per hour of trawling and higher) was also considerably higher (45 percent of the trawls) during cruise 56 than during the other four cruises (Fig. 4.1.13).

9. Temperature (°C)

Temperature is considered to be among the most prominent abiotic factors influencing growth, survival, and spawning of penaeids (Zein-Eldin and Aldrich, 1965; Aldrich, Wood, and Baxter, 1968; Allen and Costello, 1969; and Barrett and Gillespie, 1973).

The surface and bottom temperatures recorded during the five cruises varied from 22.2° to 29.3° and from 22.2° to 28.5° C, respectively. The differences in temperature between surface and bottom increased with depth. At depths up to about 15 fath (25.6 m), these differences were less than 2° C, in 82 percent of the observations. At depths from 16 to 45 fath (29.3 to 82.3 m) differences were less than 4° C in 94 percent of the observations and in only a few instances were differences as high as 5° C.

Even though our data represent only a limited number of observations, the temporal changes in temperature, as expected, were more pronounced than areal changes. The mean surface temperature in February (25.8° C) was lower than the corresponding range of values in May, June, and July (26.6-28.0° C). Similar temperature differences were noted near the bottom also, thus indicating the existence of seasonal changes in water temperature throughout the water column. Neumann, Beatty, and Escowitz (1975), in their study of seasonal changes of oceanographic and marine climatological conditions in the equatorial Atlantic, presented zonal mean sea surface temperatures between 10° N and 10° S for each month and yearly mean. Comparison between our temperatures and their long-term mean temperatures showed a discrepancy of only 0.2-0.5° C - a remarkable overall correspondence in values between our and their study.

Numerous studies concerned with the responses of penaeids to the changes in temperature demonstrate the importance of temperature in their ecology and biology. Kutkuhn (1966) reported occurrence of young penaeid shrimp in water temperatures ranging from near 0° to 35° C. Costello and Allen (1970) in their synopsis of biological data on the pink shrimp P. duorarum discussed temperature as a limiting factor in the distribution and survival of shrimp. The temperature at which shrimp spawn on the Tortugas grounds was reported by Jones, Dimitriou, Ewald, and Tweedy (1970) to be between 19.6° and 30.6° C. A positive correlation between temperature of bottom water and the occurrence of ripe female shrimp on the Tortugas grounds was noted by Cummings (1961).

Aldrich, Wood and Baxter (1968) studied the responses of postlarvae of P. aztecus and P. setiferus to low temperatures under controlled conditions. Postlarvae of P. aztecus regularly burrowed into silty clay substrate at temperatures 12-17° C and emerged at temperatures 18-21° C, but P. setiferus did not exhibit such activity. The temperature ranges shown by Aldrich, Wood, and Baxter (1968) to elicit the burrowing and emergence phenomena are commonly found in their natural habitats along the Texas-Louisiana coasts. Zein-Eldin and Griffith (1969) have shown that although postlarvae of P. aztecus and P. setiferus can tolerate a wide range of temperatures, their metabolic rates are controlled by specific temperatures. Growth of postlarvae of P. aztecus was rapid between 15° and 20° C and continued to increase but at a slower rate between 20° and 25° C; at 35° C the growth rate decreased and no animals survived more than 35 days. For P. setiferus an almost constant growth rate was recorded at temperatures between 15° and 25° C and growth rate decreased between 32.5° and 35° C. Further experiments with larger tank sizes by Zein-Eldin and Griffith (1969) suggested that growth of P. setiferus increases with temperature at least to 32.5° C. Zein-Eldin and Aldrich (1965) noted the most marked increase in growth rate of postlarvae of P. aztecus between 11° and 25° C.

The temperature variations and species of shrimp in the above-cited instances represent the geographic area of the Gulf of Mexico and Atlantic water off the southeastern coast of the U.S.A.. The annual temperature range (22.2° - 28.5° C) for the Guiana-Brazil fishing area obtained from our survey differed markedly from the corresponding area of the Gulf of Mexico and Atlantic water off the southeastern coast of the U.S.A. (6° -32° C). Even though brown, pink, and pink-spotted shrimp off Guiana-Brazil are closely related to their counterpart species of the Gulf of Mexico, they are different species and their tolerance toward temperatures have not been studied. In the absence of comparative data on temperature preferences of penaeids off the Guiana-Brazil shrimp grounds, we can compare our observed temperature ranges for P. subtilis (22.2° - 28.5° C), P. brasiliensis (22.5° - 28.5° C), P. notialis (22.5° - 28.5° C) or P. schmitti (22.5° - 28.5° C) with the above-cited information of their counterpart species from the northern Gulf of Mexico and tentatively find these ranges to be within their tolerance levels.

10. Salinities (o/oo)

Penaeids differ in their preferences or tolerances for certain ecological factors (Williams, 1965; Broad, 1965). In addition to temperature, salinity is the most frequently studied variable in their ecology (Gunter, 1950, 1961 a, and 1961 b; Gunter, Christmas, and Killebrew, 1964; Zein-Eldin and Griffith, 1969).

The conclusions reached from field studies on the relationship of shrimp to salinity differ substantially (Zein-Eldin and Aldrich, 1965). Whether the salinity per se or the variables which accompany salinities (temperature, organic and inorganic nutrients, flora and fauna, related changes in bottom type, turbidity, and pollution) influence the distribution and abundance of penaeids continues also to remain among unanswered questions. Based on the results of the laboratory observations on postlarval penaeids by Zein-Eldin and Aldrich (1965) and Zein-Eldin and Griffith (1965) the observed salinity ranges from our surveys, which will be presented in the following paragraphs of this section, were well within the tolerance levels for brown, pink-spotted, pink, and white shrimp.

The salinity data for cruises 38, 44, 58, and 66 are presented as isohalines in Fig. 4.1.16. The data from cruise 56 did not lend themselves to be presented as isohalines because the entire cruise consisted of simulated commercial fishing with considerable crowding of stations is a very small area. The influence of precipitation by fresh-water outflow was reflected in surface salinities (Fig. 4.1.16). The surface waters were basically marine with a slight admixture of fresh water and the waters near the bottom were strictly marine, except in the vicinity of the mouth of the Amazon and the two offshore locations, one off Guyana and the other off French Guiana.

Seasonal differences in salinity were noted between the dry months of the year (January and February) and the rainy months (May, June and July). Off French Guiana and Suriname, during the months of the rainy season (cruises 38, 58, and 66), the surface salinities were lower than corresponding values during the dry season (cruise 49).

The first attempt to study the seasonal variations in salinities off the northern South American coast between 10° S and 10° N was made by Neumann (1969). His report is based primarily on data assembled by the National Oceanographic Data Center (NODC) and on data from other investigations and on all available historical data. Neumann computed mean monthly salinity values for each 1° square and constructed monthly isohalines for all months except May and October. The greatest effect of precipitation on surface salinities was observed at a point northeastward from the mouth of the Amazon River. Our data from cruises 58 and 66 also show the lowest salinities northeastward off the mouth of the Amazon River and a gradual increase in salinity toward French Guiana (Fig. 4.1.16). According to Neumann the annual march of reduced salinities starts from off the mouth of the Amazon River in February and progresses in a northwesterly direction along the Guianas current as far as Guyana and ends in about October. The annual salinity minimum of the Amazon is attained in March and April and is steadily delayed when proceeding in a north-northwesterly direction along the coasts of French Guiana, Suriname, and Guyana; off French Guiana, the yearly salinity minimum is attained in June and July and in August and September low values (32-34 percent) extend from the mouth of the Amazon to the western border of Guyana. To observe the geographic and temporal differences in surface and bottom salinities and compare them with

Neumann's observations, we computed the mean values for each 1° square and for each cruise (Table 4.1.7). Even though our data represent only a few months (Fig. 4.1.16 and Table 4.1.7), they are in agreement with the long-term observations presented by Neumann. Furthermore, our data indicate presence of isolated patches of low salinity water off Suriname. According to Ryther, Menzel, and Corwin (1967) and Cochrane (1965, 1966), isolated patches of low salinity water seem to appear during some seasons in the western tropical Atlantic with little or no connexion to each other. The same authors associate the existence of an active shrimp fishery based in the Guianas presumably to the mechanism of nutrient enrichment in this region, which is associated with sloping water. According to these authors, a rapid increase in nitrate occurs at depths below roughly the density of 24 σ_t surface. Water of this density is found in the euphotic layer, as in the coastal waters, providing the stimulus for increased biological productivity - reflected in large phyto and zooplankton populations. Further studies will be necessary to ascertain the validity of the suggested link between the shrimp fishery of the Guianas and the nutrient enrichment of this region by upwelling. Naidu and Boerema (1972) and Jones and Dragovich (1977) report highly productive shrimping grounds extend from off the mouth of River Pará, Brazil, to the Orinoco River, an area not characterized to have upwelling along the entire stretch.

11. Grain Size and Organic Matter of the Sediments of the Surface Layer of the Sea Floor

The purpose of collecting sediment samples was to determine (1) the grain size and organic matter of the sea floor over which the trawls were made, and (2) to see any correlation existing between the occurrence of shrimp species and certain characteristics of substrate. The samples were analysed for percent gravel (>2mm), percent sand ($\leq$2mm - $\geq$62.5μ), percent silt ($\leq$62.5 - >3.9μ), and percent clay ($\leq$3.9μ). If there was less than 5 percent total silt and clay, these samples were not analysed by pipette for percent silt and percent clay, but rather just lumped as percent fines ($\leq$62.5μ). Total organic carbon (TOC) was determined by microcombustion of freeze-dried samples as described by Hatcher (1978) from the sediment samples collected during cruises 46, 56, and 58.

The density of sampling and the method of sampling used in our study allow only a rough examination of the differences in the texture of the sediment samples. The results indicated that we trawled over a bottom consisting of an admixture of gravel, sand, silt, and clay. In certain areas off Brazil, the substrate consisted of small and large coral heads and stones, making trawling hazardous.

To show the relationship between sand, silt and clay, we used the triangle diagram (Shepard, 1954) as a graphic method (Fig. 4.1.17). The sand and gravel grain size were combined into one category in the triangle diagrams since gravel was present in very small quantities and in only a very few samples. The gravel size was usually in the form of coral pieces. The sediment type off Guyana, Suriname, and French Guiana consisted primarily of sand type and encompassed extensive areas (for both cruises 38 and 49), which were separated off Suriname by a mixed zone of clayed sand, silty sand, and sand silt-clay (Fig. 4.1.17). The patchiness in the distribution of sediment types was more pronounced throughout the area studied during cruise 38 than during cruise 49. The well-deliniated mixed zone of finer grain type bottom off Suriname during cruise 49 grades in the direction of the Guiana current from sand into sand silt-clay and clayed sand. In addition to this mixed zone, patchy areas of finer bottom types than sand are bordering the extensive sandy areas (cruise 38 and 49, Fig. 4.1.17). These small patchy areas of finer material are represented by silty clay and clayed silt and are located primarily between the large sand areas and seashore. To a lesser extent, some of these patchy areas of finer materials are found also along the seaward border of these extensive sand-dominated bottoms.

During cruise 56, which was mainly off French Guiana, the sediment type of the continental shelf was mostly sand with smaller areas of clayed sand, silty sand, and sand silt-clay. In the area of the continental slope at depths up to 400 fath (732 m), the sediment consisted for the most part of fine grain deposits - clay and silty clay and a small area of sandy bottom.

During cruise 58, the sandy-type bottom was found farthest offshore, stretching from Cape Orange to the area off the mouth of the Amazon River. Silty clay and clayed-silt type of bottom was prominent in the areas closer to the shores of northern Brazil between Cape Orange and the mouth of the Pará River. A relatively large area of clay deposits was present just south of Cape Orange.

Kempf (1970) in his study of benthic biology of the N-NE Brazilian shelf noted a well-marked progressive selection in grain size toward the open sea. He also reported that in the Amazonian (offshore) region the soft bottom mud becomes a dominant factor. According to Kempf, the influence of Amazon discharge extends northwestward over the greatest part of the shelf area, and bottom types seawardly from the mouth of the Amazon represent a succession of mud, a mixture of mud and sand (mud or sand fraction 80 percent in the total sediment), and finally quartz sand partially mixed organographic elements in its lower level. The distributional pattern of the grain sizes off Brazil obtained during our study is in general agreement with that of Kempf.

To observe the relationship between the type of the bottom and the shrimp catches we plotted the average catch per hour of shrimp (all species combined) against the bottom types (Fig. 4.1.18). In 60-80 percent of the observations, the bottom types were classified as sand or hard bottom and the remaining bottom types were usually a mixture of various proportion between sand, silt, and clay. All bottom types "produced" high catches and low catches. Good commercial catches (over 20 lb/h) were made over all types of bottom, but most of these catches were over sandy bottom. We also plotted the occurrence of each species of shrimp against the same bottom types as represented in Fig. 4.1.17. The three principal shrimp species - brown, pink-spotted, and pink - were found principally over sandy bottom. All white shrimp were collected over soft bottom consisting principally of clay. In the area of the continental slope, scarlet prawns were collected exclusively over the soft bottom consisting of fine grain deposits, clay, and silty clay.

The areal distribution of TOC values has shown no specific pattern. During cruise 49 higher values of TOC were recorded off Suriname and lower off French Guiana. Higher TOC values off Suriname can be perhaps traced back to the discharges of the Suriname River. The range of TOC values for cruise 49 was from 0.23 to 2.33 percent with a mean value of 1.77 percent; for cruise 56 from 0.28 to 2.06 percent with a mean value of 0.82 percent and for cruise 58 from 0.08 to 2.38 percent with a mean value of 0.80 percent. Similarly to our observations, Allersma (1971) reported the TOC content of the Guiana sediment to be 1 to 2 percent.

Correlation coefficients were calculated between the percentage of "fines" (material 62.5 m) and percent of TOC. Good correlation (r= 0.94) existed only for cruise 56. The correlations value for cruise 56 is perhaps attributable to two factors: (1) the dense arrangement of stations and (2) that sampling did not occur over such a wide range of conditions.

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Table 4.1.1 Numerical and Weight Relationships Between the Different Species of Shrimp for Each Cruise (expressed in percent)

Cruise	Brown	Hopper	Pink	White
	Weight (%)			
38	52.6	41.0	5.9	0.4
49	55.0	43.5	1.0	0.5
56	76.2	23.8	0.1	0.0
58	99.0	1.0	0.0	0.1
66	88.2	4.7	5.0	2.1
	Numerical (%)			
38	66.3	28.8	4.8	0.1
49	63.3	35.7	0.9	0.1
56	60.7	39.2	0.1	-
58	95.6	1.2	-	-
66	89.4	7.4	2.3	0.9

Table 4.1.2 Mean total length, standard deviation, and sample size of shrimp (by species and sex) collected on cruises 38, 49, 56, 58, and 66 of FRV OREGON II off the northeastern coast of South America, 1972-76

TOTAL LENGTH	Cruise 38			Cruise 49			Cruise 56			Cruise 58			Cruise 66			All Cruises		
	Mean	Std D	N	Mean	Std D	N	Mean	Std D	N	Mean	Std D	N	Mean	Std D	N	Mean	Std D	N
Penaeus subtilis																		
Both Sexes	127.8	25.5	855	141.3	23.7	750	159.6	20.14	2672	129.3	24.3	1414	136.6	23.2	2163	142.6	26.1	7854
M	123.4	20.2	344	133.1	16.3	370	146.1	12.5	1127	1215	16.4	683	123.2	13.5	826	131.7	18.4	3345
F	130.9	28.2	511	149.2	26.9	380	169.4	18.9	1545	136.6	28.0	731	144.9	24.0	1337	150.8	27.9	4499
P. brasiliensis																		
Both Sexes	171.1	20.7	351	166.8	19.7	1061	186.1	16.7	1597	163.1	32.4	61	175.9	20.0	198	177.2	20.8	3268
M	158.7	13.5	173	155.0	12.6	517	171.7	7.6	731	147.7	23.6	34	162.8	11.6	96	163.6	13.6	1551
F	183.2	19.2	178	178.0	18.7	544	198.3	11.8	866	182.4	31.9	27	188.2	18.4	102	189.5	18.5	1717
P. notialis																		
Both Sexes	165.7	19.9	218	164.8	18.2	80	191.2	5.4	6	-	-	0	162.2	16.4	51	165.4	19.2	355
M	153.1	11.5	128	152.3	7.9	47	-	-	0	-	-	0	148.6	8.4	25	152.3	10.4	200
F	183.5	15.2	90	182.7	13.1	33	191.2	5.4	6	-	-	0	175.3	10.4	26	182.3	14.2	155
P. schmitti																		
Both Sexes	178.2	11.1	17	155.2	12.8	12	-	-	0	-	-	0	163.6	9.9	42	165.7	13.1	71
M	167.2	5.2	6	155.2	11.2	6	-	-	0	-	-	0	158.5	6.4	26	159.3	7.9	38
F	184.3	8.2	11	155.2	15.4	6	-	-	0	-	-	0	171.9	8.8	16	173.0	14.1	33
All Species																		
Both Sexes	144.7	31.2	1441	156.6	24.6	1903	169.5	22.9	4275	130.7	25.6	1475	140.8	25.4	2454	153.2	29.0	11548
M	139.0	23.8	651	146.2	17.5	940	156.2	16.6	1858	122.7	17.7	717	128.7	18.6	973	142.3	22.3	5139
F	149.4	35.4	790	166.7	26.3	963	179.8	21.7	2417	138.2	29.4	758	148.8	26.2	1481	162.0	30.8	6409

Table 4.1.3 Analysis of variance of average lengths of *Penaeus subtilis*, and *P. brasiliensis* collected on cruises 38, 49, 56, 58, and 66

Source	S.S.	D.F.	Mean Square	F Ratio	
A Species	6.04476E 03	1	6.04476E 03	4.11034E 02	411.03 1/
B Cruise	1.47178E 03	4	3.67946E 02	2.50197E 01	25.01 1/
C Sex	2.37402E 03	1	2.37402E 03	1.61429E 02	161.42 1/
AB	1.27512E 02	4	6.82408E 01	4.64026E 00	4.64 NS
AC	1.27512E 02	1	1.27512E 02	8.67063E 00	8.67 1/
BC	6.12970E 01	4	1.53242E 01	1.04202E 00	1.04 NS
REM	5.88250E 01	4	1.47062E 01		
TOT	1.04112E 04	19			

1/ P (larger Fx) = 0.05

Table 4.1.4 Analysis of variance of average lengths of *Penaeus subtilis*, *P. brasiliensis*, *P. notialis*, and *P. schmitti* collected on cruises 38, 49, and 66

Source	S.S.	D.F.	Mean Square	F Ratio	
A Species	5.10797E 03	3	1.70266E 03	8.62498E 01	86.24 1/
B Cruise	3.48775E 01	2	1.74387E 01	8.83378E-01	0.88 NS
NSC Sex	2.32460E 03	1	2.32460E 03	1.17755E 02	117.55 1/
AB	7.12386E 02	6	1.18731E 02	6.01444E 00	6.01 1/
AC	3.34232E 02	3	1.11411E 02	5.64362E 00	5.64 1/
BC	1.96908E 01	2	9.84541E 00	4.98730E-01	0.49 NS
REM	1.18446E 02	6	1.97410E 01		
TOT	8.65220E 03	23			

1/ P (larger F) = 0.05

Table 4.1.5 Relationships between total length and weight, carapace length or tail weight for shrimp collected on cruises 38, 49, 56, 58, and 66 off the northeastern coast of South America, 1972-76

	Species	Sex	Relationship	r	N
Total Total Weight-Length	*Penaeus subtilis*	M	ln W = -12.26 + 3.105 ln L	0.99	328
		F	ln W = -12.43 + 3.146 ln L	0.99	326
	P. brasiliensis	M	ln W = -11.13 + 2.892 ln L	0.98	213
		F	ln W = -12.25 + 3.121 ln L	0.99	205
Carapace Length	*P. subtilis*	M	CL = -3.020 + 0.249 TL	0.96	3345
		F	CL = -5.862 + 0.277 TL	0.98	4499
	P. brasiliensis	M	CL = -1.192 + 0.239 TL	0.91	1551
		F	CL = -9.235 + 0.297 TL	0.95	1717
	P. notialis	M	CL = -0.158 + 0.227 TL	0.86	200
		F	CL = -6.063 + 0.277 TL	0.88	155
	P. schmitti	M	CL = -9.261 + 0.281 TL	0.93	38
		F	CL = -8.636 + 0.287 TL	0.87	33
Tail Weight - Total	*P. subtilis*	M	Tail W = 0.2671 + 0.6118 Total W	0.99	229
		F	Tail W = 0.5408 + 0.5921 Total W	0.99	223
	P. brasiliensis	M	Tail W = 0.6745 + 0.6385 Total W	0.98	132
		F	Tail W = 2.9857 + 0.5614 Total W	0.98	120

Table 4.1.6 Distribution of OREGON II Fishing Effort, Total Catch and Mean Catch per Hour by 5-fathom Intervals for Cruises 38, 49, 56, 58 and 66

	Cruises					Total
	38	49	56	58	66	all cruises
5 - 9.9 fms						
No. of drags	-	-	-	-	10	10
Hrs. fished	-	-	-	-	5	5
Total catch (lbs)	-	-	-	-	6,778.0	6,778.0
Catch/hour	-	-	-	-	1,355.6	1,355.6
10-14.9 fms						
No. of drags	-	-	-	3	19	22
Hrs. fished	-	-	-	1.5	10.5	12
Total catch (lbs)	-	-	-	980	12,138.0	13,118.0
Catch/hour	-	-	-	653.3	1,156.0	1,093.2
15-19.9 fms						
No. of drags	11	-	-	13	12	36
Hrs. fished	8.05	-	-	10.00	6	24
Total catch (lbs)	3,732	-	-	3,713	6,751.0	14,196
Catch/hour	463.6	-	-	371.3	1,125.2	591.5
20-24.9 fms						
No. of drags	14	12	2	8	7	43
Hrs. fished	10.32	12.58	2.15	7.00	3.5	35.55
Total catch (lbs)	4,106	2,606	576	3,433	1,122.0	11,843.0
Catch/hour	397.9	207.2	267.9	490.4	320.6	333.1
25-29.9 fms						
No. of drags	11	14	16	10	8	59
Hrs. fished	7.91	27.95	38.85	5.00	9.0	88.71
Total catch (lbs)	2,631	4,664	17,720	4,210	4,246.0	33,471.0
catch/hour	332.6	166.9	456.1	842.0	471.8	377.3
30-34.9 fms						
No. of drags	14	9	8	7	3	41
Hrs. fished	8.53	8.00	21.36	3.50	3.5	44.9
Total catch (lbs)	2,449	1,805	5,623	1,180	1,519.0	12,576.0
catch/hour	287.1	225.6	263.3	337.1	434.0	280.1
35-39.9 fms						
No. of drags	12	5	-	7	12	36
Hrs. fished	8.15	4.00	-	3.50	19.6	35.2
Total catch (lbs)	2,686	729	-	5,098	3,823.0	12,336.0
Catch/hour	329.6	182.2	-	1,456.6	195.0	350.4
40-44.9 fms						
No. of drags	-	-	-	4	2	6
Hrs. fished	-	-	-	2.00	8	10
Total catch (lbs)	-	-	-	711	1,760	2,471
Catch/hour	-	-	-	355.5	220.0	247.1
Total all Depths						
No. of drags	62	40	26	52	73	253
Hrs. fished	42.96	52.53	62.36	32.50	65.1	255.4
Total catch (lbs)	15,604	9,804	23,919	19,325	38,137.0	106,789.0
Catch/hour	363.2	186.6	383.6	594.6	585.8	418.1

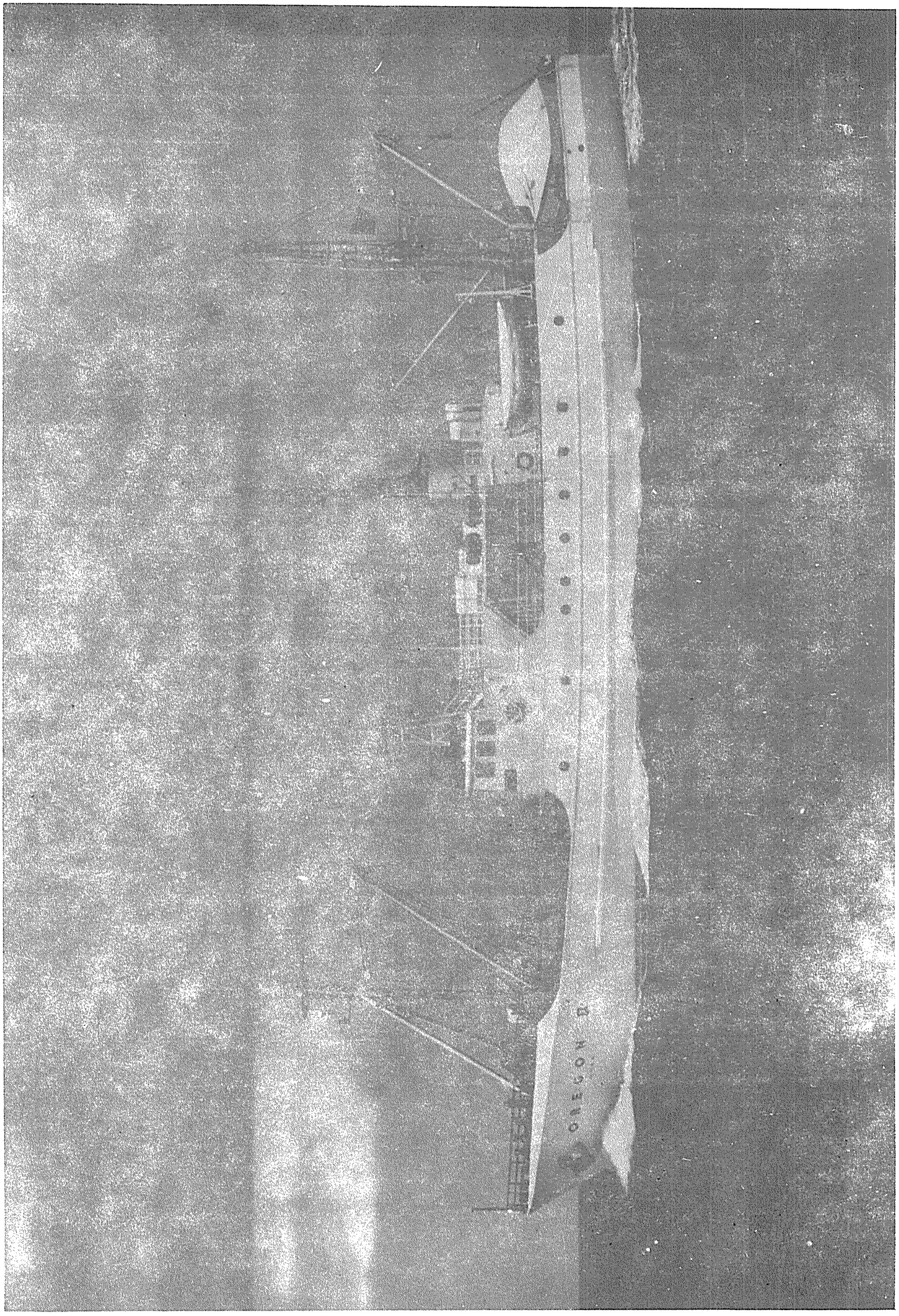
Table 4.1.7 Mean sea surface salinities for each 1° square off Guianas and northeastern part of Brazil. Numbers in parentheses indicate number of observations. These data are from five FRV OREGON II cruises reported in this paper

	59-58°W	58-57°W	57-56°W	56-55°W	55-54°W	54-53°W	53-52°W	52-51°W	51-50°W	50-49°W	49-48°W	48-47°W	47-46°W	46-45°W	45-44°W
Cruise 49 JAN-FEB 1972															
7-8°N	34.76(1)	35.50(9)	35.39(5)	34.66(3)											
6-7°N		35.38(1)	35.49(5)	35.24(6)	33.35(9)	31.61(5)	31.29(4)								
5-6°N				34.64(1)			24.84(4)	27.85(7)							
Cruise 56 JAN-FEB 1974															
7-8°N					35.89(1)	36.15(18)									
6-7°N						35.04(3)	36.08(3)								
5-6°N							33.95(16)	33.16(5)							
4-5°N								36.12(1)							
3-4°N							32.21(1)								
Cruise 58 MAY-JUNE 1975															
4-5°N								19.04(8)	17.04(6)						
3-4°N									15.68(10)	19.27(2)					
2-3°N										21.42(3)	25.57(4)	31.12(1)			
1-2°N											16.31(3)	26.14(7)	33.21(1)		19.78(4)
1-0°N												15.75(3)	33.99(4)	25.64(1)	27.24(2)
Cruise 66 MAY 1976															
8-9°N	34.75(4)	34.75(4)													
7-8°N	32.67(3)	33.00(2)		34.50(2)	31.17(6)	32.50(2)									
6-7°N						33.60(4)	29.67(6)	22.00(1)							
5-6°N								24.28(7)	15.60(5)						
4-5°N									14.50(6)	12.00(1)					
3-4°N									12.00(1)	22.84(6)					
2-3°N										5.00(1)	13.00(3)				
1-2°N															
Cruise 38 JUNE-JULY 1972															
7-8°N		35.84(10)	35.49(4)	35.38(4)											
6-7°N		35.82(2)	35.26(5)	35.68(6)	35.45(8)	33.87(8)	31.48(2)								
5-6°N						34.56(1)	31.76(7)	26.72(6)							
4-5°N								25.36(2)							

Table 4.1.8 Mean catch of headless shrimp per hour of trawling by U.S. flag vessels of the Guianas-Brazil fishery, 1972-77. For statistical zones, see Figure 2.1

	Zones 69-77	Zones 78-81	All Zones
1972			
January-June			
July-December	19.09	22.16	20.00
January-December			24.34[1/]
1973			
January-June	23.29	33.41	28.10
July-December	19.83	27.05	23.67
January-December	21.35	31.38	25.92
1974			
January-June	20.01	22.40	20.96
July-December	13.89	17.52	15.22
January-December	17.01	20.12	18.55
1975			
January-June	14.82	17.65	15.82
July-December	10.46	15.86	11.87
January-December	12.58	16.88	13.83
1976			
January-June	13.88	24.33	18.59
July-December	9.48	12.95	10.63
January-December	11.82	20.31	15.23
1977			
January-June	7.82	28.83	19.71
July-December	10.21	16.18	12.40
January-December	9.57	22.14	15.07

1/ Estimated value


OREGON II

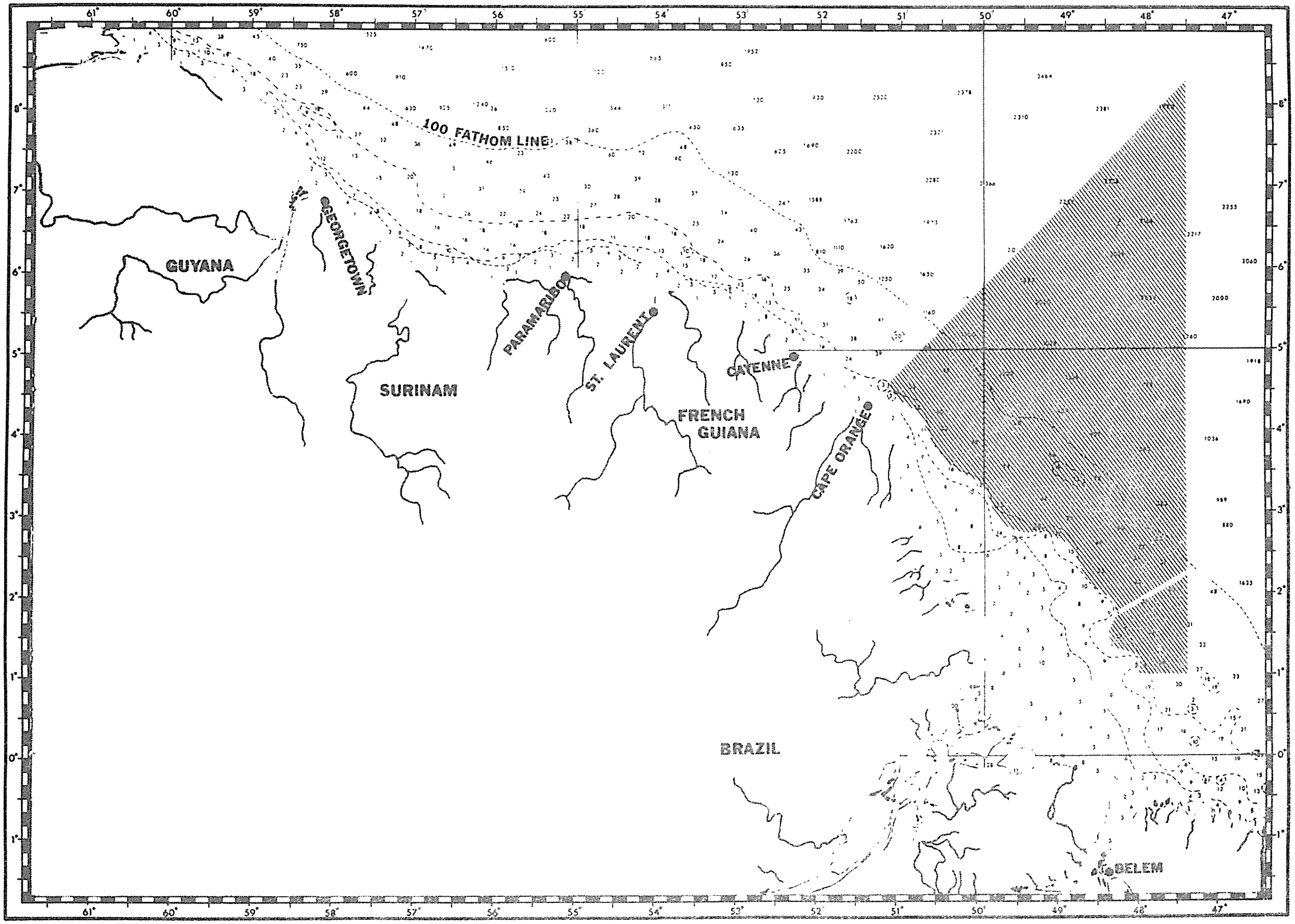


Figure 4.1.2 The area of surveys, extending from Guyana to Belem, Brazil. The shaded area represents the Agreement Area, which is bounded inshore by the 30 m contour, offshore by the 47°30' W longitude line, on the north by the northern border of Brazil, and on the south by the 1° N latitude line

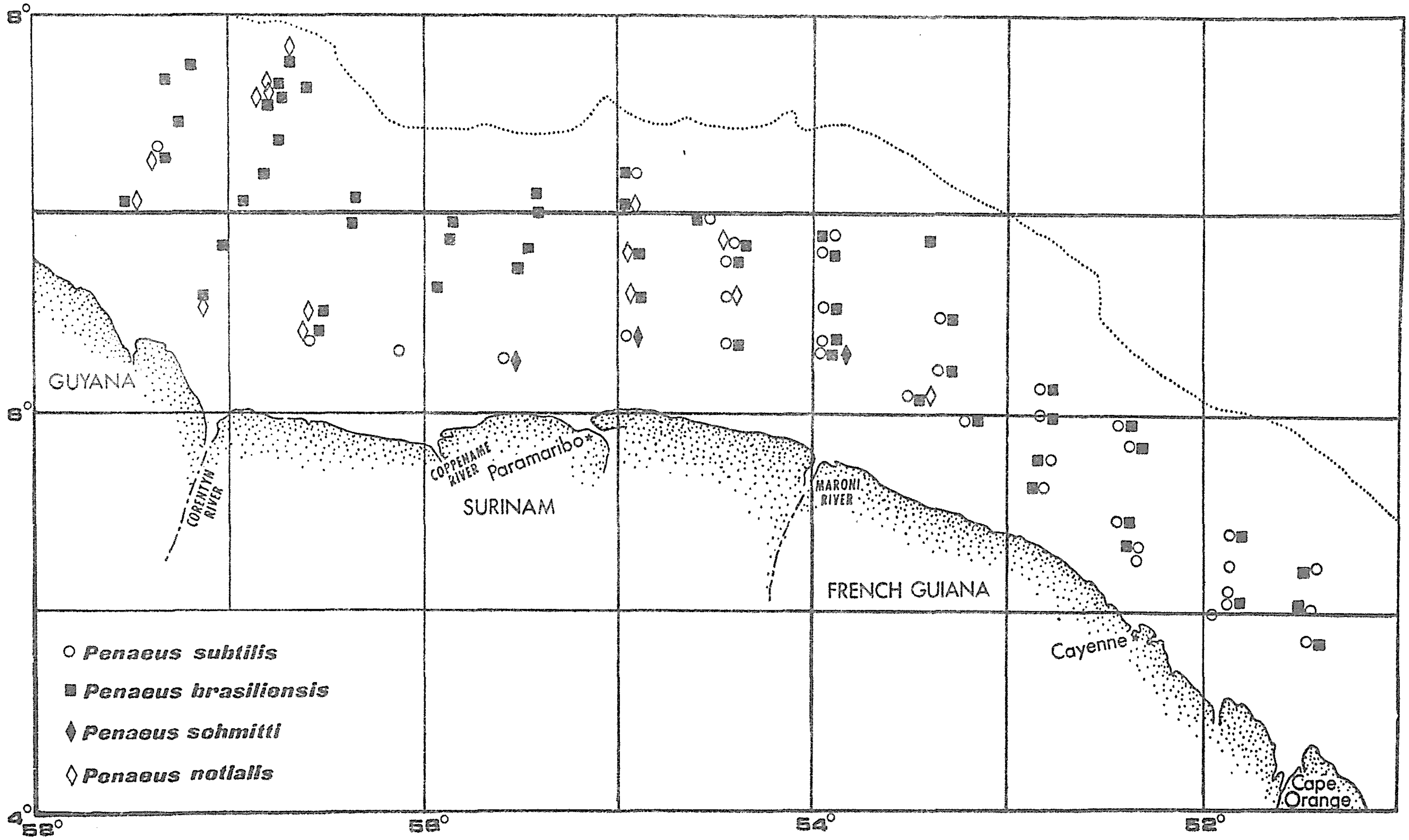


Figure 4.1.3 Occurrence of Commercially Important Species of Shrimp during Cruise 38 (FRV OREGON II)

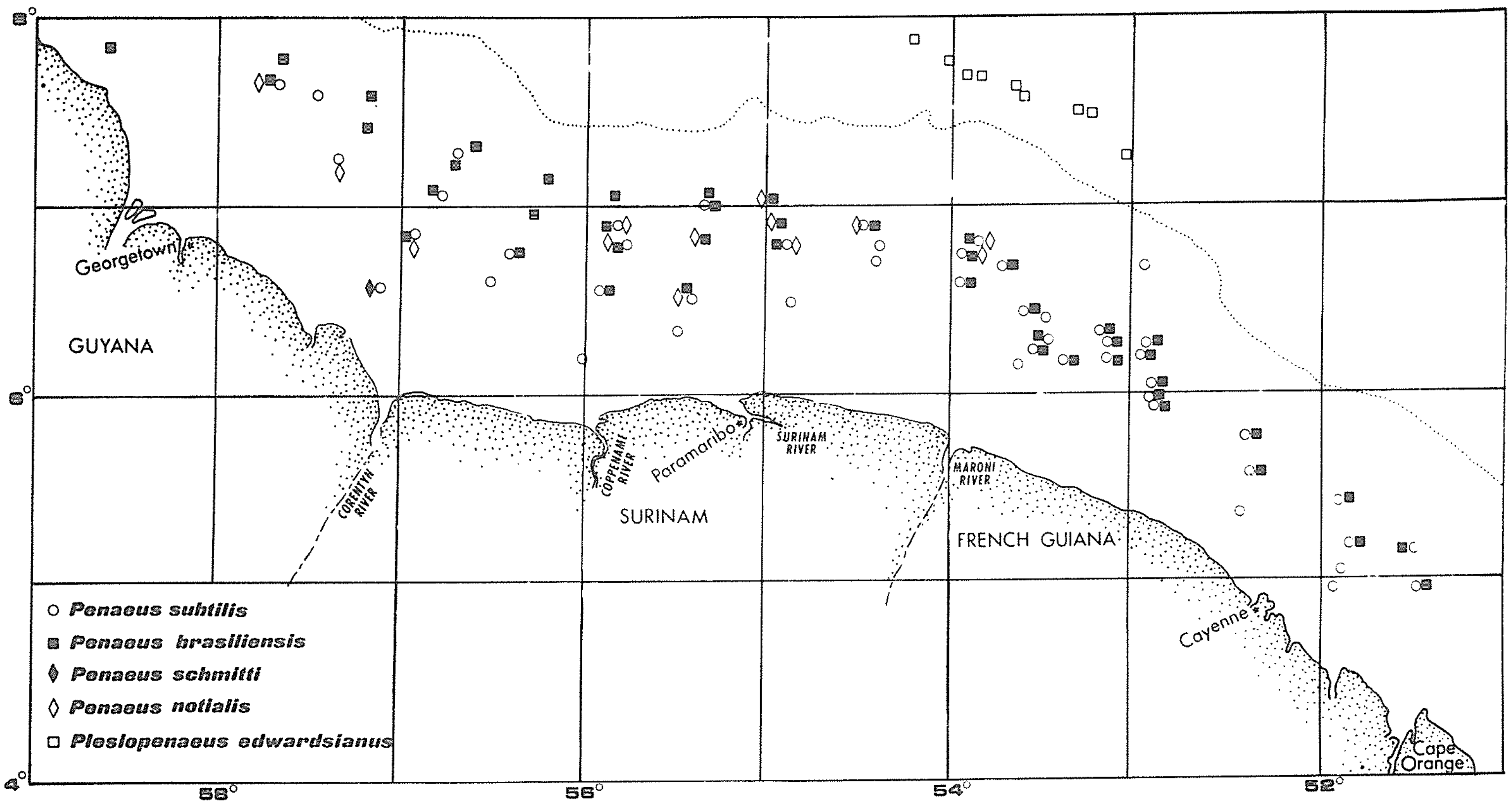


Figure 4.1.4 Occurrence of Commercially Important Species of Shrimp during Cruise 49 (FRV OREGON II)

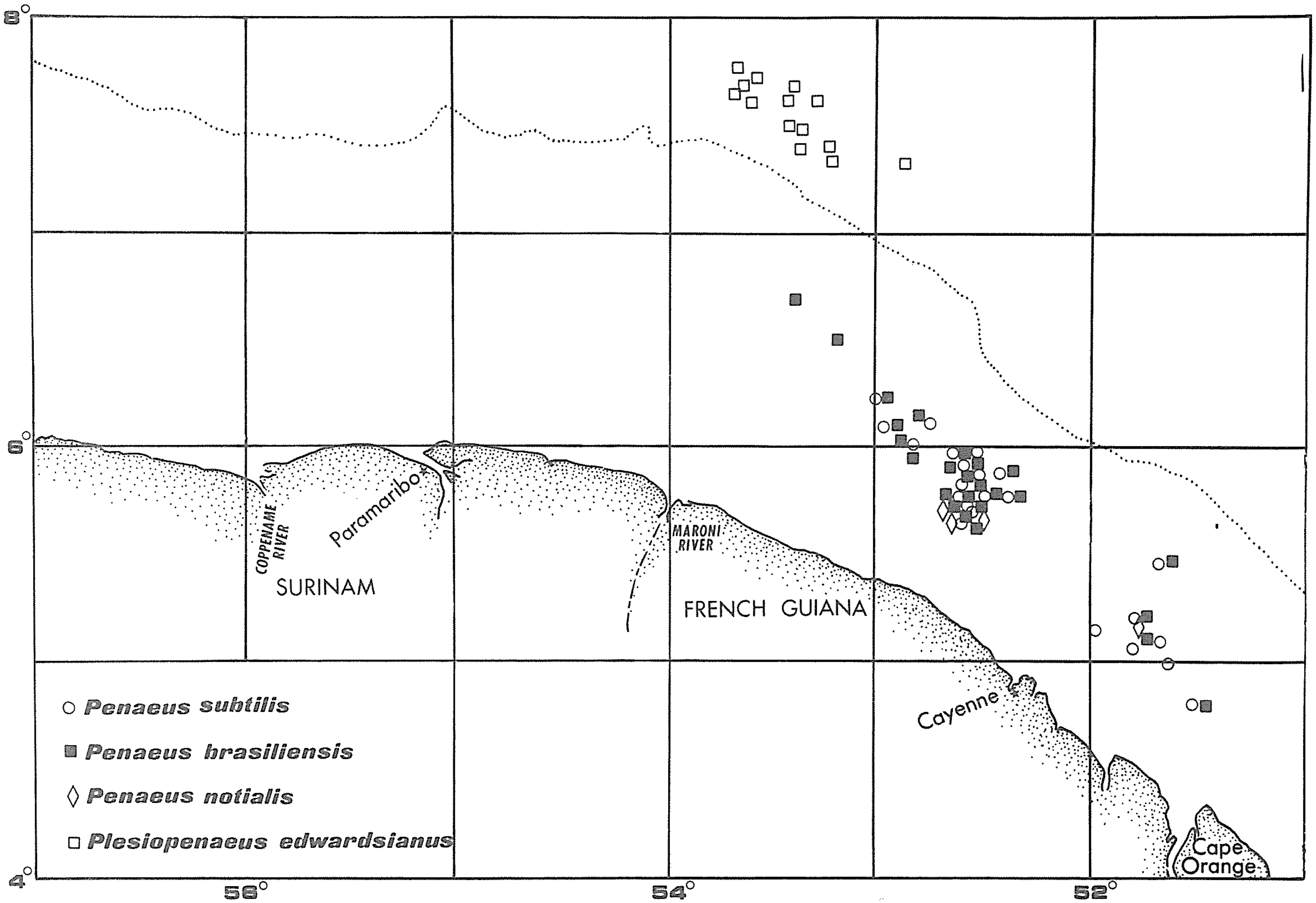


Figure 4.1.5 Occurrence of Commercially Important Species of Shrimp during Cruise 56 (FRV OREGON II)

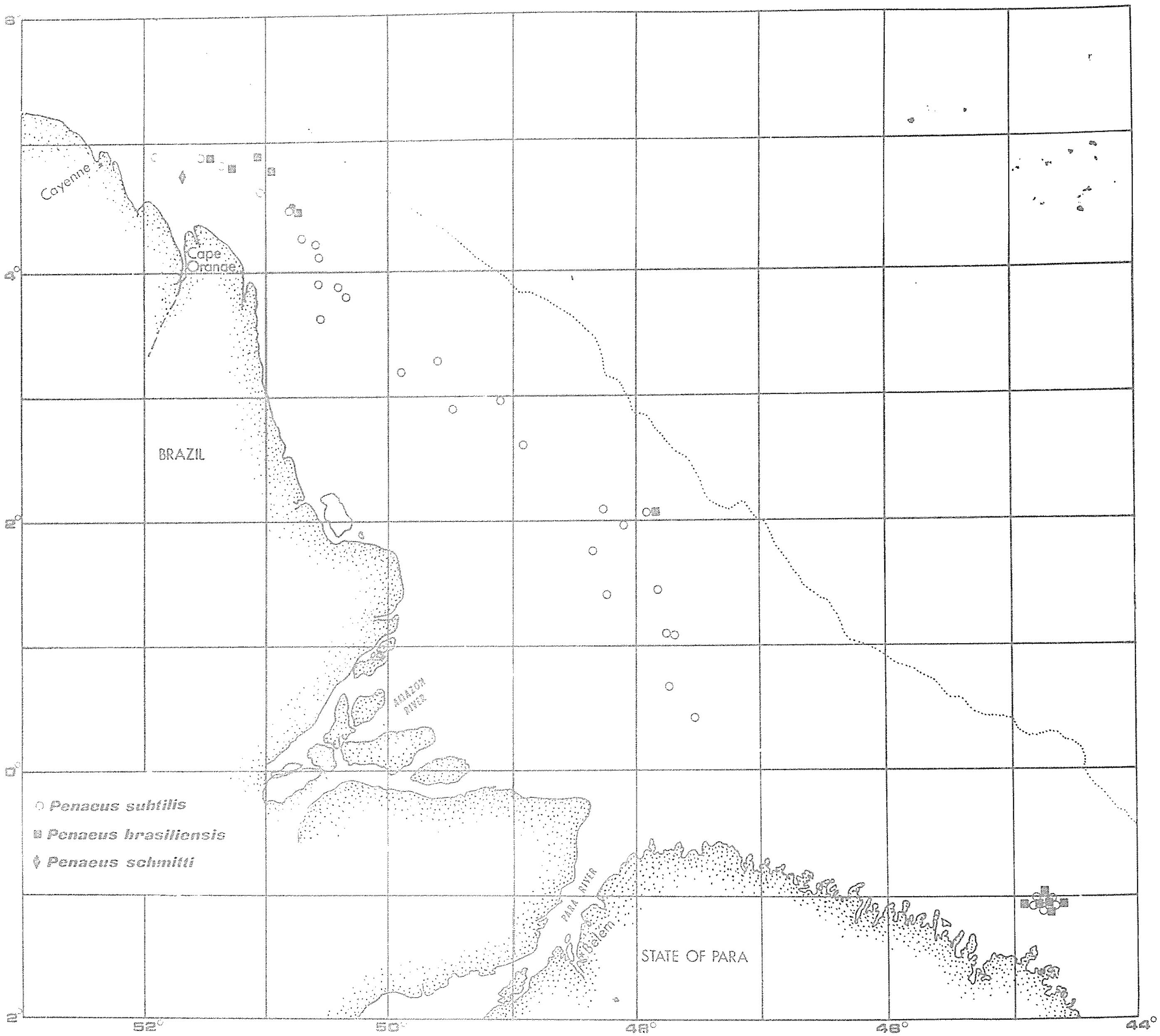


Figure 4.1.6 Occurrence of Commercially Important Species of Shrimp during Cruise 58 (FRV OREGON II)

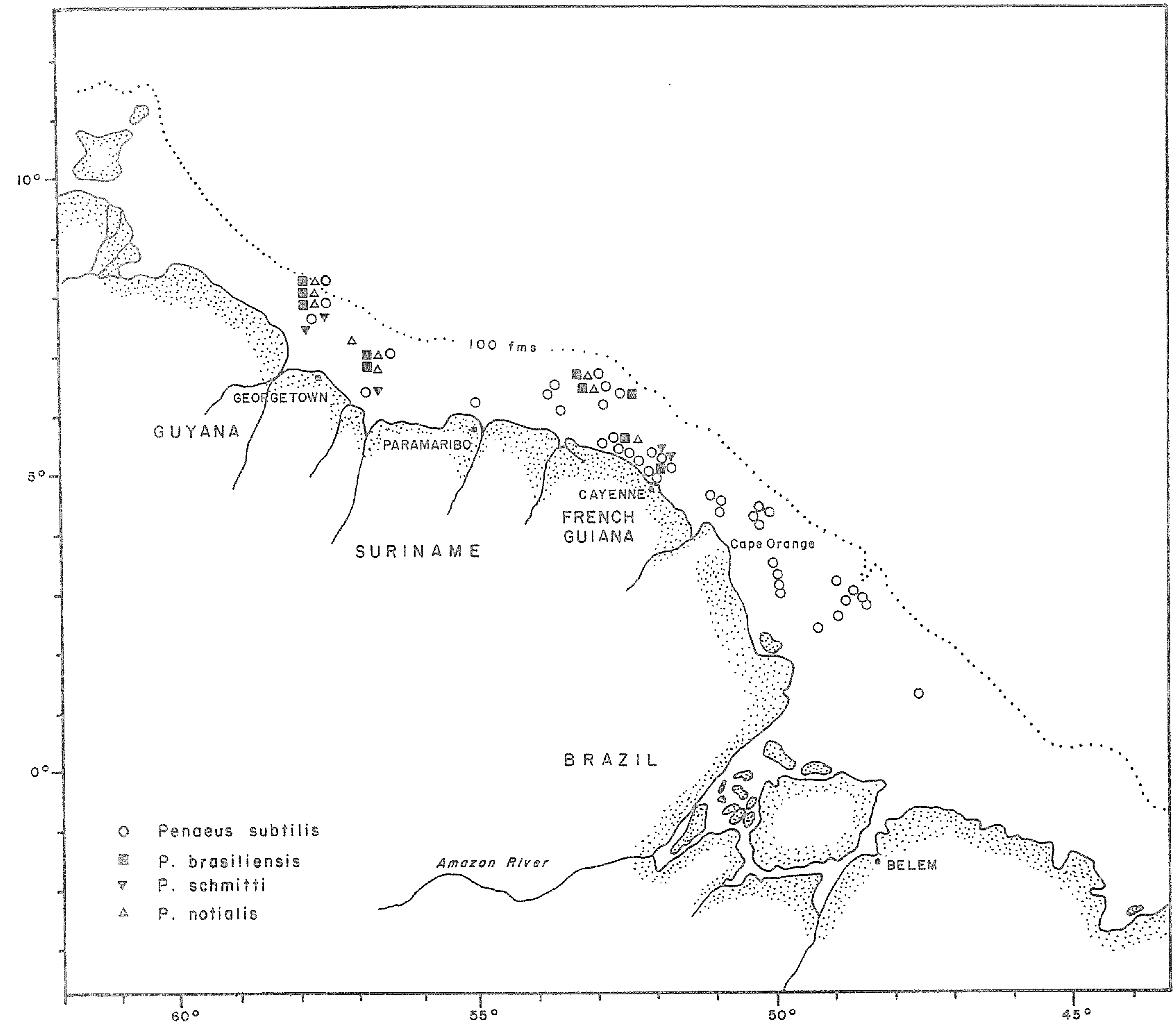


Figure 4.1.7 OCCURRENCE OF COMMERCIALLY IMPORTANT SPECIES OF SHRIMP DURING CURISE 60 (FRV OREGON II)

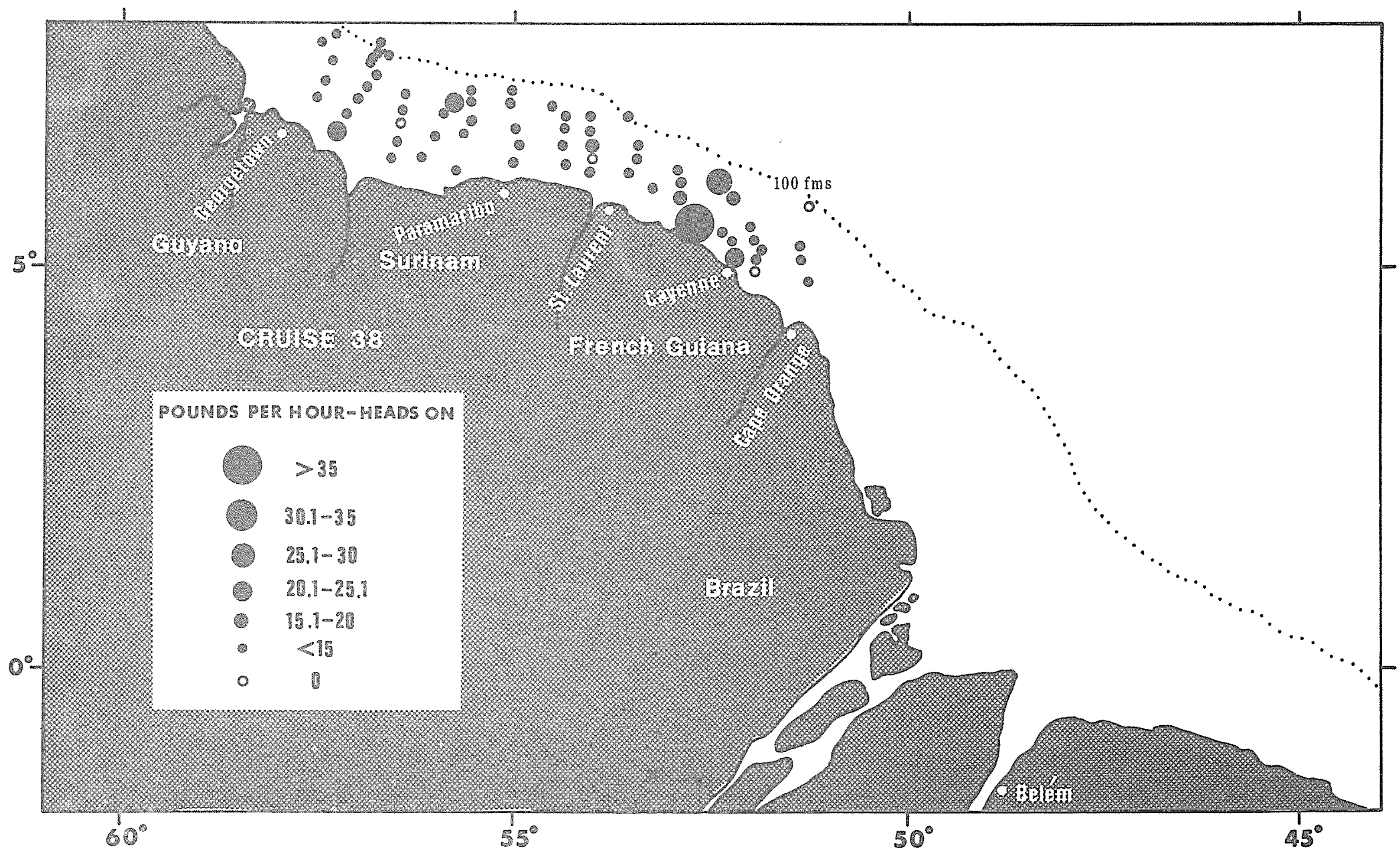


Figure 4.1.8 Distribution of the Mean Catch Rate of Four Commercially Important Species of Shrimp (brown, pink, pink-spotted, and white) during Cruise 38 (FRC OREGON II)

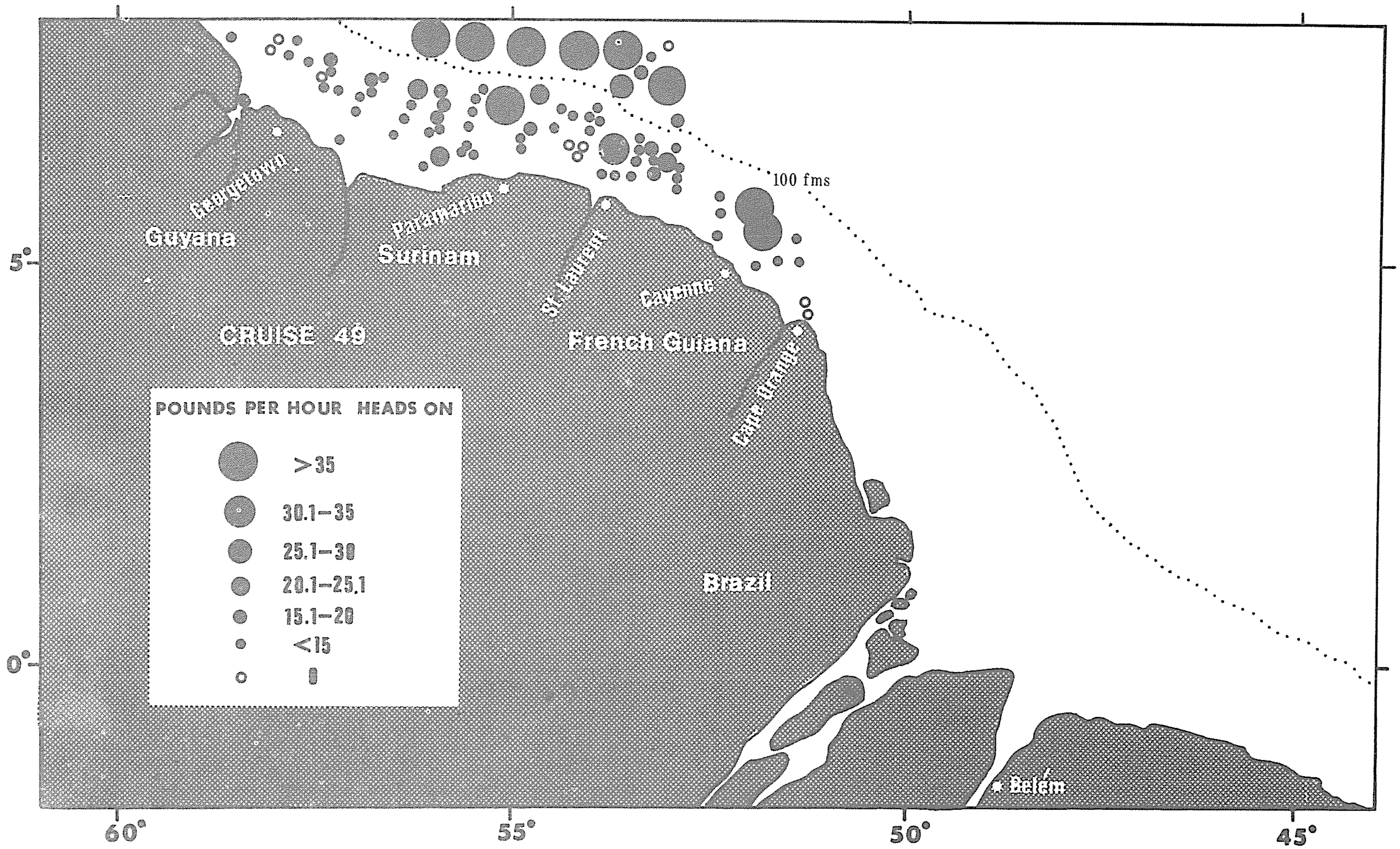


Figure 4.1.9 Distribution of the Mean Catch Rate of Commercially Important Species of Shrimp during Cruise 49 (FRV OREGON II). The plots inside of the 100 fath line represent mean catches of four species (brown, pink, pink-spotted and white) combined, and plots outside of 100 fath line represent mean catch rates of scarlet prawn.

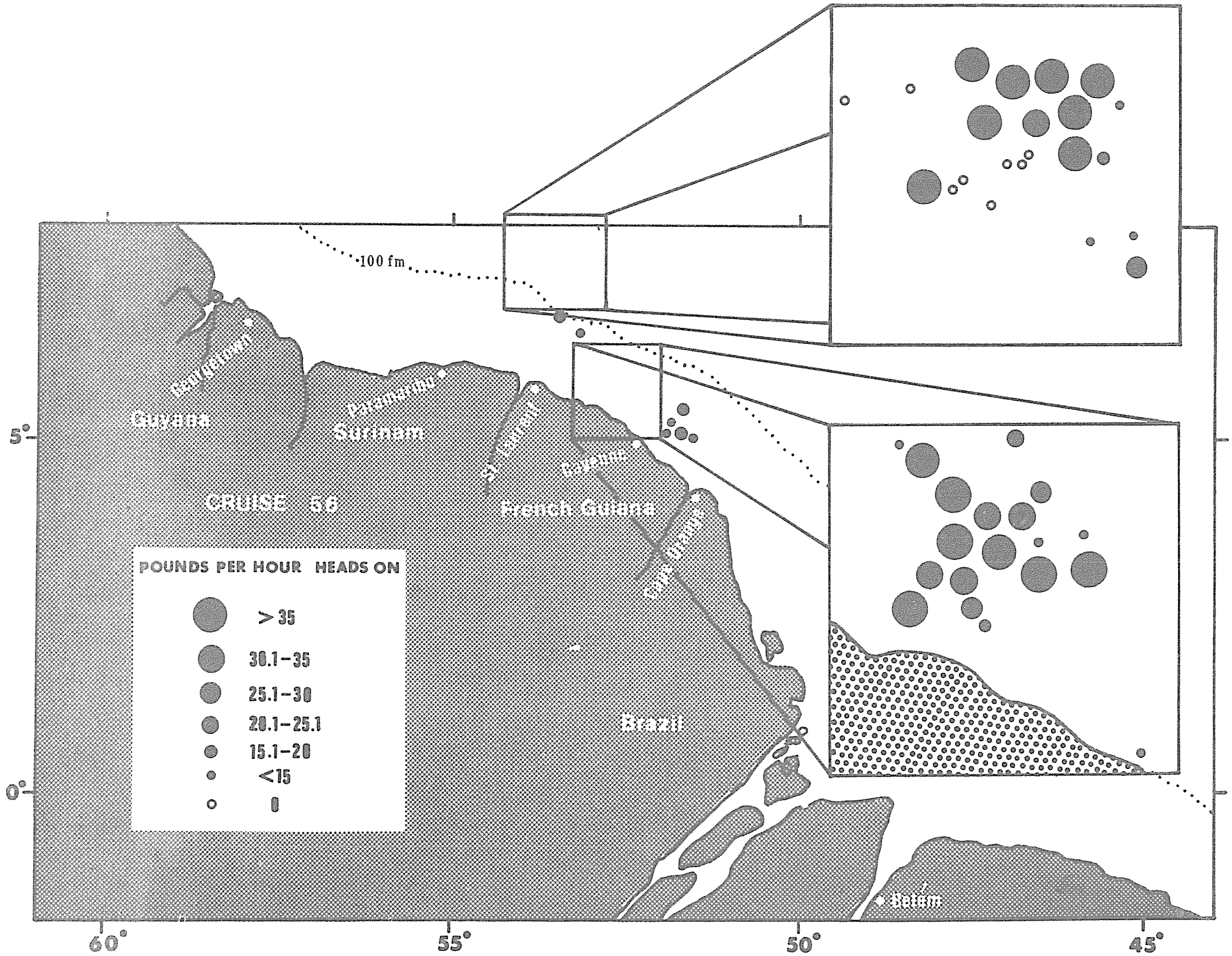


Figure 4.1.10 Distribution of the Mean Catch Rate of Commercially Important Species of Shrimp During Cruise 56 (FRV OREGON II). The plots in the upper rectangle represent mean catch rates of scarlet prawn and in the lower rectangle represent the mean catch rates of brown, pink, pink-spotted and white shrimp.

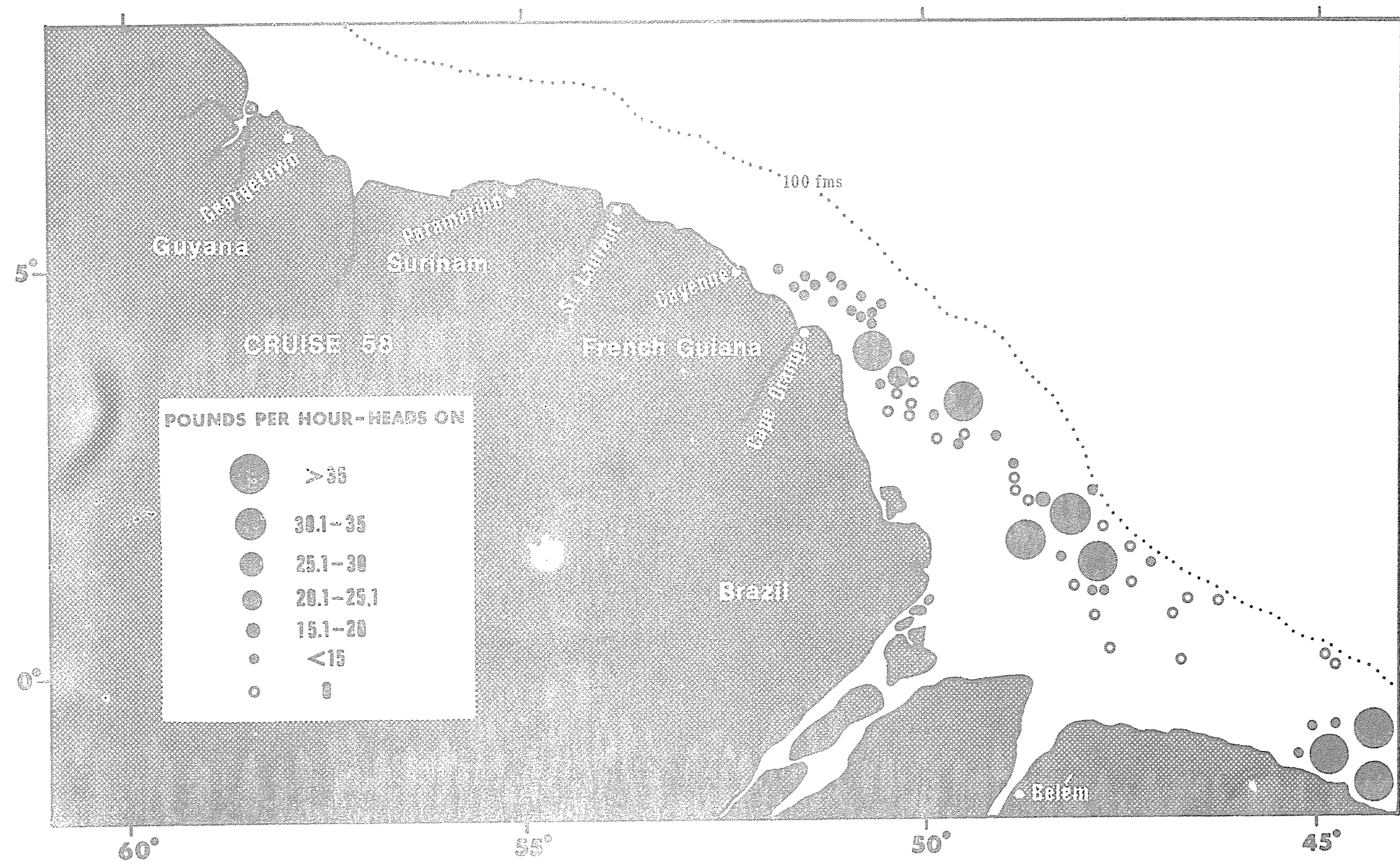


Figure 4.1.11 Distribution of the Mean Catch Rates of Four Commercially Important Species of Shrimp (brown, pink, pink-spotted and white) During Cruise 58 (FRV OREGON II).

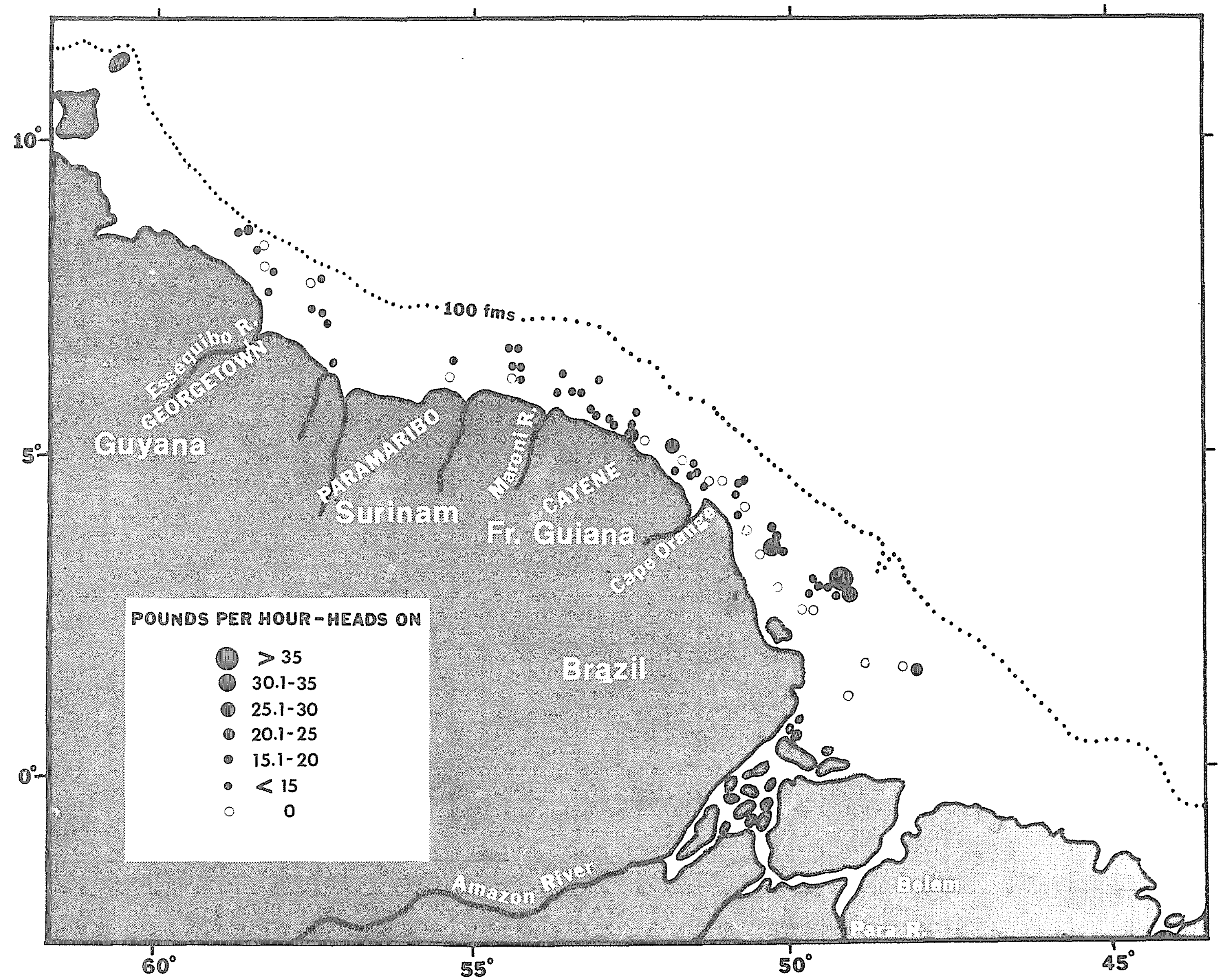


Figura 4.1.12 Distribution of the Mean Catch Rates of Four Commercially Important Species of Shrimp (brown, pink, pink-spotted and white) During Cruise 66 (FRV OREGON II).

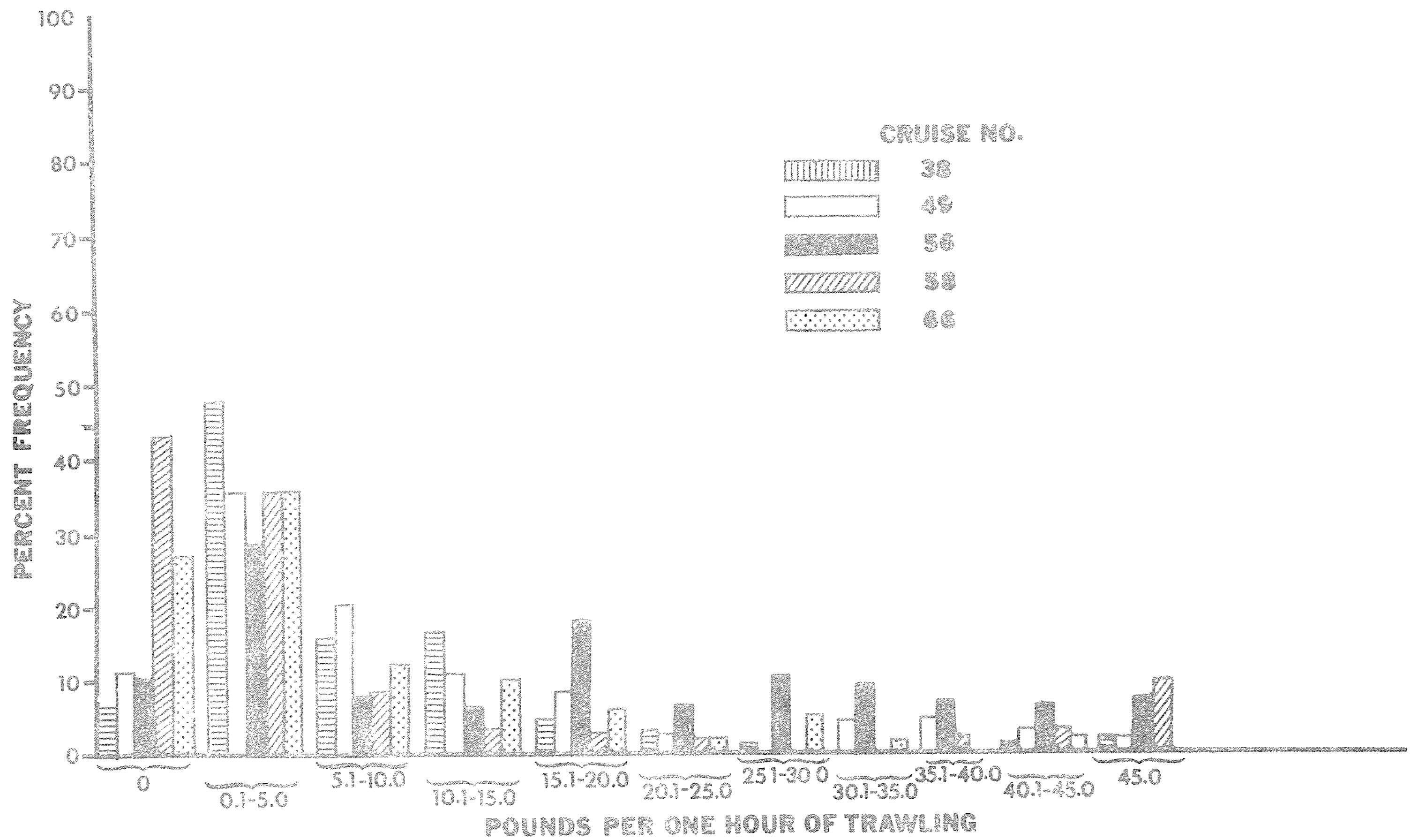


Figure 4.1.13 Frequency Distribution of Shrimp Catches During Five Cruises of FRV OREGON II. Catches expressed as average catch per hour of trawling.

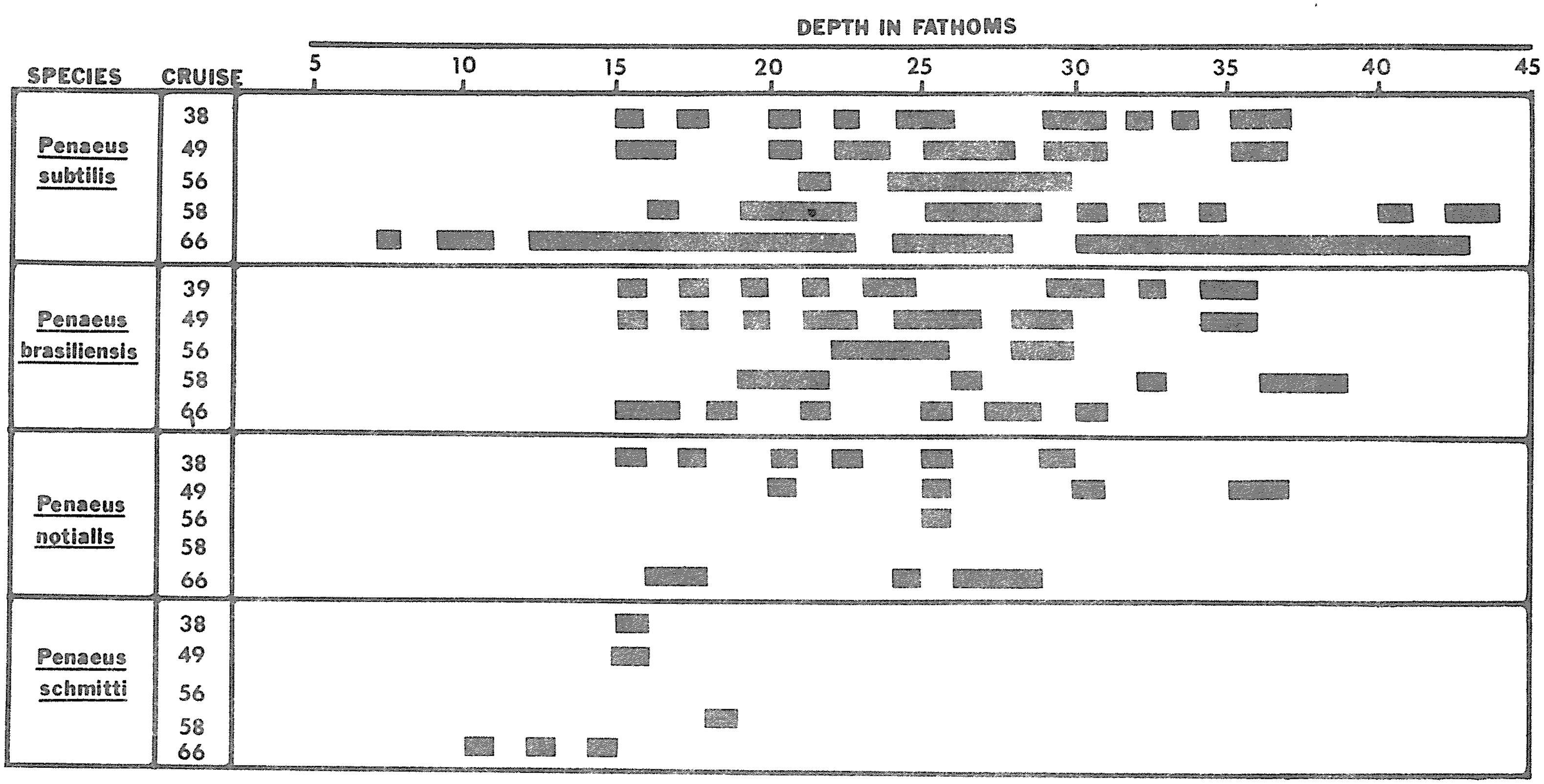


Figure 4.1.14 Occurrence of Four Commercially Important Species of Shrimp at Different Depths of the Guianas-Brazil Shrimp Fishery Grounds, as Observed During Five FRV OREGON Cruises.

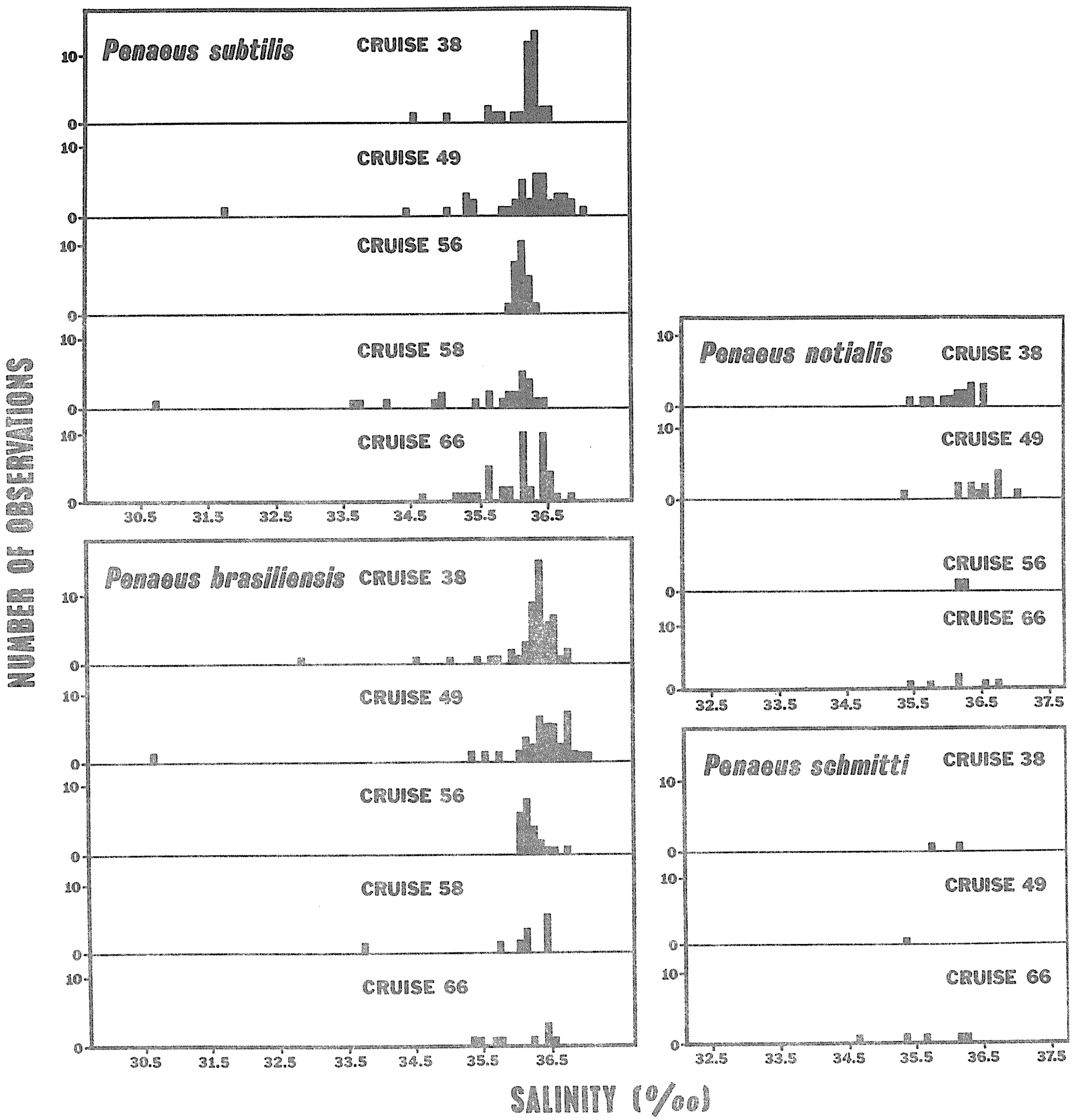


Figure 4.1.15 Frequency of Occurrence of Penaeus subtilis, P. brasiliensis, P. notialis and P. schmitti at Different Salinity Ranges. The data were collected during FRV OREGON II cruises (1972-76) off the three Guianas and Brazil.

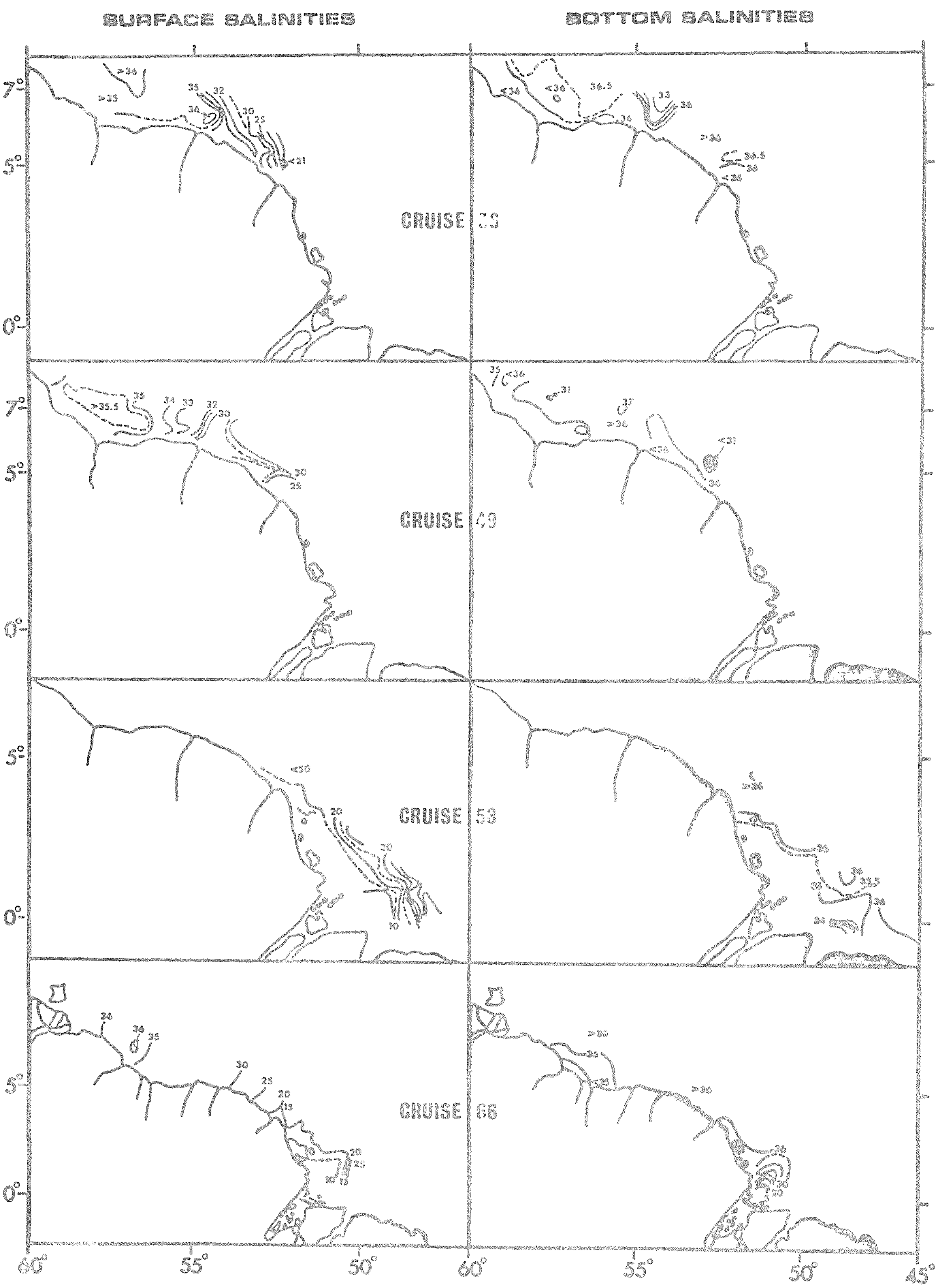


Figure 4.1.16 Surface and Bottom Salinities for FRV OREGON Cruises 38,49, 58 and 66.

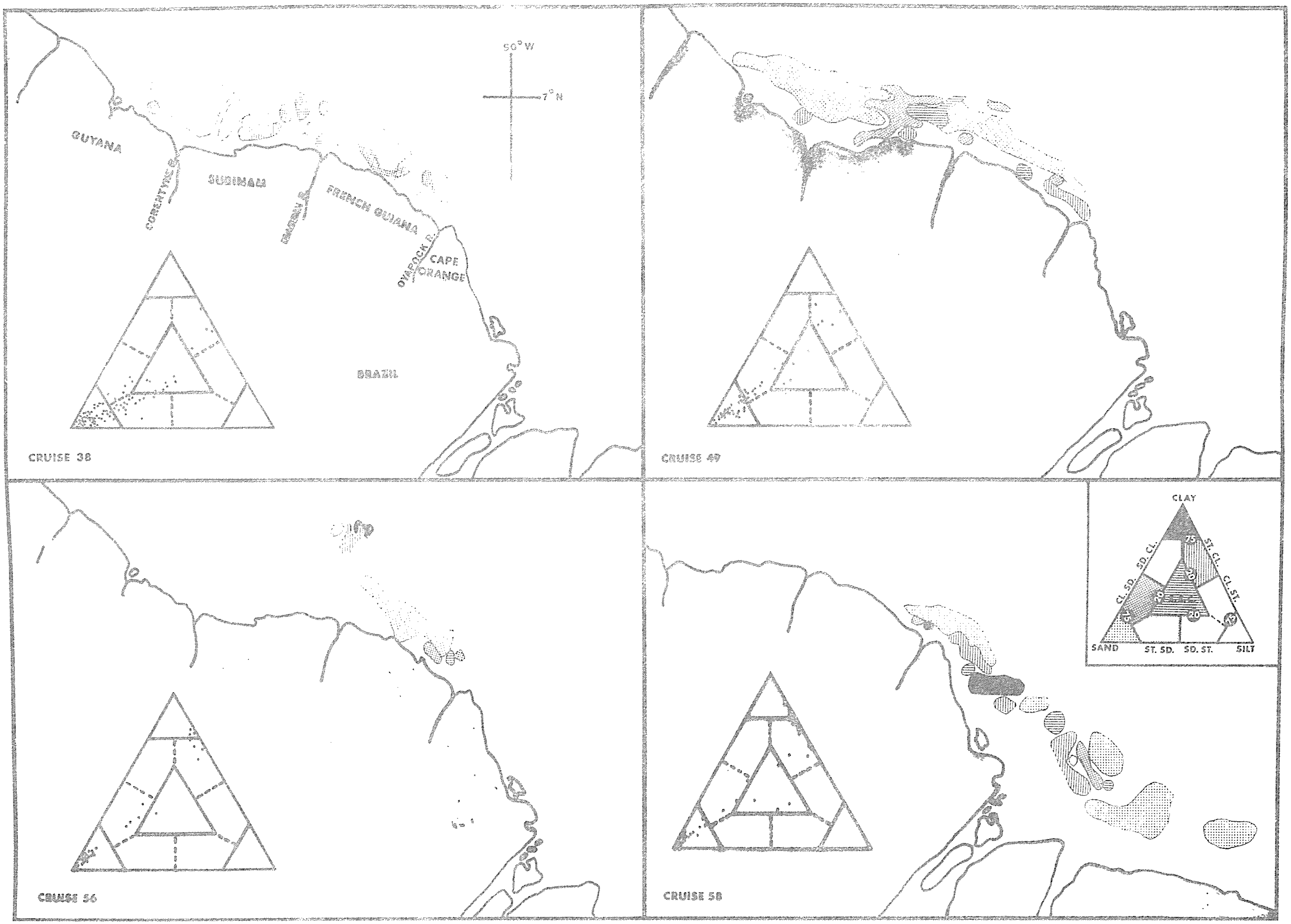


Figure 4.1.17 Textural Classification of Sediments Collected During FRV OREGON II Cruises Off the Coast of of Guianas and Off the Northeastern Coast of Brazil. System of nomenclature based on Sheppard's triangle method as proposed by Sheppard (1954).

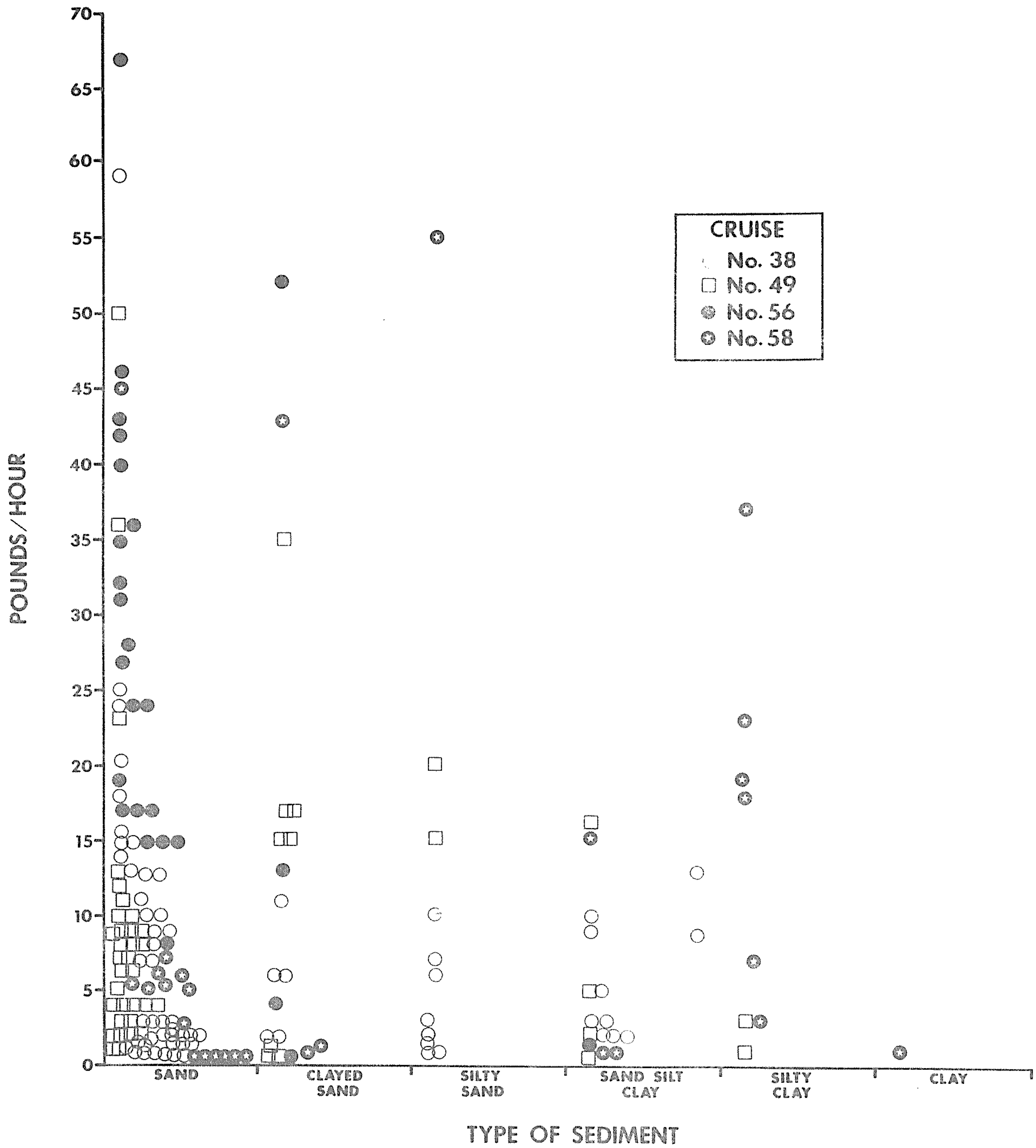


Figure 4.1.18 Scatter Diagram of Average Catch of Shrimp (all commercial species) Per Hour of Trawling Versus Type of Sediment for Four R/V OREGON II Cruises.

Contribution 4.2

The National Marine Fisheries Service Shrimp Research Programme in the Gulf of Mexico

by

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Table of Contents

1. Summary

The Fishery Conservation and Management Act of 1976 extended U.S. jurisdiction from the coastline out to 200 mi and provided authority to manage coastal fishery resources within this zone. Conservation and management of the fishery resources as defined by the Act are based on the best scientific information available. In this paper, the status of the scientific information for U.S. shrimp management in the Gulf of Mexico is reviewed and evaluated. The current Shrimp Research Programme is based upon management needs and is described in terms of goals, objectives and the current programme. The programme is aimed at documenting the geographical boundaries of the shrimp resources, developing surplus production models, developing models which predict potential yield under various levels of fishing, and developing a quantitative model which will estimate current surplus production. Extensive mark and recapture experiments are being conducted in the western portion of the Gulf of Mexico on both white and brown shrimp to obtain information on growth, mortality and migration. Experimental results on growth and migration are described.

2. Introduction

The shrimp fishery in the southeastern United States is the most valuable fishery in the country. In 1977, the Gulf and Atlantic coastal states produced 283 million pounds of whole shrimp valued at over US$ 321 million. Historically, the Gulf of Mexico has been the major production area for shrimp in the U.S. and accounts for approximately 80 percent of the total value of shrimp landed in the U.S. Shrimp production in the area has fluctuated from 134 million pounds in 1961 to 280 million pounds in 1977. The predominant species in the Gulf of Mexico are brown shrimp (*Penaeus aztecus*) accounting for over 53 percent of total production, white shrimp (*P. setiferus*) accounting for about 26 percent, and the pink shrimp (*P. duorarum*) accounting for 15 percent of the total production in the Gulf of Mexico.

Major emphasis on shrimp research was initiated in the late fifties by the Gulf coastal states and the Galveston Laboratory of the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) in an exploration of the shrimp resources and definition of basic biological parameters (Temple, 1973; Caillouet and Baxter, 1973). Since that time, the Gulf states have continued a strong research role in providing scientific information for management of the shrimp resources. Each state was funded by its respective legislator and undertook programmes which provided appropriate information for management. The Federal Government provided biological, catch and fishing effort, and some economic information to the Gulf states. In the early sixties, intensive surveys by the Bureau of Commercial Fisheries throughout the Gulf of Mexico provided basic information on the biology, spawning cycle, maturation, growth and life history of the major shrimp stocks. These findings were summarized by Lindner and Cook (1970), Cook and Lindner (1970) and Costello and Allen (1970). In the late sixties, the Bureau of Commercial Fisheries significantly decreased its emphasis on shrimp research.

In 1976, the U.S. Congress enacted a bill which extended U.S. jurisdiction from the edge of state territorial waters offshore to 200 mi and created regional management councils which have the responsibility for developing management plans for all of the U.S. coastal ocean resources. As a result of this action, emphasis was again placed on providing scientific information for the management of the shrimp resources. This accelerated activity was exemplified by the role of the NMFS Southeast Fisheries Center's Galveston Laboratory in expansion of shrimp research to provide basic scientific information for management to the appropriate management entities.

This paper summarizes expanded shrimp research programmes presently underway at the Galveston Laboratory and describes their objectives, activities and some of the results obtained in the last year and a half.

3. Background

3.1 The Fishery

The distribution and relative abundance of white, brown and pink shrimp have been described by Osborn, Maghan and Drummond (1969), and are depicted in Figure 4.2.1. The brown shrimp population is distributed throughout the northern and western Gulf of Mexico with the center of abundance off Texas. The number of stocks included nor their boundaries have as yet been documented. White and pink shrimp are also distributed throughout the northern half of the Gulf with the center of abundance of white shrimp off Louisiana and that of pink shrimp in southern Florida with highest concentrations around the Dry Tortugas area. White shrimp are believed to have continuous distribution throughout the northern half of the Gulf and into Mexico. Lindner and Anderson (1956) described the results of tagging studies which clearly indicated white shrimp moved across the U.S.-Mexican border. There appears to be two separate stocks of pink shrimp, one on the Campeche Bank off Mexico and the other off South Florida on the Tortugas and Sanibel grounds.

3.2 Description of Tagging Techniques

Shrimp stock assessment has been based largely on information obtained from tagging studies. Shrimp probably were first tagged in the Gulf of Mexico in the mid-thirties (Lindner and Anderson, 1956) using Petersen disk tags. Since that time, many investigators have used an assortment of different tags and techniques to obtain various information on growth, mortality, and movement. Neal (1969) reviewed the marks and marking procedures used up to that point in time. It was recognized in the fifties that the Petersen disk tag was not completely suitable for these studies and as early as 1955, Menzel (1955) successfully marked white shrimp by injection of a solution of fast green biological stain. Costello (1959), and Costello and Allen (1962) perfected the use of biological stains for penaeid shrimp and evaluated the effectiveness of these stains and stain injection techniques. This stain injection technique was later used in the Gulf area by Klima (1964), Allen and Costello (1966), Knight and Berry (1967), and Klima (1974). The stain injection technique was severely limited because only groups of shrimp and not individuals could be identified. As a result, the number of marks was limited as well as the data derived from these studies. This led to the use of fluorescent pigments (Klima, 1965) and PVC internal tags (Neal, 1969); both used secondary marks to permit identifying individuals or groups. Welker *et al.*(1975)

compared modified Petersen disk tags (i.e., 6 mm in diameter compared to 10 mm in diameter of previous Petersen tags) and biological stains used with internal tags as marks for shrimp. In conclusion, they found no significant difference between recovery rates or growth rates using either tag. However, there appeared to be small non-significant differences in the growth rates in which the shrimp tagged with biological stains had a faster growth rate.

The next stage in the evolution of tags was the development of the ribbon tag by Marullo et al. (1976). The ribbon tag was developed and tested to a stage where it could be employed by the National Marine Fisheries Service in the ongoing investigation. It has been modified slightly from the paper described by Marullo et al. (1976) in that the tag is now tapered at the end attached to the needle so that it is easy to insert between the muscular tissue of the shrimp. An Aureomycin mixture is routinely used prior to application to the shrimp to retard infection and secondary bacterial growth. Tags 4 mil in thickness are used to tag juvenile shrimp 50 to 100 mm in total length but for larger shrimp a thicker 6 mil tag is employed.

Present tagging procedures and methods have been described by Neal (1969) and Emiliani (1971). To protect tagged shrimp during release from predation on the sea floor, Emiliani (1971) developed a release canister. Tagged animals are placed in an expendable canister and released overboard while the vessel is underway. The canister drops to the bottom and in ten minutes it opens and the tagged shrimp are released. This greatly reduced mortality by predation at the release site and is a standard technique presently used today.

To insure maximum recovery of tagged shrimp, an incentive system, in one form or another, had been used throughout the Gulf of Mexico. In past instances, awards of US$ 0.50 to US$ 5.00 have been offered for recovered shrimp. On the average, recovery of a tagged shrimp was worth US$ 2.00 to the finder throughout this region for many years. With the initiation of massive tagging programmes more than the usual US$ 2.00 incentive is necessary since some shrimp fishermen have stated it is not worth their time to return shrimp for only US$ 2.00. Conversely, many fishermen return shrimp without monetary reward. To increase the return of recaptured shrimp, a fishing contest was established in which awards ranging from US$ 500 to US$ 50 are paid for recovered shrimp. Fishing contests are run every 45 days during major recovery periods, with four winners for each contest awarded 1st, 2nd, 3rd, and 4th prizes of US$ 500, US$ 200, US$ 100 and US$ 50, respectively. Winning numbers are preselected by computer at the time of release by a priority system. If the first priority tag selected is not recovered, then the second priority is selected and so on until four winners are identified. This tagging incentive system was established for all 1977-78 tag recoveries in the studies which are described in this paper. Tagged shrimp were returned to port agents located in the major ports. These agents normally collect catch and fishery effort statistics, but also handle the recovery of tagged shrimp and have a major responsibility of obtaining and verifying pertinent information on area and date recaptured.

3.3. Biological Data Base

Wise (1976) indicated that the shrimp fisheries of the Gulf of Mexico are near maximun utilization. Lindner (1968) noted and Wise (1976) concurred, that an increase in shrimp yield could be realized by increasing the average size of shrimp harvested. These authors utilized information presently available, however, they recognized that present data did not allow proper quantification of the shrimp populations in the Gulf of Mexico.

Christmas and Etzold (1977) reviewed the available fishery data and summarized information on growth, mortality and weight/length relationships. The growth information presently available is for a few specific localities and seasons and may not be applicable throughout the range of the species and/or stock. Lindner and Anderson (1956) analysed tagging information obtained in the thirties to estimate growth; however, it is felt by many investigators that the large Petersen disk tag used by these scientists to mark shrimp may have curtailed or decreased growth rates of marked individuals. Therefore, estimates of white shrimp presented by Lindner and Anderson (1956) may be underestimates. Growth information summarized by Klima (1964 and 1974) was based on white shrimp marked with biological stains and identified by size groups rather than individuals. The growth model developed was based on average sizes and may not provide information as accurate as that obtained from individuals tagged with numbered tags for which growth of individuals can be estimated. Parrack (1978) modeled brown shrimp growth, utilizing data from shrimp tagged with small Petersen disk tags, in which growth of individuals was recorded. He summarized results of tagging experiments from 1968 through 1974 utilizing recoveries of 5 100 individuals, and compared his growth model with those developed by Chavez (1973) for the brown shrimp stocks off Mexico and by McCoy (1972) for brown shrimp stocks off North Carolina. Growth estimates for pink shrimp off North Carolina have been made by McCoy (1972) using shrimp marked with biological stains. Iverson and Jones (1961), Kutkuhn (1966) and Berry (1967) estimated pink shrimp growth for south Florida; Kutkuhn and Berry used biological stains and Iverson and Jones used Petersen disk tags.

Available mortality estimates for brown and white shrimp are limited to a few locations and seasons. If the estimates represent the actual mortalities for the stocks concerned, then each stock may be subjected to extremely different rates of exploitation and to vastly different rates of natural mortality. However, one must question whether the lack of consistency among these authors in estimates of mortality are real or an artifact due to differences in shrimp marking procedures and techniques in estimating mortality. A prime example of the variation in mortality rates is exhibited in the available estimates for weekly instantaneous total mortality (Z) for pink shrimp, which range from 0.11 (Berry, 1969) to 1.51 (Kutkuhn, 1966). Variability and lack of confirmation in estimates of growth and mortality does not provide a good information base required to develop relatively accurate yield models.

Recruitment, survival and growth of white and brown shrimp have been shown to be related to environmental conditions in the estuary during the juvenile and sub-adult phases of the shrimp's life history by St. Amant (1962), Barrett and Gillespie (1975), and Grady and White (1973). These authors and other scientists along the Gulf Coast believe that environmental conditions do affect recruitment of shrimp stocks in the estuarine systems. At this point in time, however, there is not a clear understanding of the degree of variation in growth or mortality between seasons, areas, and years.

Recognizing the problems associated with the dynamics of the penaeid shrimp stocks in the Gulf of Mexico, Christmas and Etzold (1977) identified four high priority biological research objectives to be accomplished for shrimp management as follows:

(1) To develop data on natural mortality rate, age, and growth rates;
(2) To delineate the offshore spawning grounds of commercial shrimp, and to determine the recruitment patterns for larvae and postlarvae;
(3) To determine those commercial landings not reported and the accuracy and precision of data collection techniques;
(4) To determine yield relationships including MSY.

The Gulf of Mexico Fishery Management Council, which has responsibility for developing fishery management plans for all fisheries in the Gulf of Mexico, concurred with Christmas and Etzold's (1977) recommendations regarding the high priority research areas. They further indicated that research be undertaken to identify the boundaries of brown and white shrimp stocks which overlap the U.S. and Mexico, and estimates should be obtained on growth, mortality, and yield for these "trans-boundary" stocks.

In summary, the information available for management of the shrimp resources of the Gulf of Mexico is wanting and specific information needs to be developed on growth and mortality for the major stocks.

4. Present Research Programme

The goal of the present shrimp research programme is to improve the quality of scientific information provided to the Regional Fishery Management Councils for management of U.S. shrimp resources. It is anticipated that the following four major steps will be required.

(1) Document the geographical extent of the shrimp resources.
(2) Develop a surplus production model.
(3) Develop a model which predicts the potential yield under various fishing strategies.
(4) Develop a quantitative model which estimates current surplus production.

The first step will be to document the geographical boundaries of each stock. Specifically, the geographical origin or genetic makeup of individuals in the stock are of little interest, however the spatial limits occupied by the exploited population are required.

The second step, the catch and effort model, will be developed from catch and effort data to derive estimates of the surplus production. Application of this approach to allow for the unique biology of shallow-water shrimp could be a long-term ongoing project. We recognize that this type of approach appears straightforward and simple; theoretically, it is not and may not be directly applicable to the shrimp fisheries at all. As a management tool, this approach may not be the most straightforward or realistic for shrimp stocks that undergo drastic seasonal changes in abundance (Geibel and Heimann, 1976). However, as a first approximation, it can provide useful information.

The third approach will develop an analytical model to predict the potential yield under different harvesting regimes. This model is commonly referred to as a yield-per-recruit model as described by Beverton and Holt (1957). We plan to utilize the approach Paulik and Bayliff (1967) modified to account for age-season natural mortality and growth variable exploitation patterns and other factors specific to shrimp stocks in the Gulf of Mexico. I believe this model, if properly constructed, can be used as a guide to manage the exploitation of shrimp stocks and to maximize yield from these stocks. This model, however, cannot estimate the magnitude of the yield nor be used to derive a fishing strategy that will guarantee sustenance of a stock size that will continue to produce the maximum yield.

The fourth step will overcome shortcomings of the first two steps in that current estimates of stock size will be input into a model to provide accurate estimates of surplus production. This model will require accurate input data in terms of natural mortality, growth, and current estimates of stock size. The major problem will be estimation of current stock sizes. Cohort analysis will be applied to age-catch data to estimate past stock sizes and fishing mortalities, then a history of recruitment abundances and fishing mortalities can be derived. At this point, the dynamic biological system for the resource is quantified. Catch quotas can be set with known results, and the impact of any management regime and environmental circumstances can be defined.

There is a need for improved estimates of growth and mortality because yield models are dependent on accurate estimates of these parameters. It has been previously shown that the present information on growth and mortality is limited, and in conclusion, there are unsolved questions concerning variation in growth in relation to (1)geographical area,(2) season, and(3) between years. Information is lacking on natural mortality and variations associated with(1) age,(2) area, and (3) season.

The objectives for the shrimp research programme undertaken from the Galveston Laboratory in the first year of study are:

(1) To define the growth of juvenile white and brown shrimp cohorts from a single estuary;
(2) To determine juvenile shrimp migration routes; and
(3) To estimate mortality of adult brown and white shrimp associated with a specific estuary.

The objectives for the second year are identical except to expand the programme to obtain information on the "trans-boundary" brown shrimp stocks which occur from Corpus Christi, Texas to Tampico, Mexico.

4.1. Documentation of Geographical Extent of the Shrimp Resources

Catch and effort information was used to document the geographical boundaries of major stocks within the Gulf of Mexico, and this information (Fig. 4.2.1) indicates a continuum over broad geographical areas which cannot be used to define isolated stocks. Therefore, the best approach to solve this problem will be to examine the distribution of recoveries of tagged shrimp. Tagging has been conducted in many areas of the Gulf of Mexico; however, the data on recoveries have not been adequately summarized to describe the geographical boundaries of the major stocks. Therefore, the current tagging programme (as described later) will provide, along with historical tagging data, specific information on shrimp stock boundaries in the western Gulf of Mexico from New Orleans westward to Tampico, Mexico.

4.2. Surplus Production Model

Kutkuhn (1962) described the current Gulf of Mexico shrimp statistical survey initiated in 1956. Outputs from this survey are annual and monthly shrimp landing and effort statistics which are used as input to the catch and effort model. Standardized fishing effort by species is currently being determined. In the northern Gulf of Mexico vessels catch either brown or white shrimp or both on a given trip. The published landing statistics do not distinguish fishing effort by species. As a result, specifically directed effort on each species is presently not available from published reports. However, catch and fishing effort information has been recorded from interviews of fishermen and is being examined and analysed by individual trip. Total fishing effort by species can be estimated by examining individual trip slips from interview dates and allocating effort by species to the non-interview data.

The next major undertaking is to examine temporal trends in vessel characteristics. Fishing gear on shrimp trawlers has undergone significant changes in recent years (Captiva, 1966 and 1970), primarily in terms of increased size and power. Juhl (1966) and Klima (1970) described the trends in fishing gear and tactics employed by the Gulf of Mexico shrimp fleet. These studies highlighted the apparent change in fishing effort during the sixties. Trawls employed in the sixties averaged around 40 to 50 ft "head-rope length", whereas at the present time double-rigged boats are fishing with 60 to 70 ft "head-rope length" nets. Many fishing vessels in the Gulf of Mexico and along the eastern seaboard have converted from double-rig trawlers to twin-trawlers; namely, four nets fished concurrently. We plan to undertake a study to evaluate the trends in fishing effort and to standardize fishing effort. This analysis will encompass examination of size of vessel, horsepower, and size and type of fishing gear, from 1960 to the present.

Utilizing catch and effort statistics which have been collected for the past 20 years throughout the Gulf of Mexico from all the major fisheries, a logistic model was developed by Klima and Parrack (1977). They combined the shallow-water shrimp species data from 1956-76 for the Gulf of Mexico since they could not compute directed species effort. The model is described as:

$L = f(a + bf)$

where,

$a = 0.45528$, equation constant

$b = -0.9387039622 \times 10^{-6}$, equation constant

f = days fished

L - Landings

That model predicts an equilibrium landings effort relation that maximizes at 55 000 t tail weight with 225 000 days fished. Parrack (personal communication) estimated a steady state condition for the combined shallow-water shrimp fisheries in the northeast Atlantic to be modelled by the equation $L = f(4.397764236 - 0.000637235f)$. He estimates that model maximizes equilibrium landings at about 7 600 t tail weight with fishing intensity at about 3 500 operating trawls (Figure 4.2.2). In 1971, almost 9 000 t of tails were produced in this fishery and landings since indicate the resource is being fully utilized.

4.3 Model Inputs - Growth - Mortality and Stock Boundaries

White Shrimp

Information provided by mark and recapture studies will provide the major input into the white shrimp yield-per-recruit models. With the concurrence of the Gulf of Mexico Fishery Management Council, a tagging study was undertaken in Caillou Lake, Louisiana by the Galveston Laboratory in cooperation with the Louisiana Fisheries and Wildlife and Louisiana State University Sea Grant Office. Juvenile white shrimp were tagged and released each month from July to November of 1977, the period during which they are normally found in the Louisiana estuarine systems. The objectives of the study were:

(1) to measure seasonal growth and migration patterns, and

(2) to determine the distribution of the estuarine system to the offshore stocks.

Over 36 000 white shrimp were tagged and released from July through October in this estuarine area. Concurrently, 8 338 white shrimp were tagged and released offshore of this estuary from August through December. As can be seen from Table 4.2.1, approximately 9.3 percent of those released were recovered from July through April 1978. This recovery rate is high in comparison to previous mark and recapture experiments conducted in the Gulf of Mexico (Clark *et al.*, 1974). Although there was intensive fishing pressure in the study area, we believe that one of the factors contributing to the high recovery rate was the new monetary incentive system for return of recaptured tagged individuals.

Table 4.2.1 Number of tagged white shrimp released in Louisiana waters from July to December 1977 and number and percent recovered

Location	Released	Recovered	Percent
Inshore	36 639	3 807	10.4
Offshore	8 336	383	4.6
Total	44 975	4 190	9.3

The generalized movement of tagged shrimp from the Caillou Lake area is depicted in Figure 4.2.3. Most of the shrimp migrated westward although a small contingent did move eastward, as expected. Recovery data showed an unexpected movement out of the estuary to the offshore area and then back into other estuarine areas. In 71 days one tagged shrimp migrated from Caillou Lake into Galveston Bay; a distance of 220 n mi. Several shrimp tagged in the estuary moved offshore and then migrated to the upper reaches of Vermilion Bay, Louisiana. Another unexpected development was the movement inland of some of the marked shrimp. We believe that part of this was attributed to the fact that we were able to tag and release extremely small shrimp (50 mm total length). Previous to this study, the smallest marked shrimp released in the Gulf of Mexico were usually larger than 80 mm total length (Clark et al., 1974). Lindner and Anderson (1956) depicted offshore movements similar to those observed in this study. However, they did not show movement of shrimp from Louisiana into Texas waters. Most of the tagged shrimp were recovered in close proximity to the release site, Caillou Lake (Fig. 4.2.4). In analysing the recoveries of tagged shrimp, I took the opportunity to plot the recoveries of the July cohort over time (Fig. 4.2.5). Two tagged animals were recovered in July, one in Caillou Lake and the other approximately off Marsh Island, Louisiana. In August the July cohort recoveries were distributed around Caillou Lake with a large number being recovered in the offshore waters of Vermilion Bay. In addition, two marked shrimp migrated northward farther into the estuarine system. By September, most of the July cohort recoveries occurred around the 93° longitude line. Two shrimp were also recovered inside Vermilion Bay and another tagged shrimp was recovered north of the estuarine system surrounding Caillou Lake. By September, the westward movement appeared to have stopped and the shrimp appeared to be distributed along the Louisiana coast from Grand Isle to Sabine, Texas. In summary, the distribution of recoveries suggests a rapid movement out of the estuarine complex with some movement westward in August and considerable movement to the west in September. Thereafter, the tagged population appeared to remain more or less stationary. Movement patterns of small shrimp suggest for the first time that shrimp leave estuaries and migrate into other estuarine systems.

We are presently analysing the growth patterns from the recaptured shrimp and are in the process of constructing a growth model for each of the cohorts in this study. I have taken the liberty of plotting growth of the four monthly cohorts along with an approximate fit of a growth curve to the points. Figures 4.2.6 through 4.2.9, depict growth of the individual cohorts. These figures clearly indicate that growth was very rapid in July, almost as rapid in August, decreasing in September and very slow in October. A comparison of all four lines indicates that the growth is different for the monthly cohorts (Fig. 4.2.10). Probably the main reason for the change in growth rates is that water temperatures are high in July and decrease thereafter, thus reducing the growth rate. Phares (unpublished report) has developed a temperature-dependent asymptotic growth model for white shrimp that accounts for 81 percent of the variation between release size (length) and recapture size. Time-dependent asymptotic growth models using the same data set accounted for about 70 percent of the variation. She concluded that linear growth models were inadequate and that the three asymptotic growth equations (i.e. Richards, Logistic and von Bertalanffy) fit the data almost equally well. In addition to examining the growth patterns in more detail, the Galveston staff will be estimating rates of white shrimp mortality.

Brown Shrimp

During the Spring of 1978, the Galveston Laboratory in cooperation with the Louisiana Department of Fisheries and Wildlife, the Texas Parks and Wildlife and the Instituto Nacional de Pesca of Mexico initiated a major brown shrimp mark-recapture experiment. The objectives of this experiment were similar to those described previously, namely to obtain estimates of growth, mortality, and migration of the brown shrimp stocks in the Gulf of Mexico. A further objective was to delineate the stock boundaries of the brown shrimp resources which occur from Corpus Christi, Texas to Tampico, Mexico. Tagging was initiated in May in Caillou Lake, Louisiana and Port Mansfield, Texas (Fig. 4.2.11). To date 81 182 tagged shrimp were released in inshore areas and 26 877 were released in the offshore areas. In September a U.S. research vessel, OREGON II, participated with Mexico in a major mark and recapture cruise off the Mexican coast. During that month, 9 000 tagged shrimp were released from Brownsville, Texas to Tampico, Mexico.

Location and movement patterns of recoveries during the Spring and Summer months are depicted by Figure 4.2.12. The releases off Louisiana indicate a movement to the east and westward from both offshore release sites. Patterns of recaptured shrimp released around Caillou Lake clearly indicate movement along shore across Vermilion Bay to the west and some eastward movement. Texas recoveries to date have been few but these indicate a coastwide movement both to the south along the U.S. coast toward Mexico and some movement northward toward Galveston. Table 4.2.2, provides a summary of the number of releases and recoveries as of 30 October. It is anticipated that more tagged brown shrimp will be recovered throughout the next year.

Table 4.2.2. Number of tagged brown shrimp released in the Gulf of Mexico from May through September 1978 and number and percent recovered through October 1978.

LOCATION	NUMBER RELEASED	NUMBER RECOVERED	PERCENT
Inshore			
Texas	42 096	6	-
Louisiana	39 086	3 963	10.1
Offshore			
Texas	4 331	170	3.9
Louisiana	13 524	428	3.2
Mexico	9 022	1 052	11.7
Total	108 059	5 619	5.2

4.4. Other Inputs to Management

Fishery management involves two basic decisions; first, to determine the optimum resource yield, and second, to allocate this yield among the various user groups. This entails decisions and regulations which affect how and to what degree we use the resource. Contrary to the practice of the past, when the objective of management was frequently to achieve a harvest of fish at the maximum sustainable yield (MSY), U.S. fishery management will, in the future, fix the quantity that can be taken rationally on the concept of optimum yield. Recently, Roedel (1975) defined optimum yield as "a deliberate melding of biological, economic, social and political values designed to produce the maximum benefits to society from a given stock of fish". This means that the desires of all of the users of a resource will be considered in determining the allowable catch. This is different from the full utilization of maximum sustainable yield concept, where the commercial potential is the consideration in the harvest of the annual surplus. The concept of "optimum yield" put forward by Roedel is stated in broad terms and several attempts have been made to develop a more operationally useful definition. In the extended jurisdiction legislation, optimum yield is defined as "a yield which provides the greatest benefit to the United States as determined on the basis of maximum sustainable yield of a stock or stocks of fish as modified by relevant ecological, economic and social factors". Another proposal would define optimum yield as "the maximum sustainable yield modified by an explicit amount for a specific purpose". In both of these refinements, an attempt has been made to base the yield on a biologically determined value, MSY, and to depart from this value in such a manner that the subjective decisions implicit in including socioeconomic factors are clearly spelled out so that their rationale can be fully debated.

To develop information for the optimum yield concept, we have initiated social and economic research related to the shrimp fishery in three parishes in Louisiana. In 1978, we have initiated a contract with Louisiana State University to develop cost and earnings data from commercial and recreational shrimp harvesters. On the social side, LSU will be developing data on ethnic backgrounds; attitudes toward fishing, family and social links, and financial well-being of shrimp fishermen. We hope to expand these studies to other Gulf Coast states in the near future.

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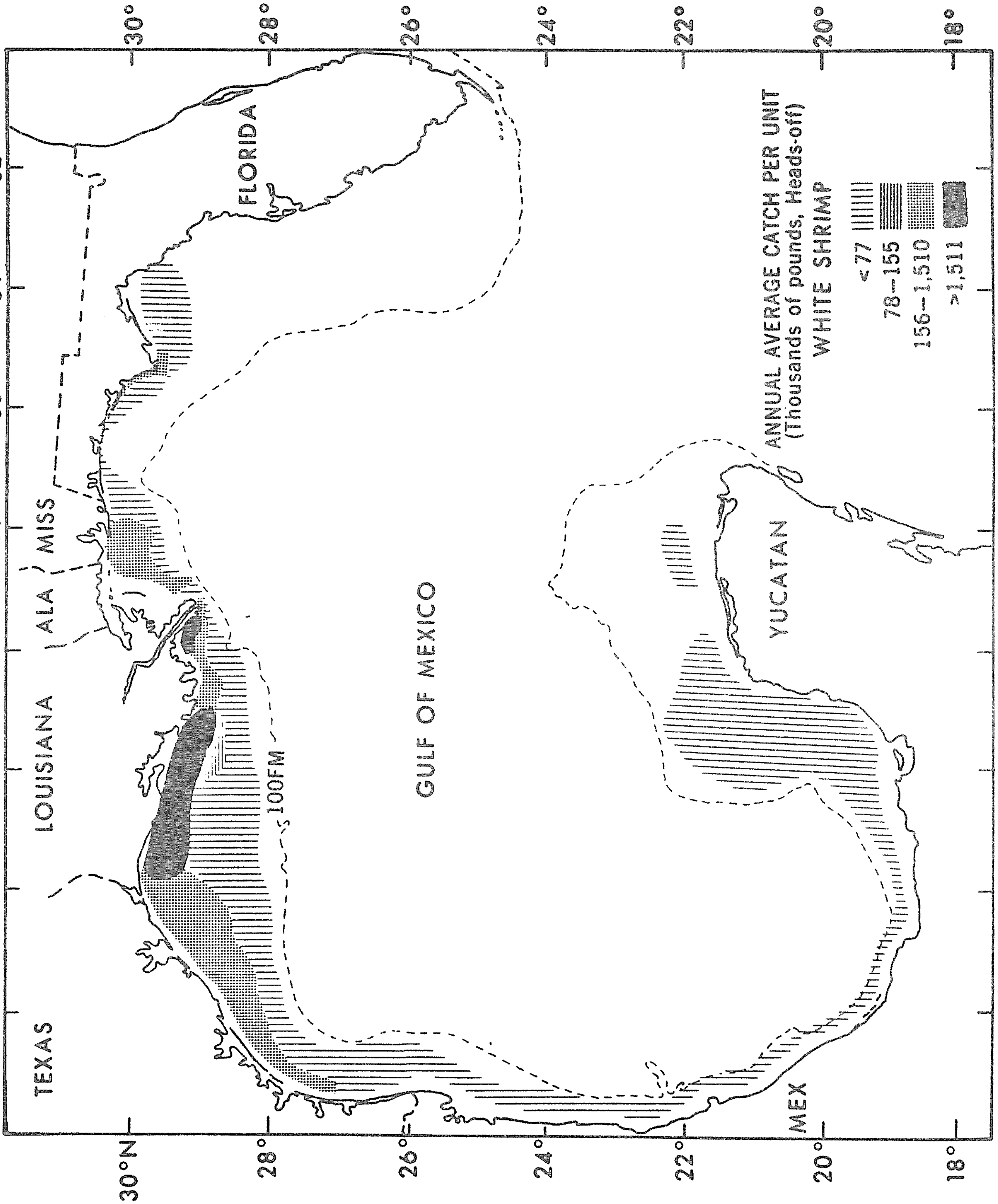

Figure 4.2.1.a Distribution of Catch per Unit (thousands of punds) of White Shrimp in the Gulf of Mexico

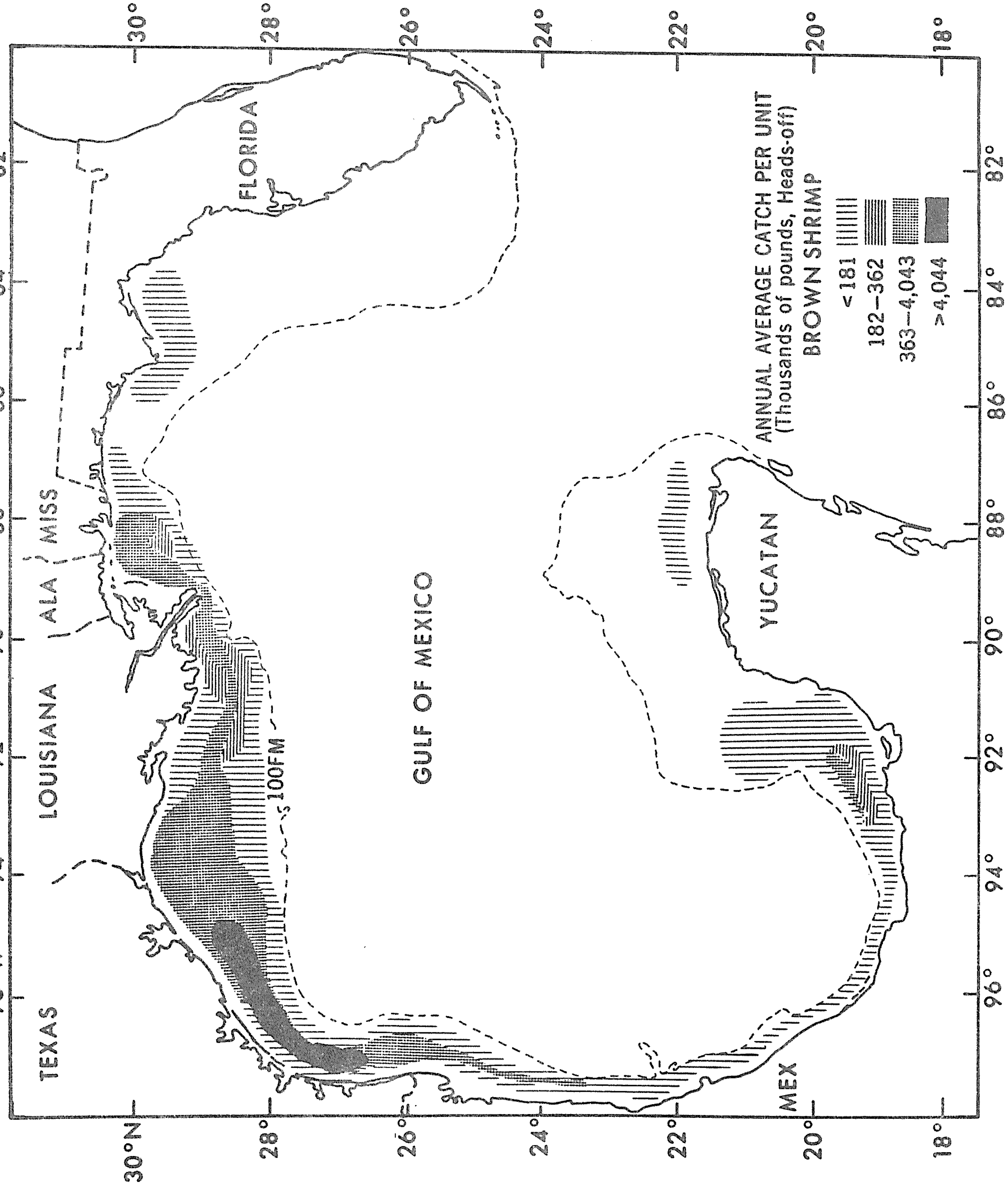

Figure 4.2.1.b Distribution of Cath per Unit (thousands of pounds) of Brown Shrimp in the Gulf of Mexico

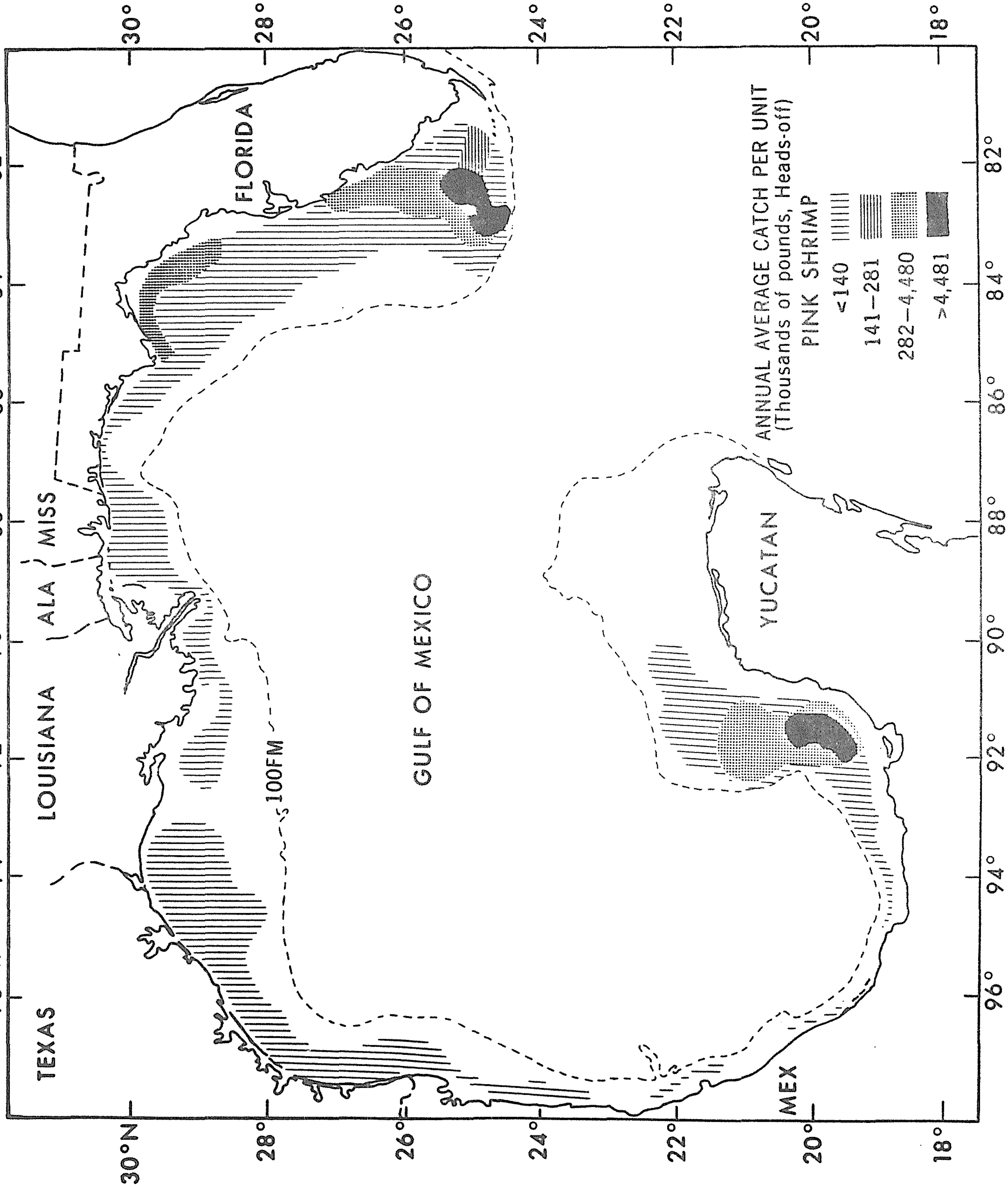

Figure 4.2.1.c Distribution of Catch per Unit (thousands of pounds) of Pink Shrimp in the Gulf of Mexico.

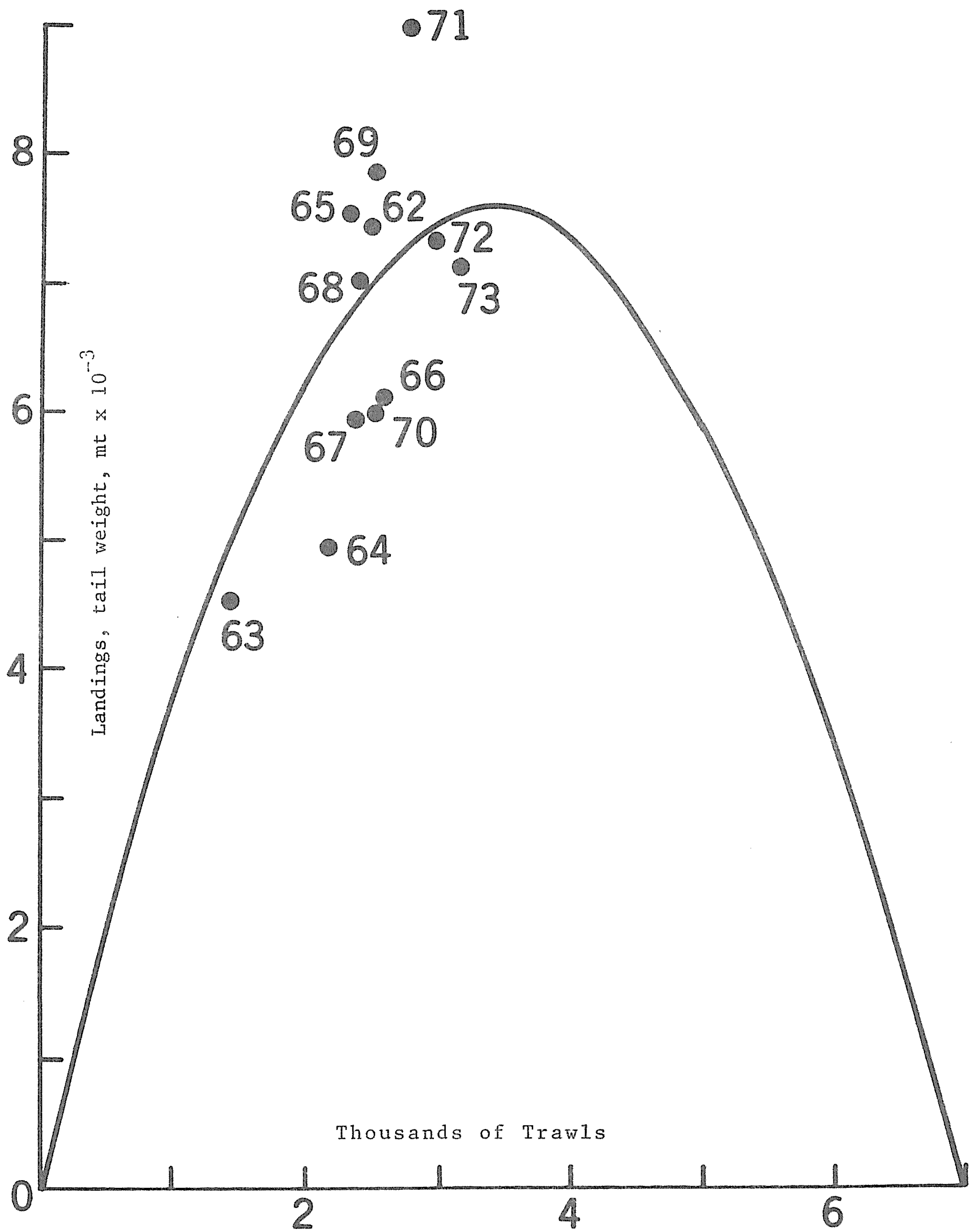

Figure 4.2.2 Relation Between Fishery Effort and Landings of Shallow-water Shrimp in the Northwest Atlantic Ocean

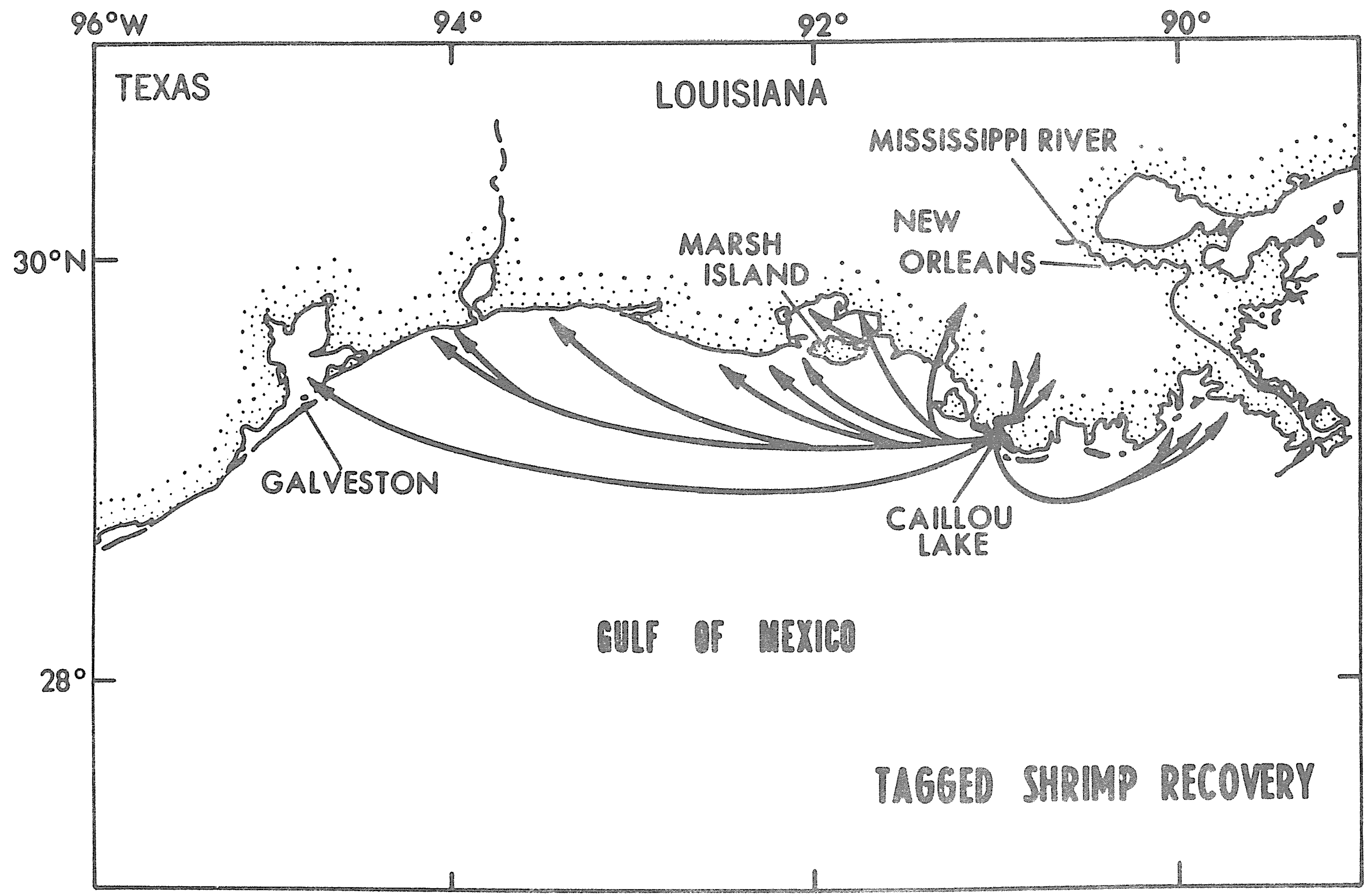

Figure 4.2.3 General Movement Patterns of White Shrimp Released at Caillou Lake from July to October 1977.

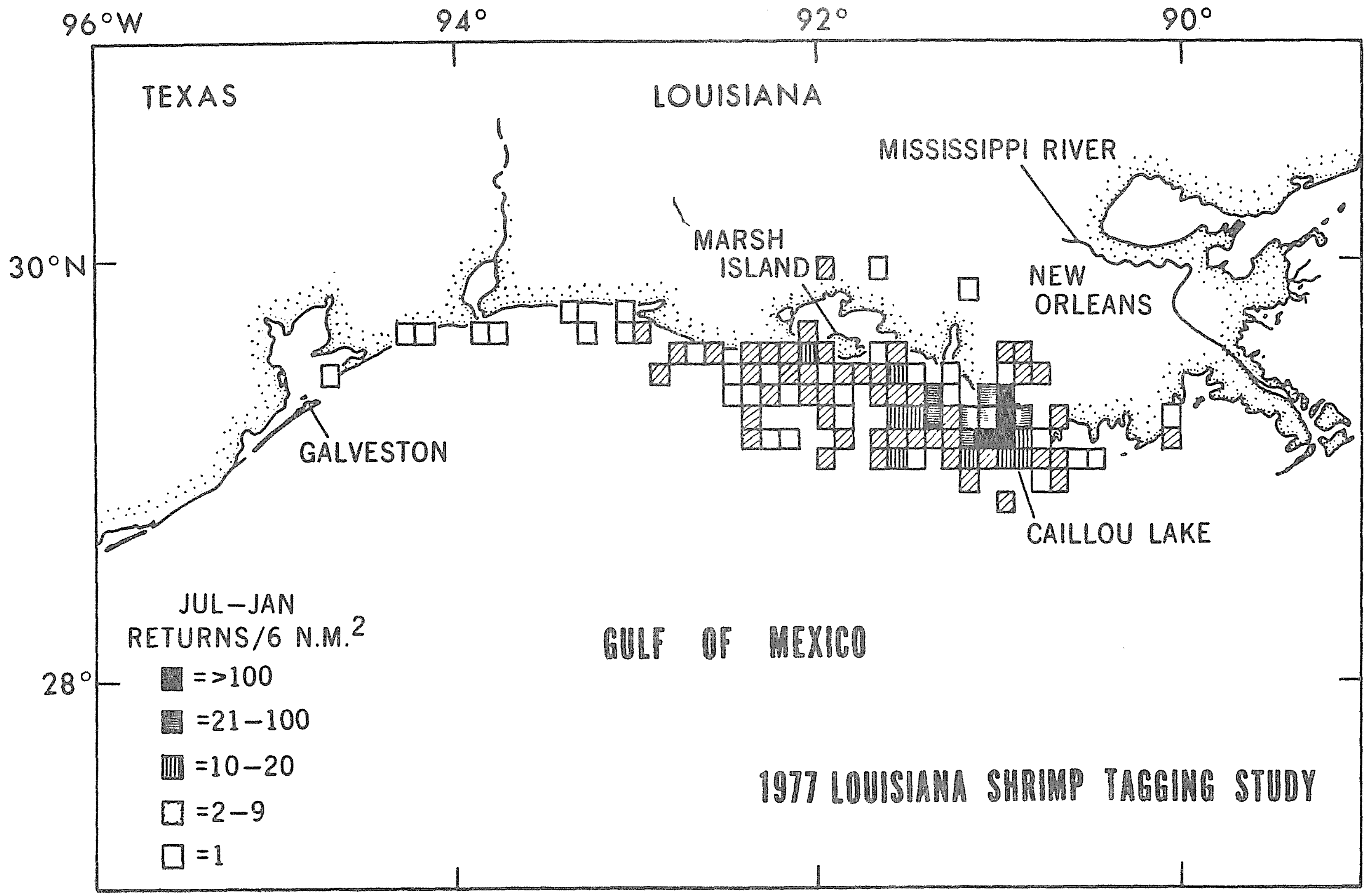

Figure 4.2.4 Density Distribution of White Shrimp Recoveries by Six Nautical Square Miles from July Through January 1978

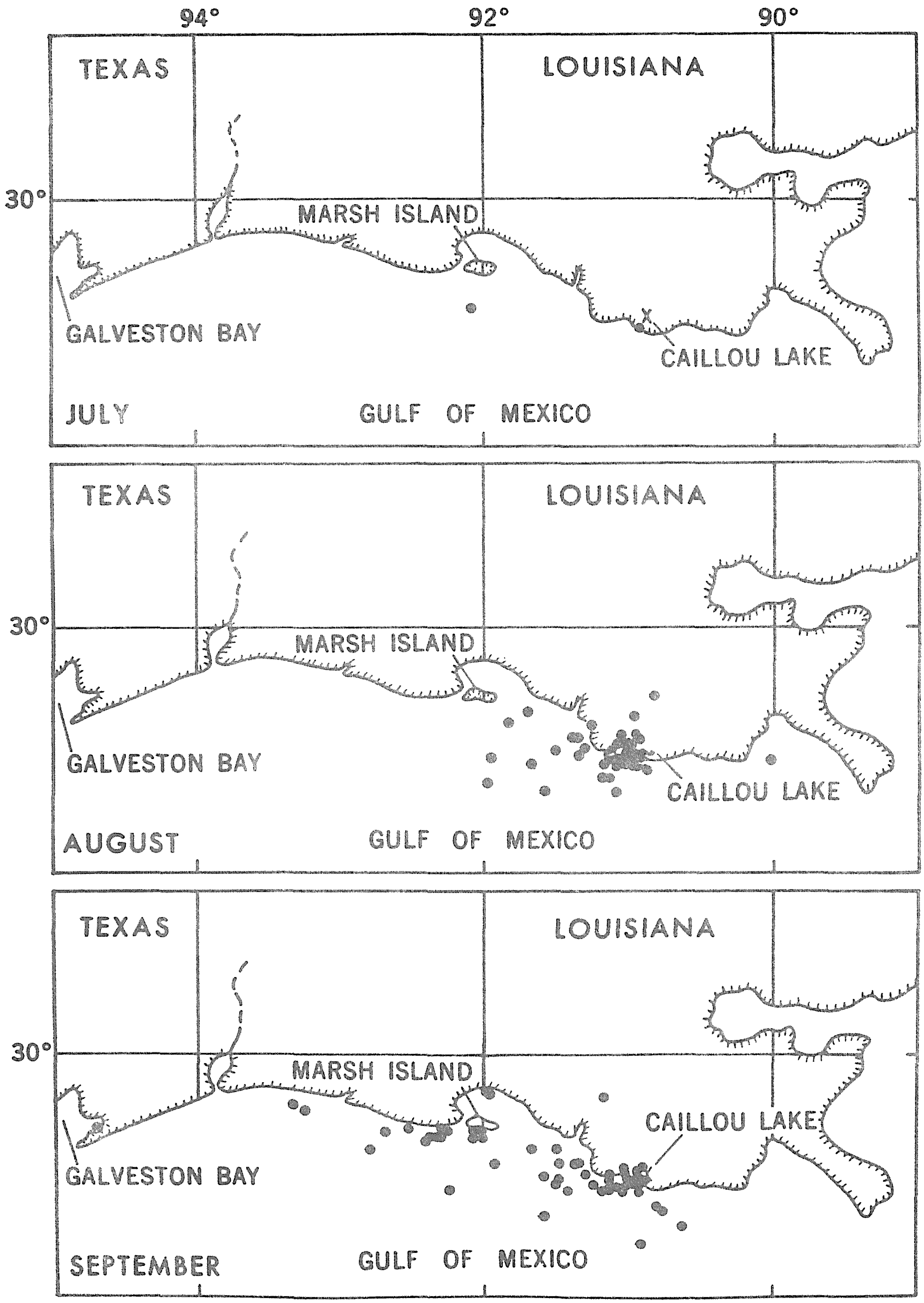

Figure 4.2.5 Distribution of the July cohort by Month

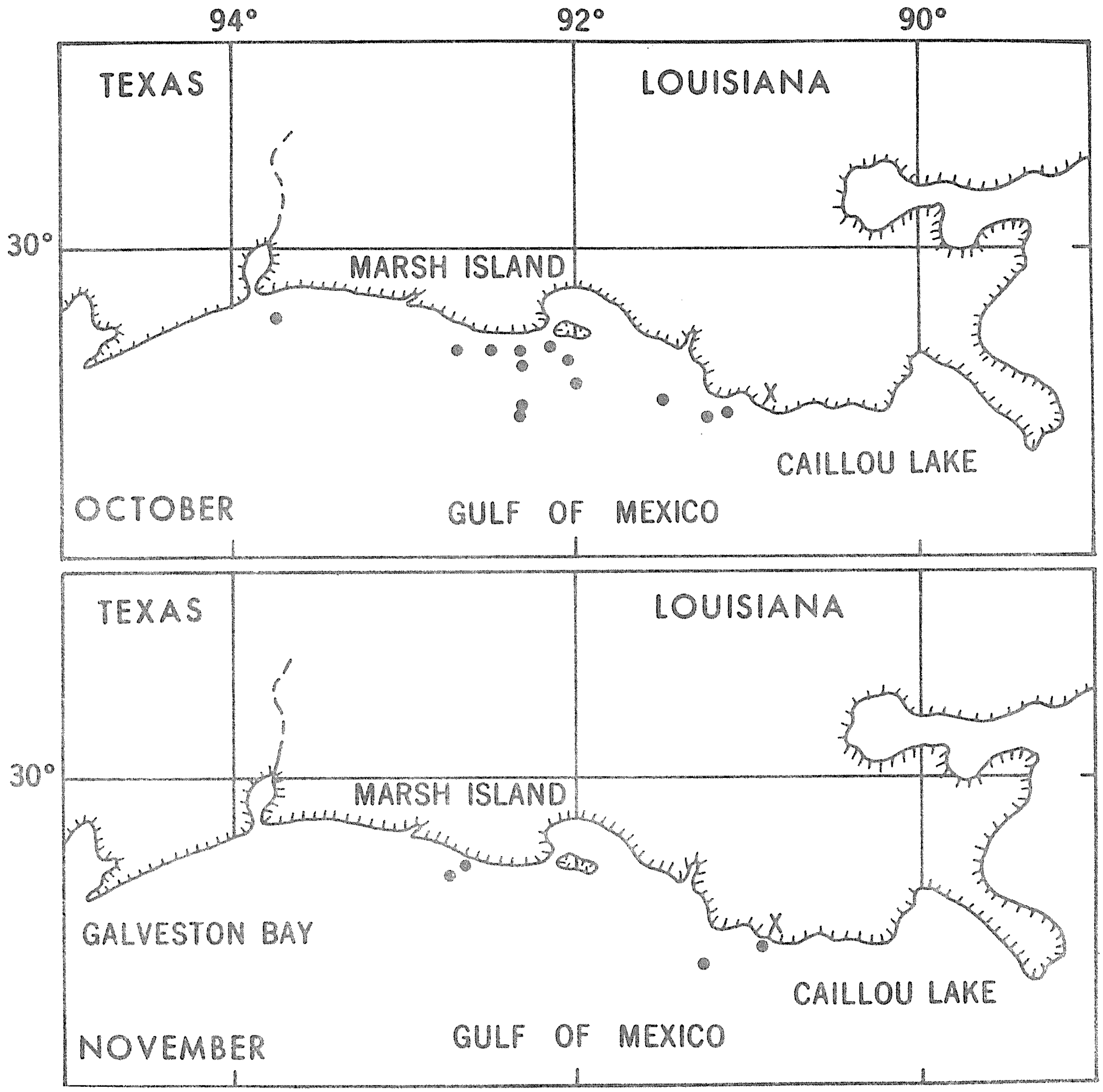

Figure 4.2.5 (Continued) Distribution of the July Cohort by Month

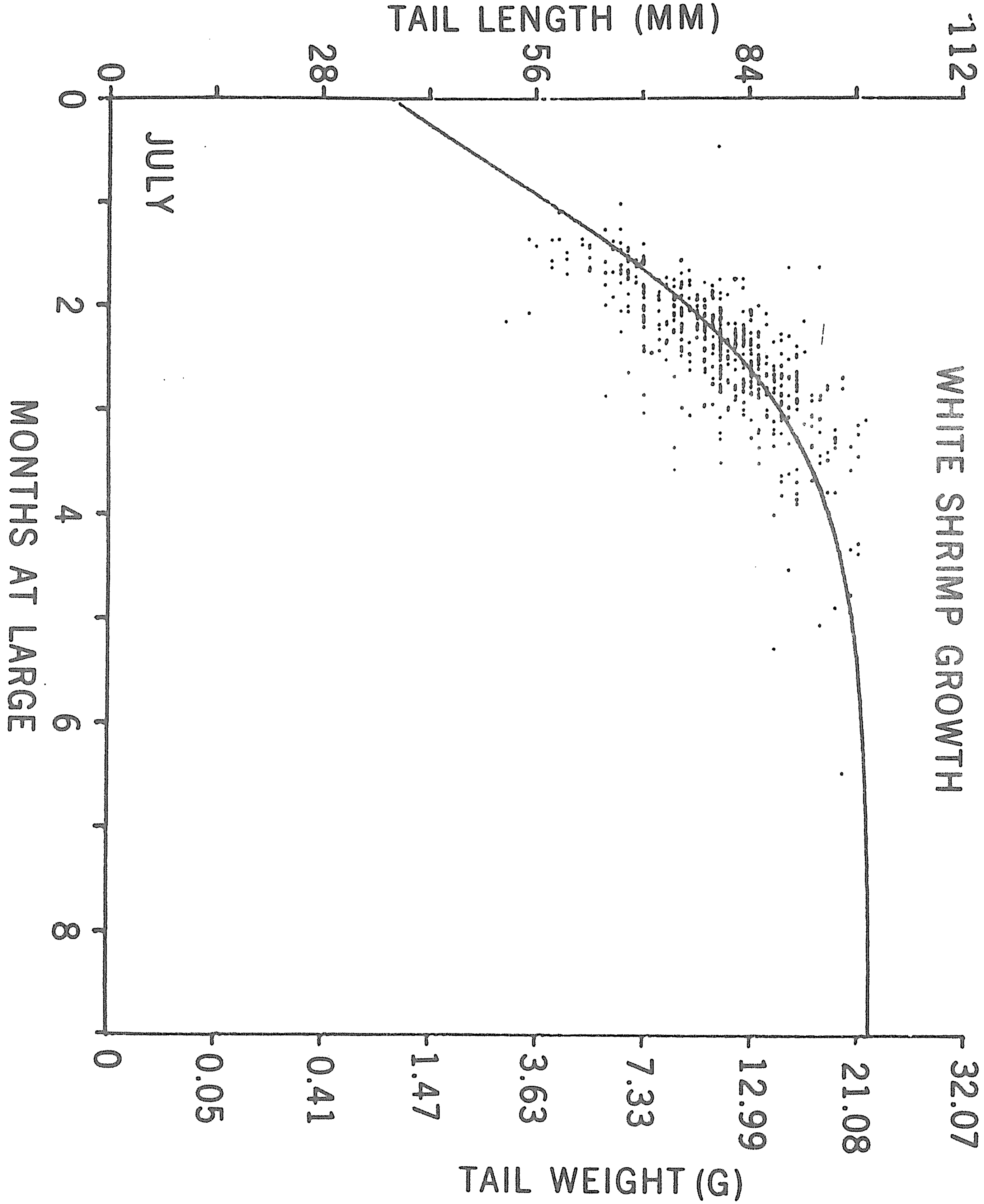

Figure 4.2.6 Growth of the July White Shrimp Cohort

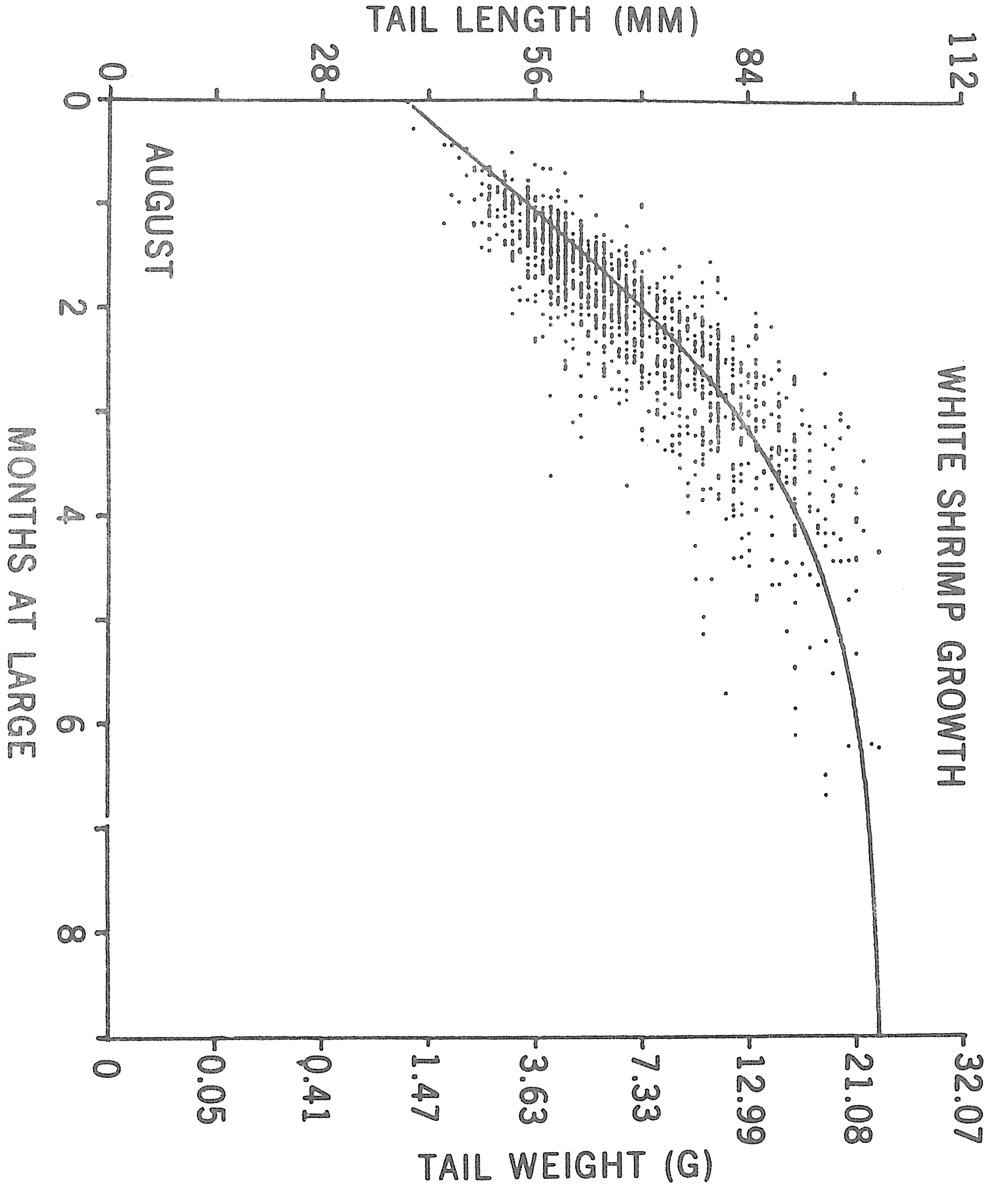

Figure 4.2.7 Growth of the August White Shrimp Cohort

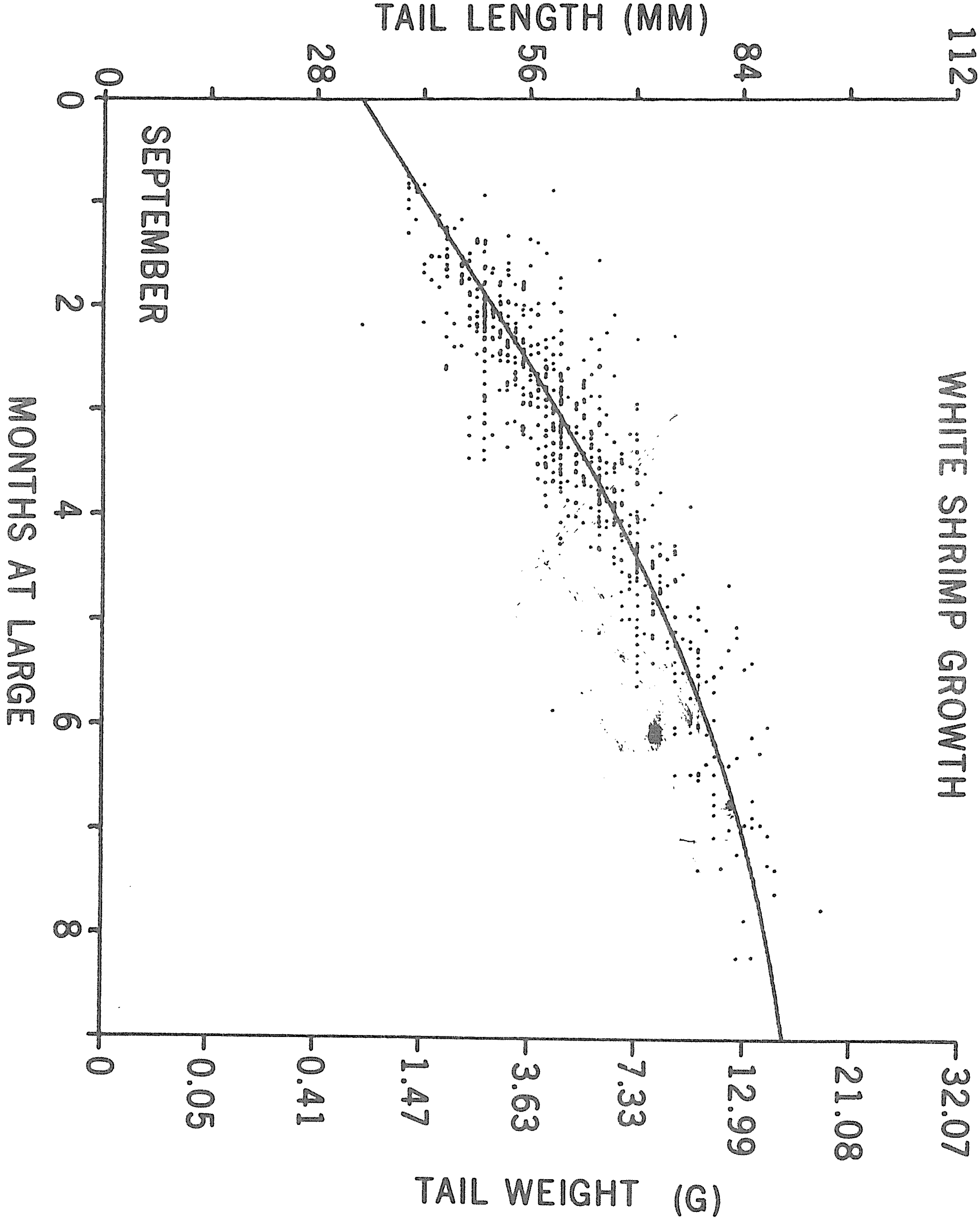

Figure 4.2.8 Growth of the September White Shrimp Cohort

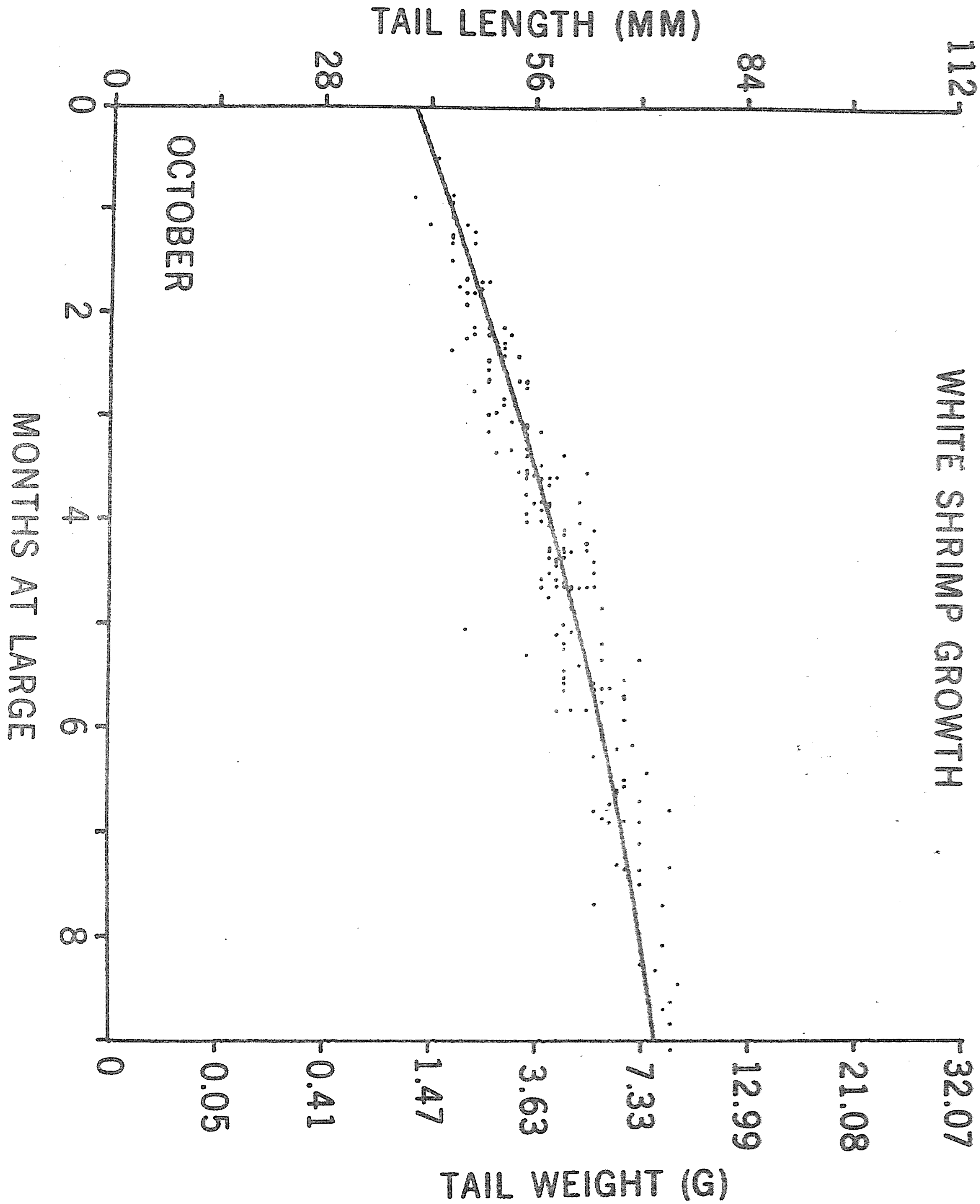

Figure 4.2.9 Growth of the October White Shrimp Cohort

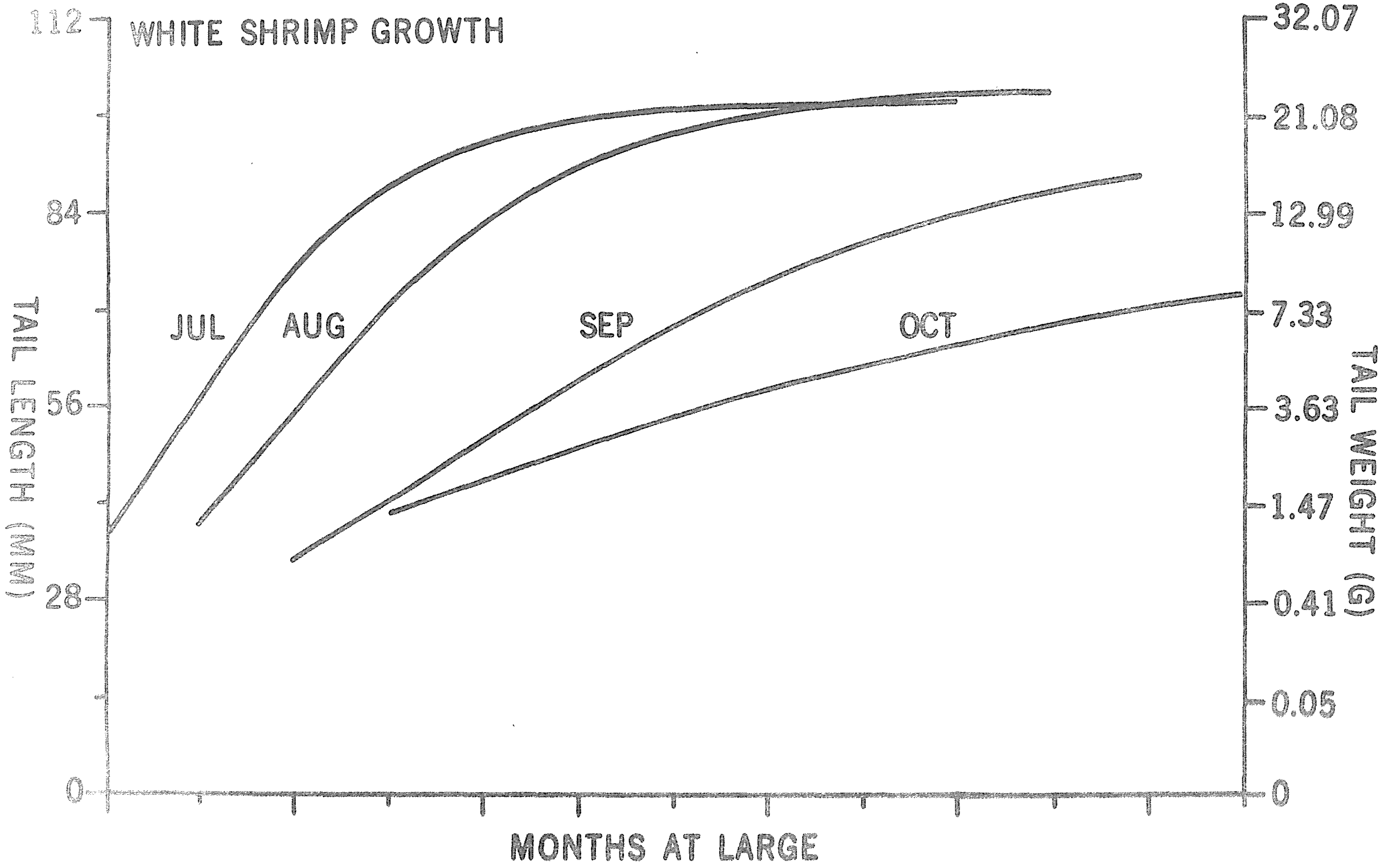

Figure 4.2.10 Comparison of Growth Curves Between July, August, September and October White Shrimp Cohorts.

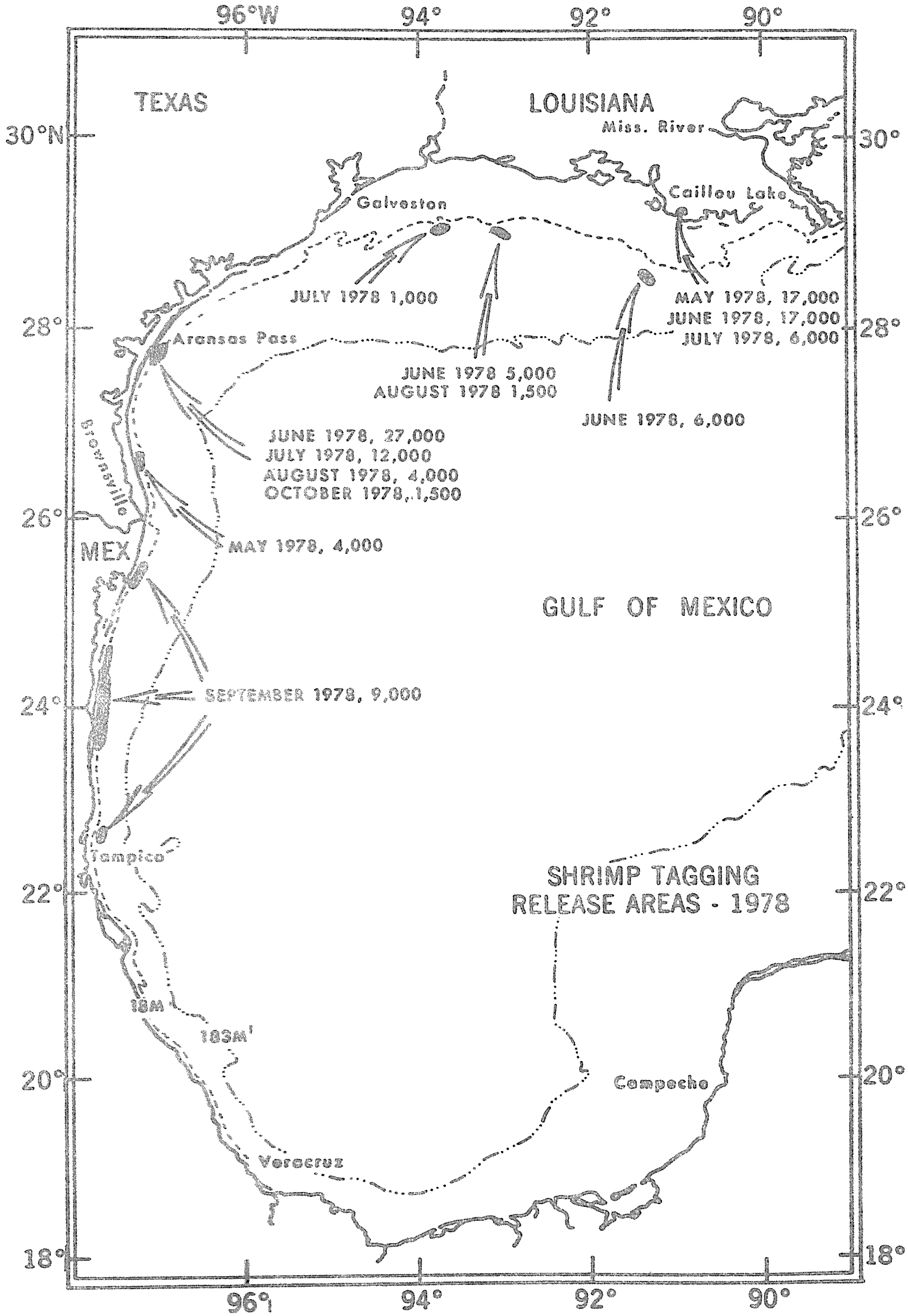

Figure 4.2.11 Location and Number of Tagged Brown Shrimp Released in 1978 in the Gulf of Mexico

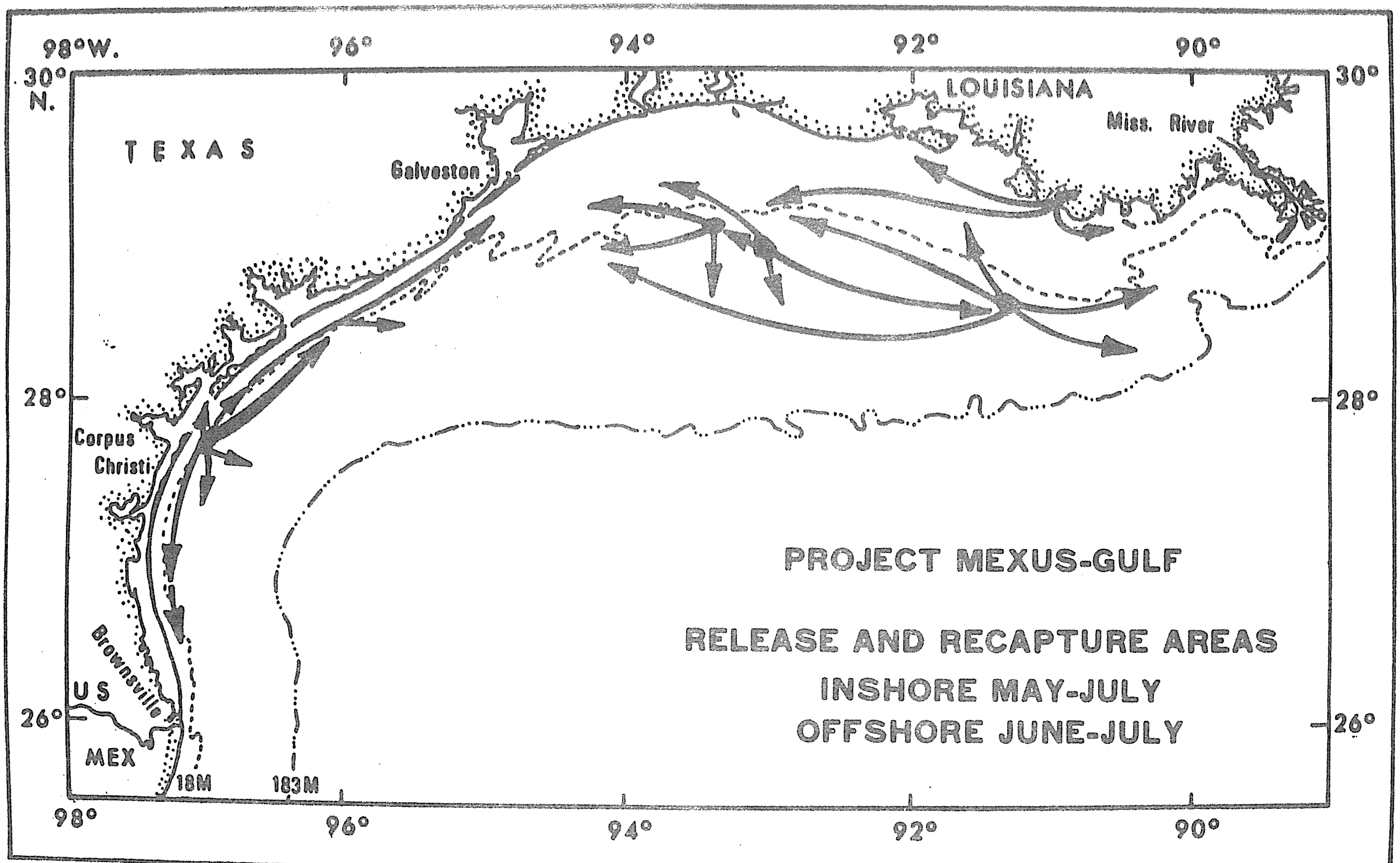

Figure 4.2.12 General Movement Patterns of Brown Shrimp Released in 1978

Contribution 4.3

The United States Shrimp Fishery off the Coast of Northeastern Brazil, French Guiana, Suriname and Guyana (1975-77)

by

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Table of Contents

1. Introduction

The fishery grounds of the Guianas-Brazil shrimp fishery encompass waters of the continental shelf extending from the Orinoco River to the Amazon (Fig. 4.3.1). The Guianas-Brazil offshore fishery consists of four species: brown shrimp *Penaeus subtilis*; pink-spotted shrimp *P. brasiliensis*; pink shrimp *P. notialis* and white shrimp, *P. schmitti*. Information on the inshore fishery for penaeids and on the artisanal fishery is scarce, but according to personal observations, these fisheries are carried out on a very limited scale and primarily for sea bob shrimp *Xiphopenaeus kroyeri*.

In this report we discuss the U.S. catch and effort statistics for 1975-77 collected from the offshore shrimping grounds off Guyana, Suriname, French Guiana and northeastern Brazil. The statistics off Brazil were collected under the terms of the U.S.-Brazil bilateral fishery agreement. Other statistics were supplied to us on a voluntary basis by U.S. fleet operators and plant managers.

The earliest exploratory fishing survey of the continental shelf of South America was made in 1944 by Whiteleather and Brown (1945), but full scale multinational commercial exploitation of the offshore shrimp resources of Guianas and Brazil did not start until after the surveys of Higman (1959) and Bullis and Thompson (1959). Naidu and Boerema (1972) reported on the offshore shrimp fishery of Guianas and Brazil for the period 1960-69. The U.S. catch data for 1972-74 from Guianas-Brazil offshore shrimp fishery were analysed by Jones and Dragovich (1977). The history of this fishery was reviewed by Naidu and Boerema (1972) and by Jones and Dragovich (1977).

2. Sources of Data and Methods Used

The data were obtained from (1) logbooks completed by the captains of U.S. shrimp vessels operating out of the ports of Cayenne, French Guiana; Paramaribo, Suriname; Georgetown, Guyana; and Port of Spain, Trinidad and (2) from the landings records of processing plants from the same ports. Most of the data on which this report is based were collected as a part of the series of U.S.-Brazil bilateral fishery agreements. The first agreement was signed in May 1972 and the last agreement expired on 31 December 1977. Under the terms of these agreements catch and effort data were collected from U.S. vessels that fished in the agreement area (Fig. 4.3.1). The same data were also mailed to SUDEPE (Brazilian Department of Fisheries). We also collected, on a voluntary basis, catch and effort statistics from the U.S. fleet fishing off Guyana, Suriname and French Guiana.

Logbook records included daily captain's entries on area fished, number of hours fished, number of hauls made, night or day fishing, estimated shrimp catch (pounds, heads-off weight) and most abundant species. Only the retained catch was reported. No estimates were made of the discarded catch. We also received monthly and annual landings data from processing plant managers. The monthly landings were from U.S. vessels and from a portion of other-than-U.S. boats that fish the same general area.

Annual landings data included both U.S. and other-flag vessels. Each landings record represented a fishing trip and included the total weight of shrimp in each commercial weight category. Based on the market price of shrimp landings were recorded in two categories as "mixed" shrimp (pink-spotted, brown, and pink) and white shrimp. In our treatment of the landings data, the "mixed"and white shrimp were combined in one category. Landings records did not contain information on area of capture.

3. U.S. Catch and Effort Statistics

3.1 Annual and Monthly Landings

The total annual landings off Guianas and Brazil for 1975, 1976, and 1977 were 19 305 097 lbs, 19 373 877 lbs, and 21 810 942 lbs, respectively. U.S. landings represented 35.2 percent, 30.4 percent, and 37.6 percent of the total international landings for the same years.

To compare U.S. shrimping activity to the activities of other fleets operating out of the Guianas and Brazil we assembled data on landings, number of boats and average catch per boat for the period 1972-77 (Fig. 4.3.2). We used the year 1972 as a starting point because in July of 1972 the first U.S.-Brazil bilateral agreement was signed. The U.S. data for 1972 represent only the second half of the year and should not be used in comparisons with the yearly data of other-than-U.S. flag vessels. The maximum U.S. catch of 13.6 million pounds was attained in 1973. In 1974, our catch dropped to 9.0 million pounds; in 1975 and 1976 it further decreased to 6.8 and 5.9 million pounds; and in 1977 increased to 8.2 million pounds. U.S. landings represented 49.8 percent and 38.8 percent during 1973 and 1974 respectively.

Fluctuation in the average annual number of U.S. vessels participating in the fishery was linked primarily to the quantities of shrimp landed during a particular year (as long as there were no other restrictions, such as enforcement of offshore limits by different nations, licensing of the vessels, economic considerations-fuel prices and inflation and a number of other causes). An excellent harvest during a given year resulted in a larger number of boats in the following year and vice versa. The maximum number of U.S. vessels (207) was reached in 1974 after a bumper crop in 1973. During 1975, 1976, and 1977 a decline in the number of boats of 24 percent, 35 percent and 32 percent was experienced paralleling the decline in annual catches (Fig. 4.3.2). Except for 1976, the mean annual catch of U.S. flag vessels was higher than the corresponding values for foreign flag boats combined.

Among many biological and ecological factors in the life history of penaeids, information on their monthly and areal occurrence is of practical value to the commercial fisherman. The monthly distributions of U.S. landings from processing plant records and logbooks for Guianas and Brazilian waters are shown in Figure 4.3.3. The monthly catches showed a slight variation from landings because they represent captains' estimates and were often landed subsequent to the month of capture. Higher catches were recorded from March to July than during the remaining months of the years. Monthly peaks were noted during the March-June period. In 1977 the opening of the season in the agreement area was in April instead of 1 March, thus the expected March peak was absent. More than one half of the logbook reported catch during the March-July periods was derived from the agreement area while the rest was harvested off the Guianas (Fig. 4.3.3). In addition to the information already discussed on the seasonal availability, we divided each year into halves and listed mean hourly rates (Table 4.3.1). In all instances, except one, the U.S. mean hourly catch rates were higher during the first half of the year than during the second. Off Brazil the catch rate for 1976 was 47 percent more during the first half than during the second. This clearly demonstrates that penaeids were more available to fishermen during the January-June period than the July-August period.

3.2 Catch Per Unit of Effort (CPUE)

Catch per unit of effort provides a measure of abundance. Forms of catch per unit of effort vary from one investigation to another, depending on the sources and accuracy of the data. For example, in the absence of a more precise form of CPUE, catch per day at sea or catch per boat per year are used as a measure of CPUE by many investigators. Catch per day at sea is an inadequate measure of CPUE because the actual number of hours fished per day are not always known. A similar argument may be applied to catch per boat per year which is based on days spent at sea. In the present report we use catch per hour of actual fishing as a method of expressing CPUE. We also present the annual average catch per boat since this is the way the efficiency is measured by all the fleets of this fishery. The mean annual catch rates for U.S. vessels in thousand of pounds were 43.4, 44.2, and 58.6 for 1975, 1976 and 1977, respectively. The highest monthly catch rates for the three years reported here were off Brazil (Zones 78-81) and off French Guiana (Zones 75-77) (Fig. 4.3.4 and Fig. 4.3.5). Even for 1975, which was a poor year for shrimping, the catch rates off Brazil were superior to those from the Guianas.

Comparison of mean hourly catch rates betwee U.S. flag vessels and those of the Japanese fleet gives the Japanese an advantage. According to Kono (1980), their mean hourly catch rate for 1975 for Zones 69-81 was 21.5 lbs, 36 percent higher than analogous U.S. catch. In 1976 and 1977 the Japanese fleet discontinued fishing off Brazil, but continued to fish off the Guianas (Zone 69-77); their hourly catch rates for 1976 and 1977 were 12.9 and 13.4 lbs, while our catch rate for 1976 and 1977 in Zones 69-77 were 11.82 and 9.57 lbs.

Lim and Hue (1980), in their report on the Korean shrimp fishery of the western central Atlantic Ocean (Guianas and Brazil), showed that the number of trawlers increased from 5 boats in 1969 to 130 in 1977 as their catch also proportionally increased. The first few years, the Korean fleet devoted to exploratory fishing and training operations for their fishermen. Thus, these years are not considered as a commercial operation. Lim and Hue reported an average catch per hour for 1976 (19.1 lbs) and 1977 (13.1 lbs).

3.3 Distribution of Fishing Effort and Catch Rates in Relation to Depth and Fishing Zone

In ecological studies of fishing grounds, geographic and depth distribution of catch rates is very important (Jones and Dragovich, 1977). Most of the effort for the entire fishery was concentrated at intermediate depths, between 21 and 35 fathoms - 53 percent for 1975 and 59.1 percent and 55.9 percent for 1976 and 1977 (Table 4.3.2). At depths less than 20 fathoms, the fishing effort was 25.8 percent, 18 percent and 14.9 percent for the years 1975, 1976 and 1977; at depths greater than 35 fathoms, the effort was 20.8 percent, 22.7 percent and 29.3 percent for 1975, 1976 and 1977. The distribution of fishing effort at ten selected depth intervals indicated a geographic pattern (Fig. 4.3.6). Off Guyana (Zones 69-71) most of the fishing was between 11 and 30 fathoms; off Suriname (Zones 72-74) and French Guiana (Zones 75-77) the fishing effort was between 16 and 45 fathoms and off Brazil it was in deeper water.

We also plotted the mean monthly hourly catch rates for each year and each statistical zone according to the ten selected depth ranges (Fig. 4.3.7). The catch rates for 1975 varied very slightly throughout all zones and depths fished. Most of the catch rates were within the 10-30 lbs category. During 1976 the highest catch rates were off French Guiana and Brazil at depths of 11-20 fath. The catch rates for Brazil were on the whole higher for all fished depths than those off Guyana, Suriname and western French Guiana. The catch rates off Guyana, Suriname and French Guiana (Zones 75 and 76) were fairly uniform. During 1977, the highest catch rates were off French Guiana and Suriname at 6-20 fath depths; off Brazil high catch rates (21.0 lbs) were obtained for the entire depth range fished; off Guyana the catch rates were fairly uniform over the entire depth range.

3.4 The Distribution of Catch and Effort in Relation to Day and Night Fishing

The daily pattern of fishing activity of commercial fishermen is largely governed by the availability of shrimp. Without an exact knowledge of the seasonal and areal distribution, related migration routes, and the diurnal behaviour of each species, the fishermen use a trial and error method in selecting the time of day for fishing. According to our data for the entire fishery, the average time for fishing spent at night was 2.8 times that spent during the day. Our data further showed the existence of areal differences (Fig. 4.3.8). Off Guyana, Suriname and a large portion of French Guiana (Zones 75 and 76) most of the fishing was at night (Fig. 4.3.8). Except for East Gullies (Zone 79) off Brazil, the reported fishing effort of French Guiana (Zone 77) and off Brazil (Zones 78, 80, and 81) was on a 24 h/day basis for more than half of the time. In the East Gullies a large portion of the fishing was done during day-time.

An examination of mean hourly catch rates as related to time of day indicates clearly that the catch rates during the day were considerably higher than those obtained at night throughout the fishery (Table 4.3.3). Examination of plots of day and night catches on the species level indicated existence of areal and diurnal differences. All four species were caught during day and night-time, but not in all zones. Brown shrimp were most abundant and were caught during the day and night-time in all zones; pink shrimp were caught primarily during the night in all zones with the highest catches in Zones 78-80 (West Gullies, East Gullies and Drop off Ridges). During day-time pink shrimp were caught only in Zones 69-71, 76-79 and 80. Pink-spotted shrimp were caught at night in all zones, except for Zone 81; day-time catches of pink-spotted shrimp were recorded in most zones (except 74, 75 and 81), with the highest catches in Zones 78-80. White shrimp occurred day and night-time in all, except four zones (74, 76, 77 and 81). The catch rates for this species were much higher during the day than at night.

3.5 Species Composition and Distribution

Our information on species composition of the catches and their geographic distribution is from vessel captain's logbooks. Skippers made daily listing of a single most abundant species to represent their catch, even though this method overestimates the more abundant species. If two or more species were present in about equal proportions, the skippers recorded the catch as mixed. The three species, brown, pink-spotted and white, are easily distinguishable from each other and we can reasonably assume that there were no errors in identification. The fourth species, pink shrimp, presents problems in identification to an inexperienced vessel captain since pink shrimp could be confused with brown shrimp. The rostral grooves of pink shrimp and brown shrimp are similar in appearance. Furthermore, while brown and pink-spotted shrimp are usually caught in large quantities and are widespread throughout the fishery, pink shrimp are found in small quantities and, based on the existing records of the Guianas-Brazil shrimp fishery, they are found only off western French Guiana, Suriname and Guyana.

Over half of the reported catch was recorded as mixed and a little less than half as single species (Fig. 4.3.9). The geographic distribution indicated definite patterns for three years (Fig. 4.3.9). Pink-spotted shrimp were prevalent off Guyana, Suriname and western French Guiana (Zones 69-76) and brown shrimp off the remaining portion of French Guiana and Brazil (Zones 77-81). Pink shrimp were reported during 1975 and 1976 from the entire area and during 1977 from Guyana, French Guiana and Brazil (zones 69, 70, 71, 76 and 78). The reported percentage of white shrimp was usually less than 1 percent in each fishing zone and for this reason was presented in Fig. 4.3.9 under the mixed category. White shrimp were found throughout the fishery, but most of them were caught off Guyana and Suriname (Table 4.3.4). The reported catches of white shrimp in this paper are not a true quantitive representation of this species, since our fishermen do not intensively fish the shallow depths at which this species occurs. Thus a more intense exploitation of shallow waters would probably result in greater catches of white shrimp.

In summary, our data on species composition and their distribution for the period 1975-77 showed brown and pink-spotted to constitute the bulk of the U.S. catch. Pink shrimp and white shrimp played a lesser role. Brown shrimp was predominant off Brazil and eastern French Guiana and pink-spotted off western French Guiana, Suriname and Guyana. Jones and Dragovich (1977) observed similar geographic distribution of the two major species for the 1972-74 period. In Japanese catches (1970-1977) the dominant species was pink-spotted shrimp, and brown shrimp was second (Kono, 1979). Higher quantities of brown shrimp in Japanese catches were reported only for 1970, when they fished Brazilian waters. During the 1971-1977 period the Japanese fished predominantly the Middle Grounds, West Grounds and East Grounds. Our findings on areal distribution of brown and pink-spotted shrimp are in general agreement with those of the Japanese.

The information on areal distribution of pink shrimp needs further confirmation since our fishermen reported pink shrimp off Brazil and western French Guiana where this species has never been reported previously (Dragovich, Jones and Boucher, 1979: Perez-Farfante, 1969). White shrimp occurred in very small quantities throughout the fishery, but mostly off Guyana and Suriname.

3.6 Size Composition of Landings

The information on the monthly and areal occurrence of different sizes of shrimp species may shed some light on the area and time of recruitment and temporal and areal availability of commercial sizes of penaeids to the fishermen. The majority of shrimp landed by the U.S. fleet during the 1975-77 period were in the size categories 16-20, 21-25 and 26-30 counts per pound (Fig. 4.3.10). Our annual plots (Fig. 4.3.10) also indicate that from 1975 to 1977 progressively more shrimp were landed in small size categories 41/50 and >50. The same trend in landing more small shrimp (>50 and 41/50) from 1973 onward was reported for the Japanese fleet by Kono (1979). Kono attributes this phenomenon to a change in fishing grounds. During 1970-72, the Japanese fished principally the Middle Grounds and East Grounds; in 1973-75, they fished the West Grounds, East Grounds and Rock.

Although there is some similarity between sizes from logbook data and the landings, the landings give a more precise picture on size distribution than captains' logbooks which chiefly report average sizes for each day of fishing. The size of shrimp represented in landings may represent a true picture on size availability but may also in some instances reflect selective forms of fishing as influenced by market price of shrimp, fuel prices, feasibility of operation, skill of the crew, condition of the boat and many other factors.

As in our previous study (Jones and Dragovich, 1977), to observe the temporal and spatial changes in size composition of shrimp catches as reported by U.S. captains, we calculated the mean size index for each statistical zone and each month for 1975-77 period (Fig. 4.3.11). The mean size index system was used to simplify the indication of sizes. We had nine size categories (>50; 46-50; 41-45; 36-40; 31-35; 26-30; 21-25; 15-20 and <15 per pound). The index for the smallest size category was assigned 1 and for the largest 9, with intermediate values representing the sizes betweem 1 and 9. The method for calculating this mean size index is described by Jones and Dragovich (1977). The smallest sizes occurred in March of 1975 and 1976 and in April of 1977. The largest sizes were in January of 1975 and 1976 and at the end of these years; intermediate sizes occurred during the summer months. In our previous study we noted somewhat similar monthly distribution for the years 1972, 1973 and 1974. The spatial distribution of sizes for 1975-76 showed that the largest sizes occurred in the middle of the fishery, off Suriname and east off French Guiana. The monthly data for each statistical zone tend to support this areal distributional pattern of sizes. The apparent prevalence of small shrimp off Brazil, eastern French Guiana and Guyana might be indicative, as in our previous studies, that these shrimp were probably recently recruited to the fishable stock. Smaller size of shrimp and higher catch rates off these two areas, as compared with the larger shrimp and lower catch rates off Suriname suggest that the young shrimp are being recruited principally to these areas. Furthermore, the monthly peaks (March and April) of small shrimp might be indicative of seasonal recruitment periods.

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Table 4.3.1 Mean catch of headless shrimp per hour of trawling by U.S. flag vessels of the Guianas-Brazil fishery, 1972-77. For statistical zones, see Figure 4.3.1

	Zones 69-77		Zones 78-81		All Zones	
1972	lbs	kg	lbs	kg	lbs	kg
Jan-June						
July-Dec	19.09	8.7	22.16	10.0	20.00	9.1
Jan-Dec					24.34*	11.0*
1973						
Jan-June	23.29	10.6	33.41	15.2	28.10	12.7
July-Dec	19.83	9.0	27.05	12.3	23.67	10.7
Jan-Dec	21.35	9.7	31.38	14.2	25.92	11.8
1974						
Jan-June	20.01	9.1	22.40	10.2	20.96	9.5
July-Dec	13.89	6.3	17.52	7.9	15.22	6.9
Jan-Dec	17.01	7.7	20.12	9.1	18.55	8.4
1975						
Jan-June	14.82	6.7	17.65	8.0	15.82	7.2
July-Dec	10.46	4.7	15.86	7.2	11.87	5.4
Jan-Dec	12.58	5.7	16.88	7.7	13.83	6.3
1976						
Jan-June	13.88	6.3	24.33	11.0	18.59	8.4
July-Dec	9.48	4.3	12.95	5.9	10.63	4.8
Jan-Dec	11.82	5.4	20.31	9.2	15.23	6.9
1977						
Jan-June	7.82	3.5	28.83	13.1	19.71	8.9
July-Dec	10.21	4.6	16.18	7.3	12.40	5.6
Jan-Dec	9.57	4.3	22.14	10.0	15.07	6.8

* Estimated values

Table 4.3.2 Distribution of fishing effort in the Guianas-Brazil fishery (Zones 69-81) expressed as hours fished, according to several depth intervals, 1975-77

	DEPTHS											
metres: fathoms:	<11 < 6	11-18.3 6-10	20.1-27.4 11-15	29.3-36.6 16-20	38.4-45.7 21-25	47.5-54.9 26-30	56.7-64.0 31-35	65.8-73.2 36-40	75.0-82.3 41-45	84.1-109.7 46-60	Total	%
1975												
Hours fished	10 879	8 614	48 492	21 326	63 875	72 773	47 936	31 427	33 918	6 760	346 000	40.2
%	3.1	2.5	14.0	6.2	18.5	21.0	13.8	9.1	9.8	1.9		
1976												
Hours fished	7 857	3 860	29.084	9.798	61 108	57 880	46 367	21 087	34 392	8 173	279 606	32.5
%	2.8	1.4	10.4	3.5	21.8	20.7	16.6	7.5	12.3	2.9		
1977												
Hours fished	8 264	1 530	14 434	10 169	53 484	48 577	29 683	23 270	38 681	7 100	235 192	27.3
%	3.5	>1.0	6.1	4.3	22.7	20.6	12.6	9.9	16.4	3.0		

Table 4.3.3 The mean hourly catch rates of shrimp for day (D), night (N) and both day and night (B) of fishing in the fishing zones of Guiana-Brazil fishery. The units are given in pounds'

Zones	1975 D	1975 N	1975 B	1976 D	1976 N	1976 B	1977 D	1977 N	1977 B
69	18.2	11.8	11.7	14.8	10.1	9.5	12.9	10.3	9.3
70	17.7	11.3	10.8	13.5	10.2	9.0	20.7	9.5	9.8
71	16.6	11.3	10.2	14.1	9.7	8.7	13.9	9.2	8.0
72	15.3	11.1	10.7	15.7	9.3	10.6		8.9	8.5
73	13.8	12.1	13.3	11.2	10.9	9.8	8.5	9.8	8.4
74	18.3	12.5	13.6	12.5	10.0	10.3	19.4	9.4	8.4
75	17.6	12.4	19.3	15.0	10.3	13.4	20.6	10.0	12.7
76	17.9	13.5	15.4	18.8	11.2	21.8	18.6	11.4	12.2
77	19.0	13.8	16.6	16.8	12.7	16.8	14.8	14.8	12.0
78	17.7	14.2	13.5	20.4	17.8	14.5	26.3	26.2	18.4
79	20.9	15.0	15.5	25.0	18.5	16.5	31.8	24.4	21.7
80	19.9	17.6	16.2	24.1	21.8	22.4	27.7	22.5	21.4
81	17.0	21.3	20.4	33.0	31.6	26.1	22.8	25.9	24.7

Table 4.3.4 The percentage of white shrimp (*P. schmitti*) in the reported U.S.A. catches off Guyana, Suriname, French Guiana and Brazil according to the fishing zones

	Guyana			Suriname			French Guiana			Brazil			
Zones:	69	70	71	72	73	74	75	76	77	78	79	80	81
Year													
1975	2.3	0.8	1.3	1.4	0	0	0	0	0.6	0.7	0	0	0
1976	0.5	0.2	0.3	0.1	>0.1	0.6	0.1	0	0	0.1	0	0	0
1977	0.7	>0.1	0.8	0.2	0.1	0.4	0.2	0.2	0	0	0.6	0	0

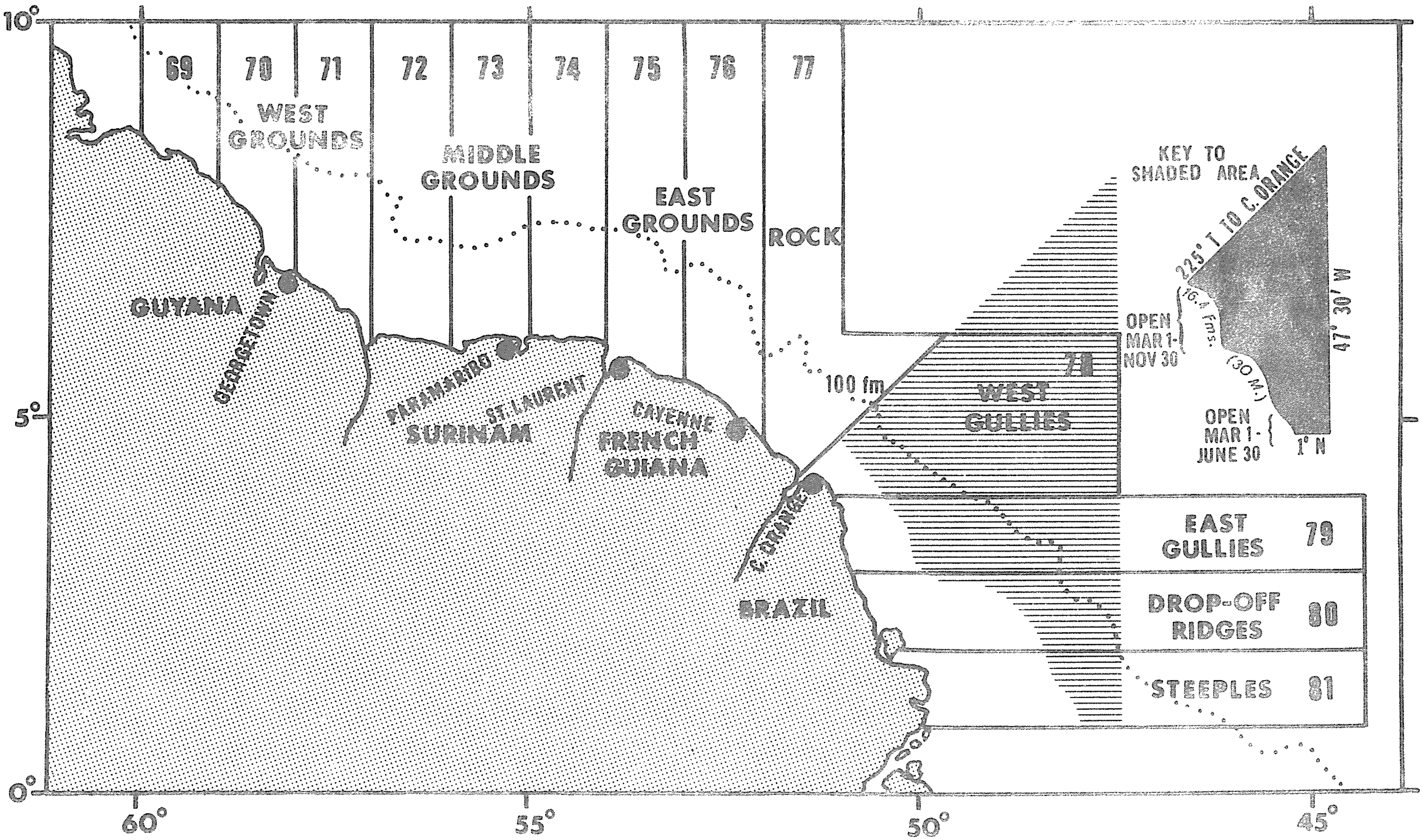


Figure 4.3.1 The Guianas-Brazil Shrimping Grounds with Fishing Zones and Their Common Names. The United States Agreement Area is shaded; the boundaries of the Area and the fishing seasons for U.S. vessels are shown in the insert.

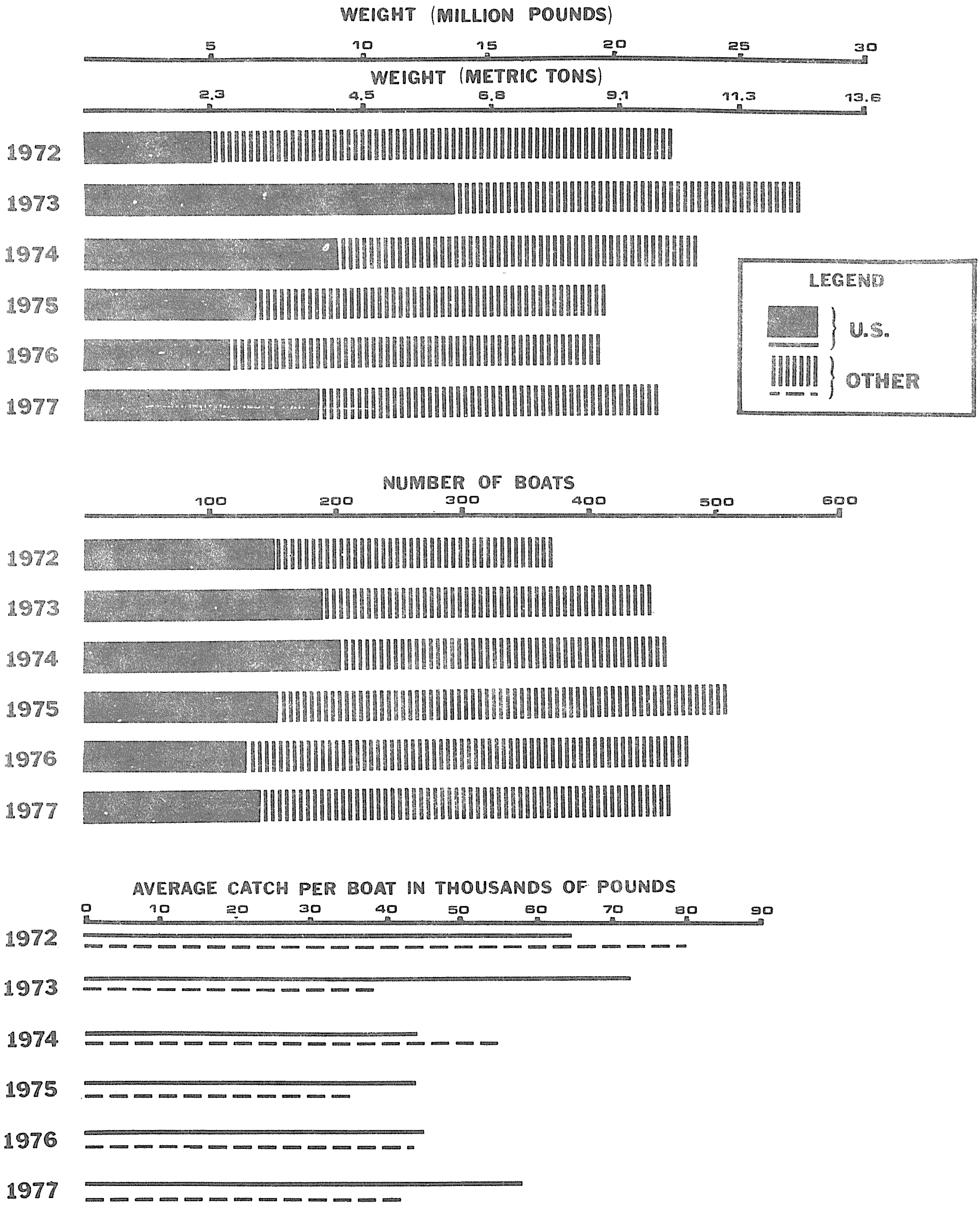


Figure 4.3.2 Yearly Landings of Shrimp (heads-off weight), Average Number of Active Boats and Average Catch per Boat for Guianas-Brazil Fishery (1972-77)

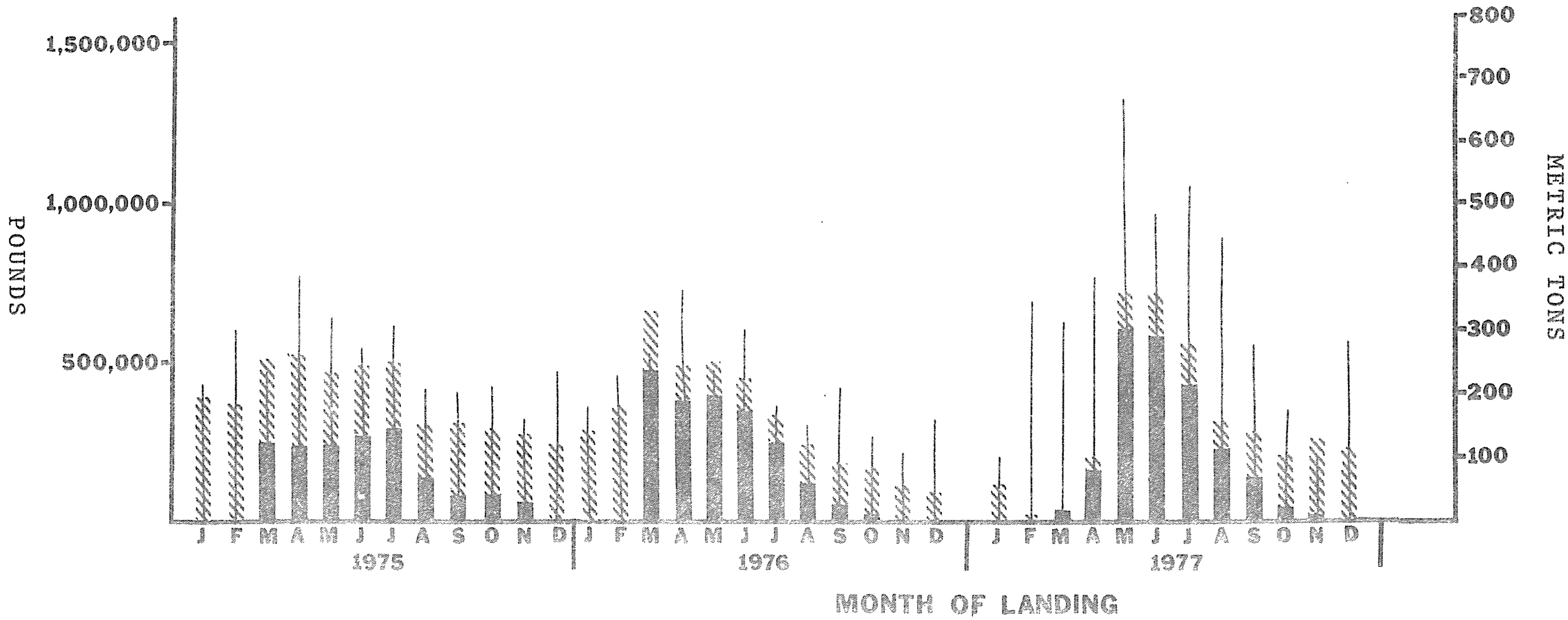


Figure 4.3.3 Monthly Shrimp Catches (heads-off weight) of U.S. Vessels by Area for the Guianas-Brazil Fishery. Vertical lines represent the total U.S. landings reported by the processing plants and are given by months in which the landings were made. Vertical bars represent the "haul" on estimated catches of U.S. vessels submitting logbooks and are reported by months of capture. The shaded area of the vertical bar represents the portion of the logged catches recorded from the United States-Brazil Shrimp Agreement Area.

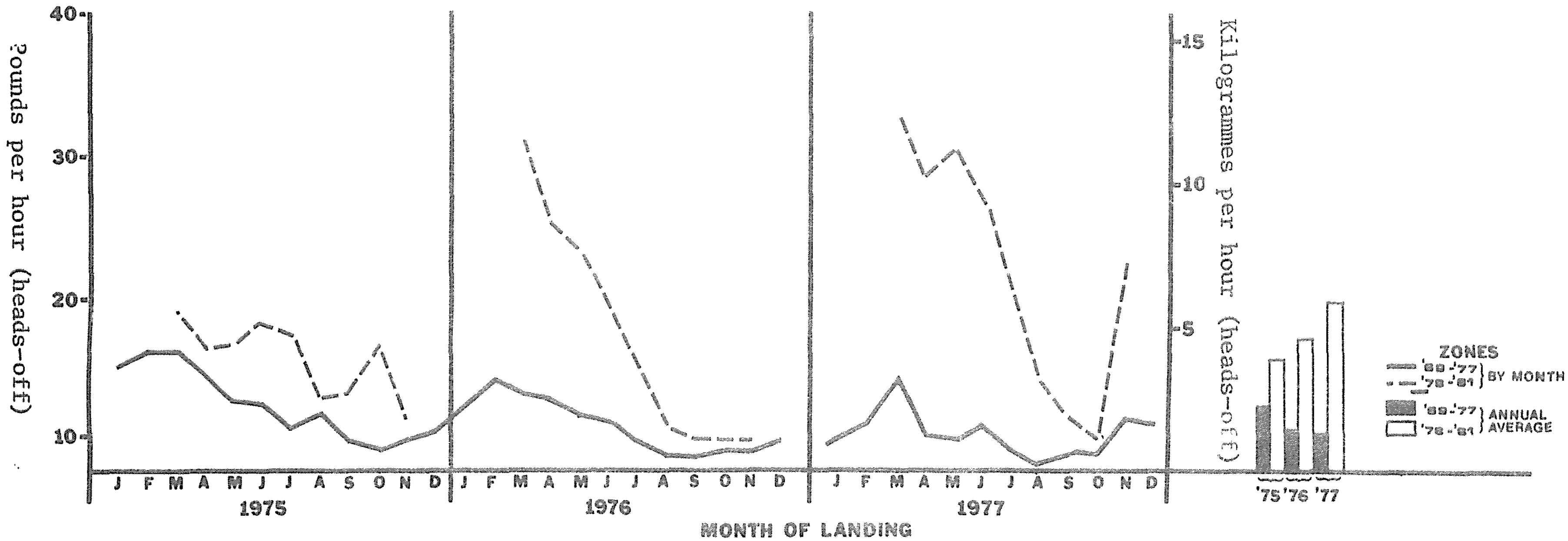


Figure 4.3.4 Monthly Distribution of the Mean Catch Rate of Shrimp (heads-off weight) for U.S. Vessels Fishing off Guianas (Zones 69-81), 1975-77

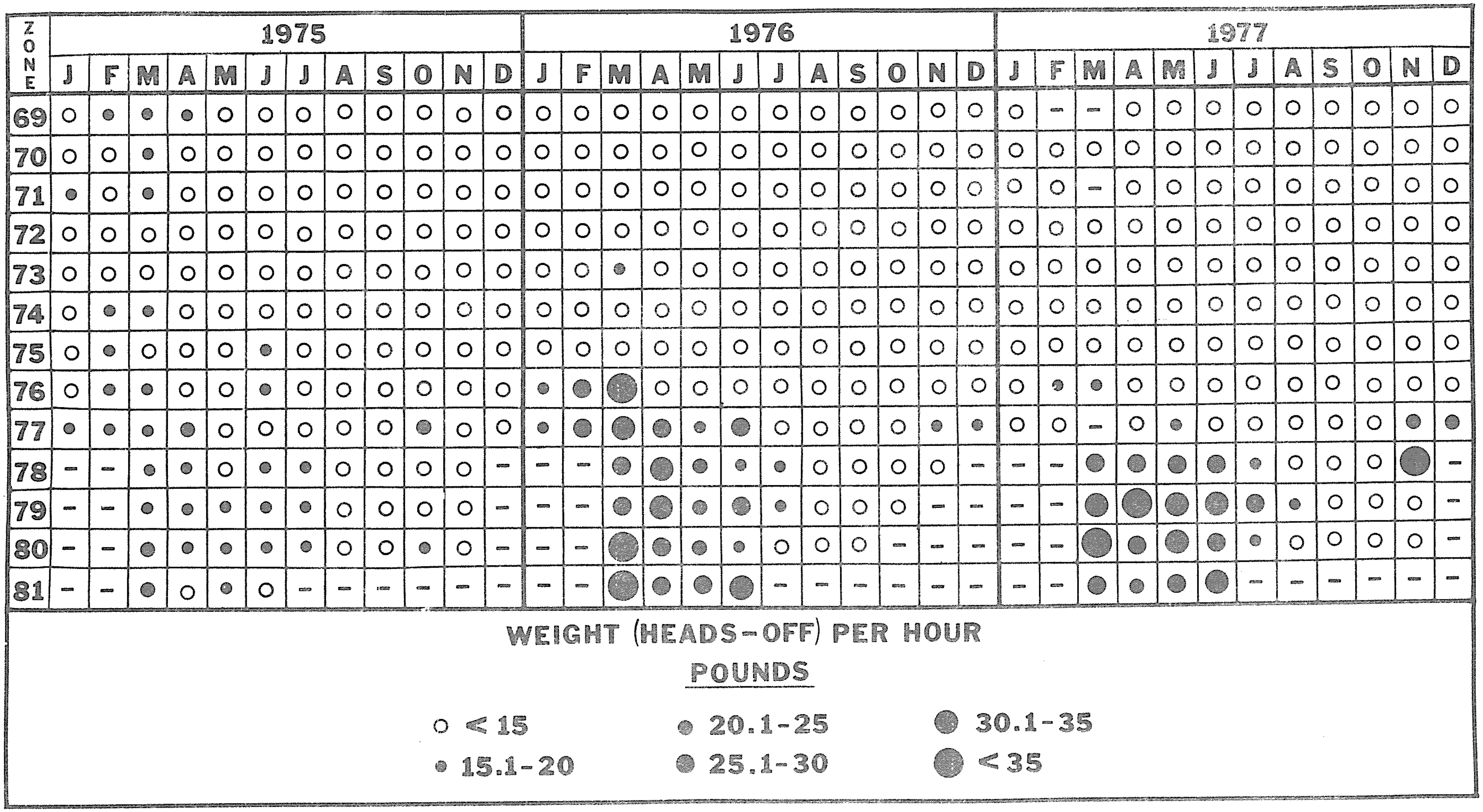
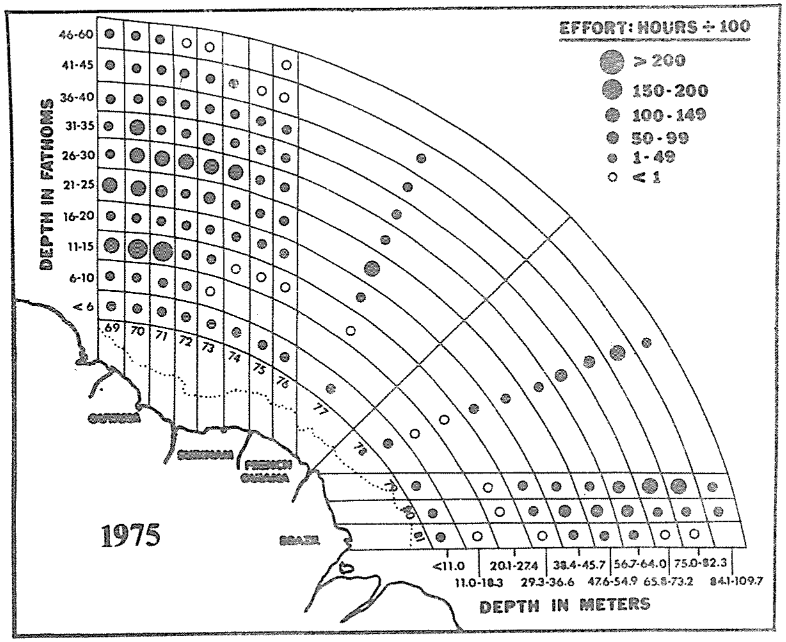
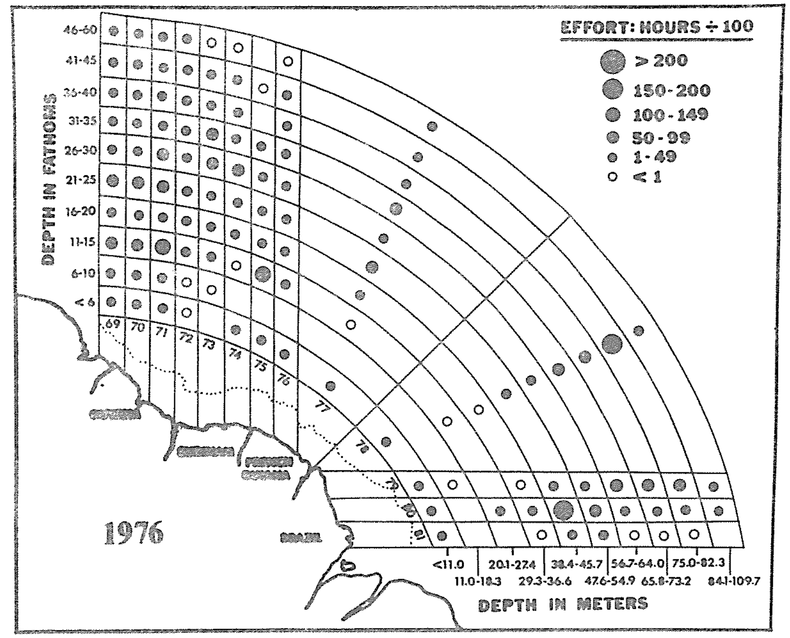


Figure 4.3.5 Mean Montly U.S. Catch Rates of Shrimp (heads-off weight) According to Statistical Zones for the Guianas-Brazil Fishery, 1975-77. See Figure 4.3.1. for location of fishing zones.





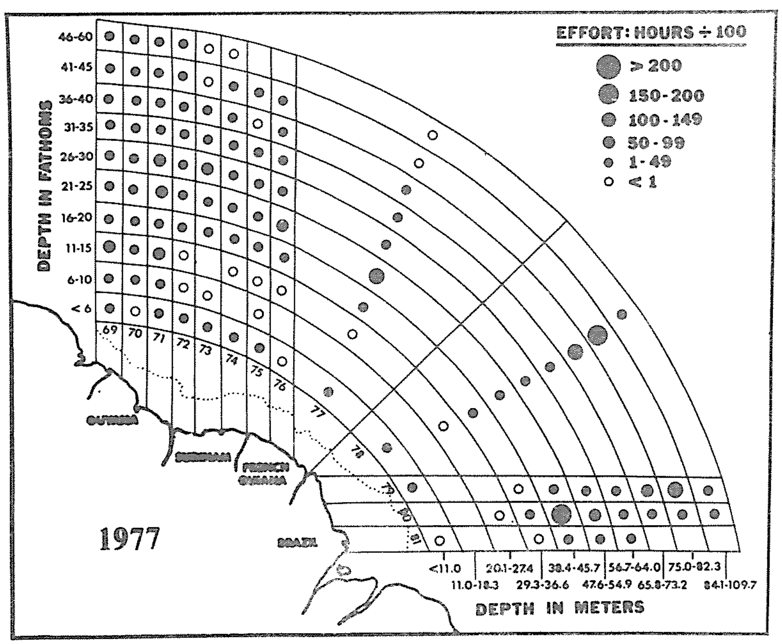
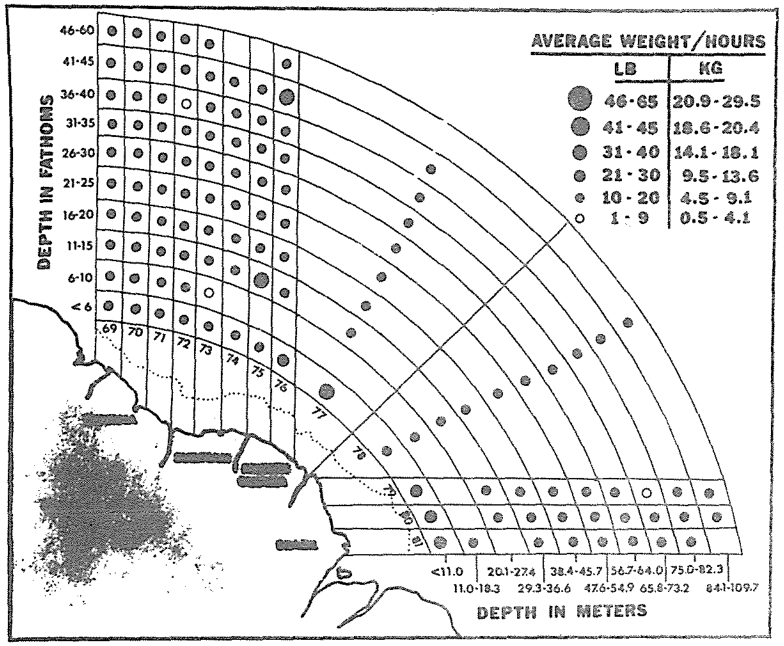
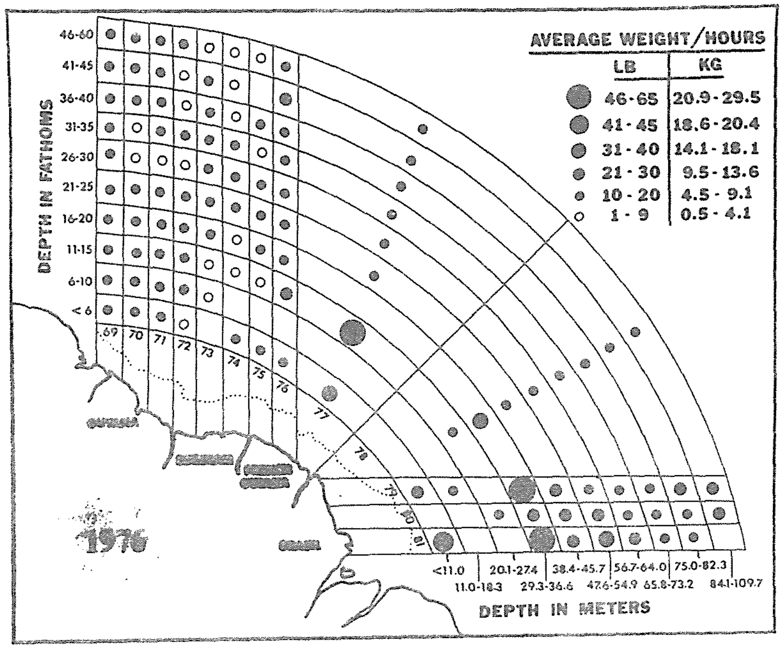


Figure 4.3.6 Distribution of Fishing Effort in the Guianas-Brazil Fishery by Fishing Zone and Water Depth for 1975-77. The data are from U.S. vessel logbooks





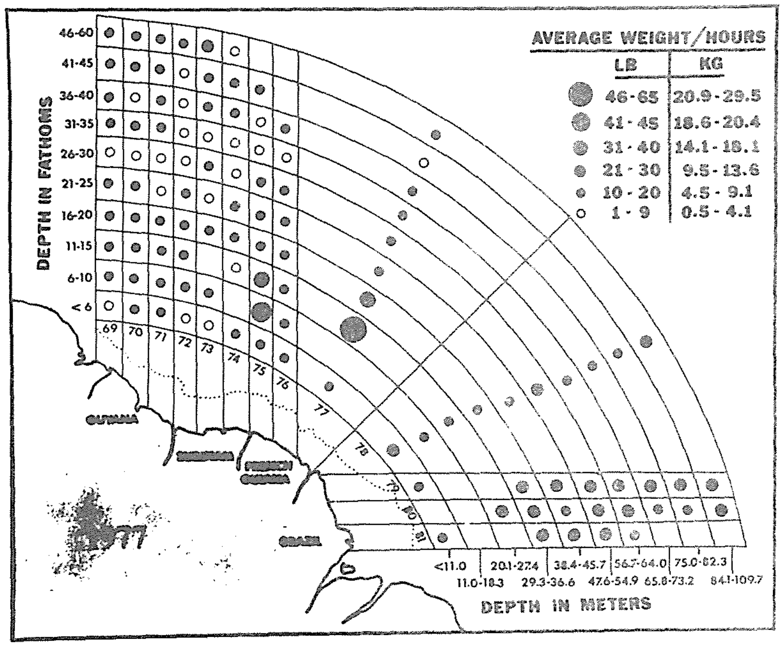


Figure 4.3.7 Distribution of the Mean Hourly Catch Rate of Shrimp (heads-off weight) by Depth and Fishing Zone for the Guianas-Brazil Fishery 1975-77. The data from U.S. vessels logbooks

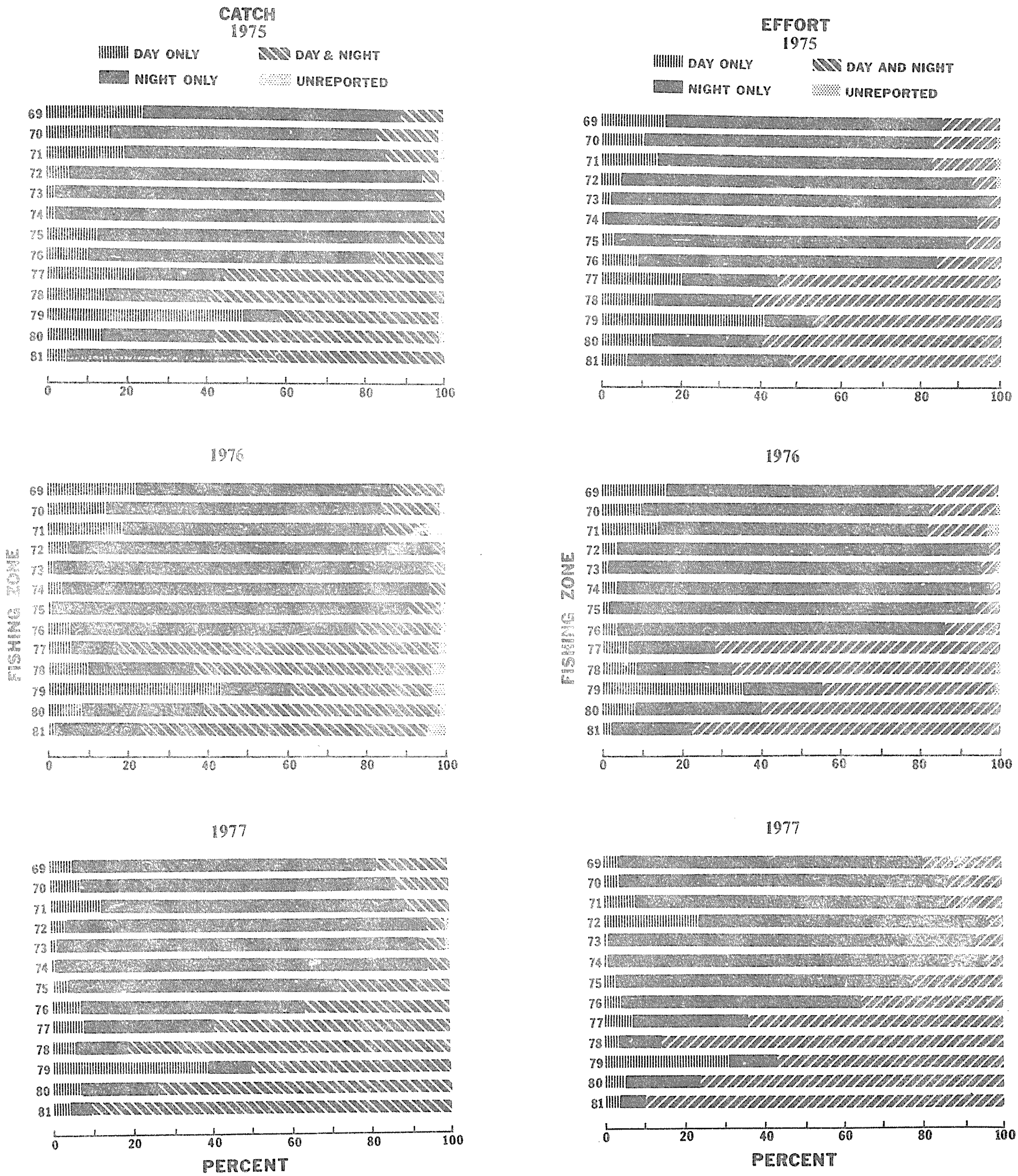


Figure 4.3.8 Distribution of U.S. Catch and Effort (both expressed as percentage of the total) by the Time of the Day and Fishing Zone for Guianas-Brazil Fishery, 1975-77

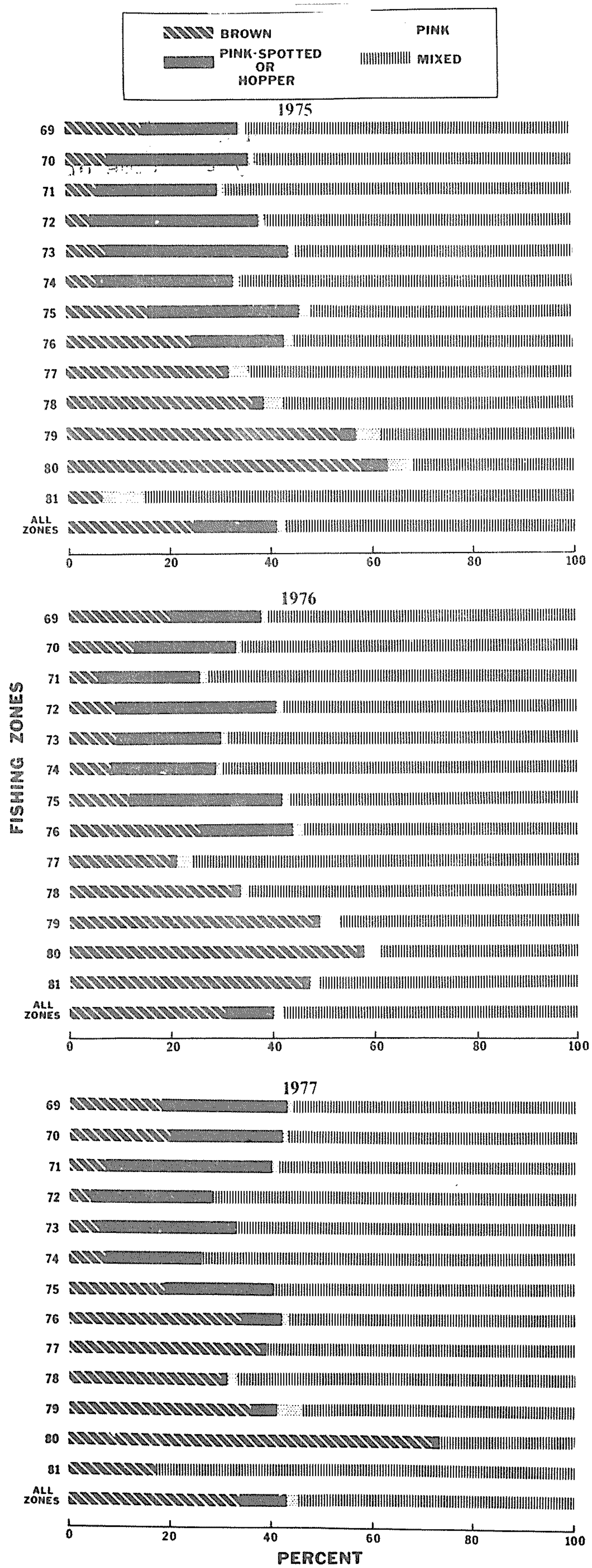


Figure 4.3.9 Species Composition of Shrimp Catches of U.S. Flag Vessels in the Guianas-Brazil Fishery, According to the Fishing Zone, 1975–77

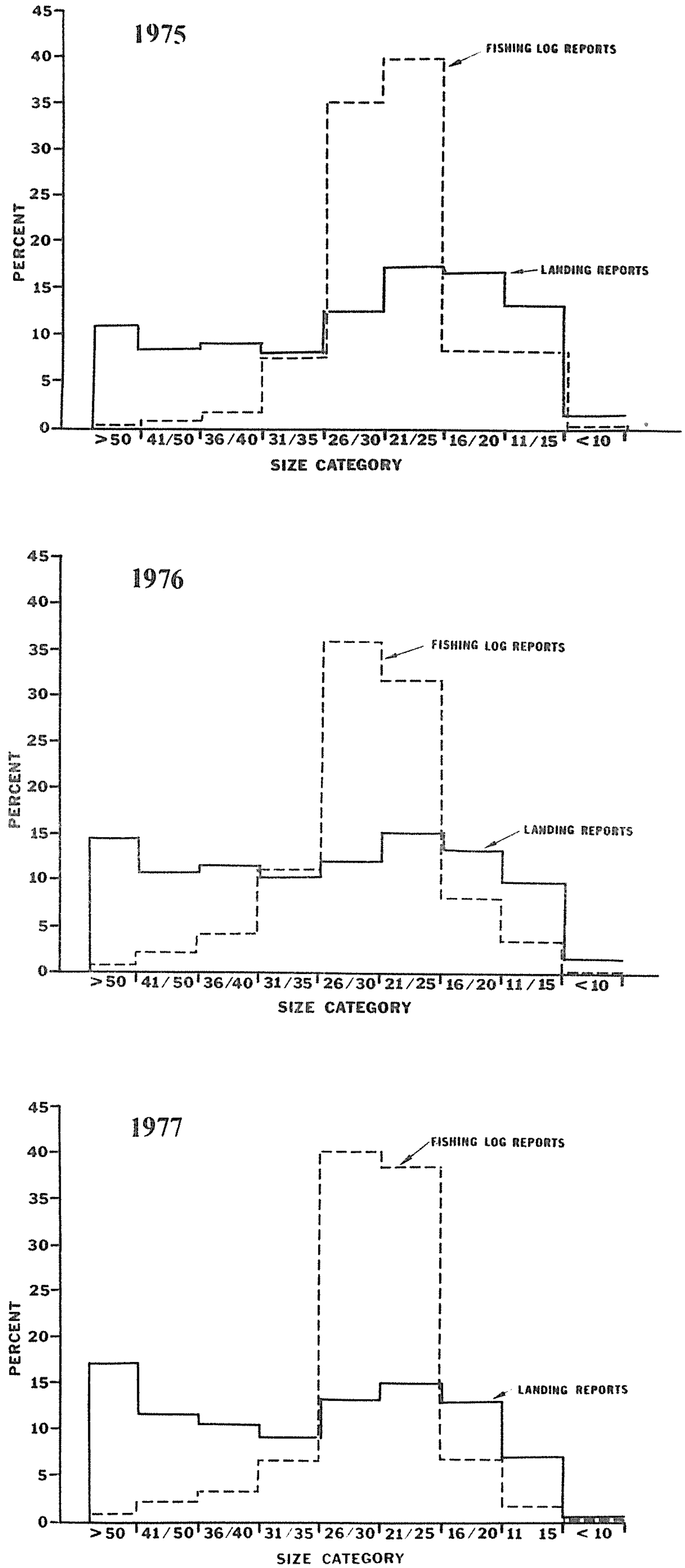


Figure 4.3.10 Size Composition of the U.S. Shrimp Catches from Landing Records and Log Reports. The size categories given are the number of heads-off shrimp per pound.

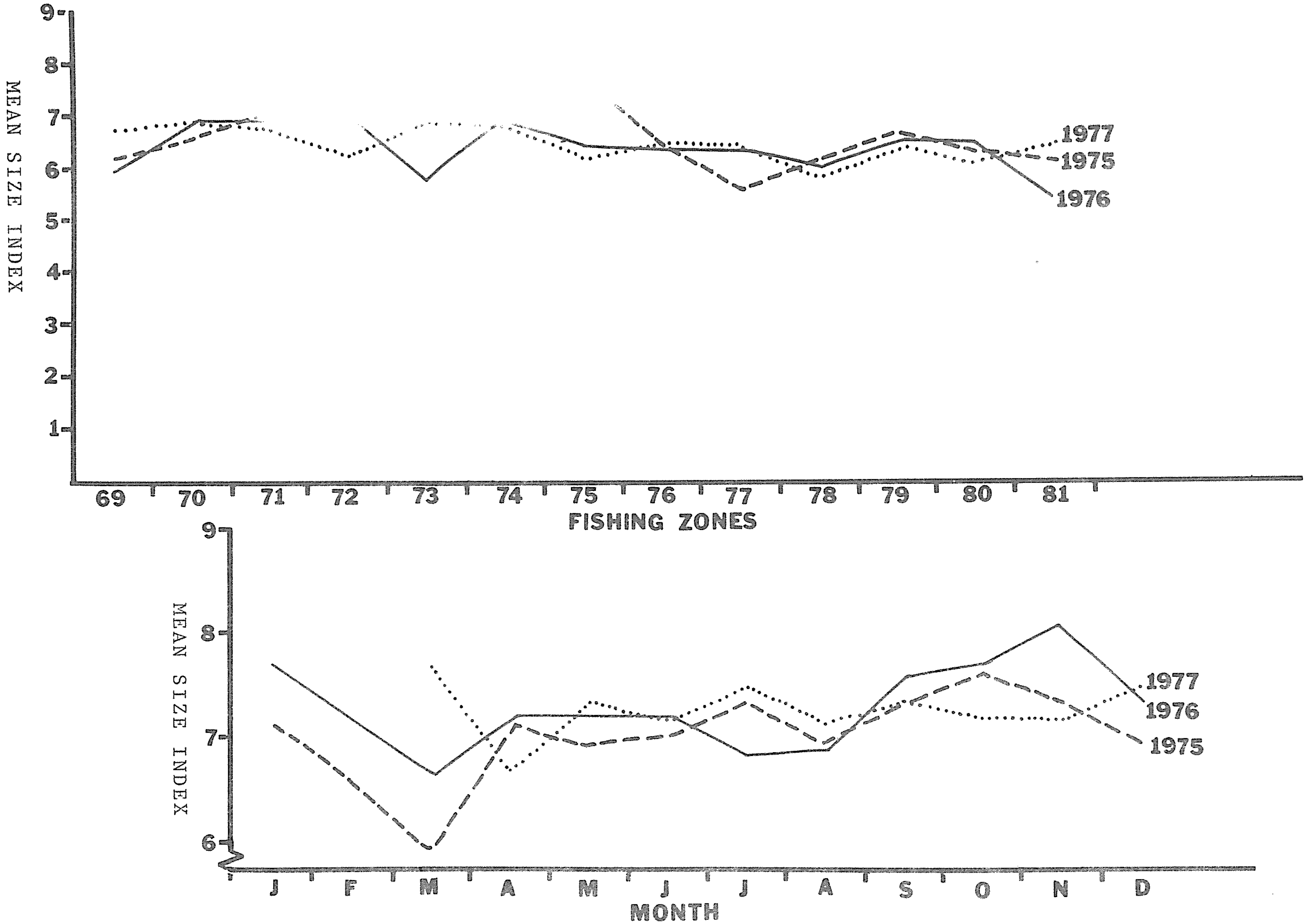


Figure 4.3.11 The Monthly and Zonal Distribution of the Mean Size Index for the U.S. Catch in the Guianas-Brazil Fishery, 1975-77. The mean size index was calculated as described in text.

Contribution 4.4

Biological Sampling of the Landings of the Guianas Shrimp Fishery

by

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In 1976, the Commercial Fisheries Investigation Programme of the Miami Laboratory initiated a project to sample shrimp landings at processing plants in Port of Spain, Trinidad; Paramaribo, Suriname; Cayenne, French Guiana; and Georgetown, Guyana. The chief purpose of port sampling was to acquire necessary data for assessment and conservation of the shrimp stocks of the Guianas shrimp fishery.

The species in the landings are recorded as "mixed" shrimp (pink-spotted, brown, and pink or Penaeus brasiliensis, P. aztecus and P. notialis) and white shrimp, Penaeus schmitti. Each landing record represents a fishing trip with date of landing and total weight of shrimp in several commercial weight size categories.

Our sampling of the landings consisted of sampling both the mixed and the sorted catch. About 250 shrimp specimens from the total mixed catch were sampled. The species composition and biological information on sex, numbers, weight and maturity stages of females were recorded. The four maturity stages of females were recorded as immature, maturing, mature and spent, based on the condition of the ovaries. We also recorded information on area and date of capture.

Approximately five pounds of each size category of sorted catch were also sampled for similar information. Shrimp species sampled were brown, Penaeus subtilis; pink-spotted, P. brasiliensis; pink, P. notialis and white, P. schmitti. From 1976 to 1978 we randomly sampled 647 shrimp landings.

This is a preliminary status report on shrimp port sampling in the Guianas for the 1976-78 period. A complete version of this paper will be published at a later date.

Most of our sampling (83 percent) took place in Georgetown (Table 4.4.1). There was some sampling in Cayenne and Paramaribo in 1976, but during 1977 and 1978 it was reduced to practically nil. The sampling in Port of Spain never did get off the ground. Thus, our report is based largely on samples from Georgetown.

Based on our samples, in 1976 the Georgetown fleet fished off Guyana, Suriname, French Guiana and Brazil, but mostly off French Guiana; in 1977 the fleet continued to fish in all four areas, but most of the activity was off Guyana(Table 4.4.2). In 1978, most of the fishing was off Guyana, fishing off Brazil ceased, and there was some activity off Suriname and French Guiana.

Brown shrimp was dominant during 1976 and 1977; in 1978 this species continued its dominance, but the percentage of pink-spotted almost doubled over the previous two years (Table 4.4.3). The second ranking species was pink-spotted followed by pink and white shrimp. Representation of pink and white was about the same for each reported year.

Based on published records, brown shrimp is the dominant species in the entire Guianas-Brazil fishery, being most abundant off Brazil and French Guiana. Second ranking in abundance, pink-spotted has the same distribution as brown shrimp, but it is most abundant off Suriname and Guyana;

pink shrimp is found only off western French Guiana, Suriname, and Guyana and in much lesser quantities than brown and pink-spotted; white shrimp is the least abundant and occurs along the entire fishery in very shallow waters and is very little fished.

The species composition from port sampling reflected the areas fished. Brown shrimp was the dominant species in 1976 when most of the catch came from Brazil, and in 1977 when a large portion of the catch came from off Brazil, French Guiana and Suriname. In 1978, as 86 percent of the sampled catch came from off Guyana, the percentage of pink-spotted shrimp almost doubled, while brown shrimp dropped 19 percent from the previous year (Table 4.4.3).

The areal species distribution of our present data further confirms that while brown shrimp is the most abundant species in the entire fishery, its abundance peaks off Brazil and French Guiana and decreases from Suriname to Guyana. The abundance of pink-spotted shrimp peaks off Suriname and particularly off Guyana. Pink and white shrimp were not represented in sufficient numbers to permit even preliminary conclusions on their areal distribution.

The sex ratio for brown shrimp in 1976 was one male to one female, in 1977 and 1978 the males outnumbered females by 2:1 and 3:1, respectively. For pink-spotted shrimp, males outnumbered females for all three years as the ratio progressively increased from 1.6:1 to 3.1:1 in favour of males from 1976 to 1978. In pink shrimp, males outnumbered females in 1976, 1.6 males to 1.0 females; in 1977 and 1978 the sex ratio was about 1:1 for both years. In white shrimp the sex ratio was about 1:1 for all three years.

The size distribution of nine commercial size categories of shrimp (>50, 41-50, 36-40, 31-35, 26-30, 21-25, 16-20, 10-15, and <10) (all species combined) was fairly even in the landing records for 1976. In 1977 and 1978 the majority of shrimp were in the >50, 41-50, and 36-40 size categories (Table 4.4.4). Size data indicated a progressive increase in small size categories (>50 and 41-50) from 1976 to 1978 (Table 4.4.4). For the same period the percentage of large shrimp in size categories 16/20 and 10/15 declined in 1977 and 1978 over the previous year.

All four stages of maturity for each species (females) occurred during each month of the year indicating year-round spawning. In 1976 all maturity stages of brown shrimp were well represented each month (data available only for June-December); in 1977 stages I and II represented the bulk of samples, stage III was less numerous than stages I and II and stage IV consisted each month of a few specimens. In 1978 stages I and II completely dominated the samples while stages III and IV were poorly represented. The occurrence of maturity stages of pink-spotted shrimp for 1976 and 1977 exhibited lack of pattern; the stage IV of pink-spotted shrimp was more numerous than its counterpart of brown shrimp. In 1978, stage I of pink-spotted shrimp made up the bulk of this species. The occurrence of maturity stages of pink and white shrimp also exhibited a lack of pattern.

Table 4.4.1 Number of shrimp landings sampled by port, year and month, Guianas-Brazil fishery

1976	J	F	M	A	M	J	J	A	S	O	N	D	Total
Georgetown	-	-	-	-	-	13	17	12	17	21	16	9	105
Cayenne	-	-	-	3	-	-	10	13	-	-	6	15	47
Paramaribo	-	-	-	-	-	13	8	11	6	2	6	3	49
Port of Spain	-	-	-	-	-	-	-	-	-	-	-	-	0
1977													
Georgetown	17	21	19	14	24	17	19	28	13	23	20	21	236
Cayenne	2	-	-	-	-	-	-	-	-	-	-	-	2
Paramaribo	-	7	2	2	-	-	-	-	-	-	-	-	11
Port of Spain	-	-	-	-	-	-	-	-	2	-	-	-	2
1978													
Georgetown	22	20	19	15	29	19	19	12	11	23	6	-	195
Cayenne	-	-	-	-	-	-	-	-	-	-	-	-	0
Paramaribo	-	-	-	-	-	-	-	-	-	-	-	-	0
Port of Spain	-	-	-	-	-	-	-	-	-	-	-	-	0
													647

Table 4.4.2 The number of times (expressed in percent) Georgetown shrimp vessels fished in each fishing zone during 1976-1978. The data represent only vessels whose landings were sampled

		Country												
		Guyana			Suriname			Fr. Guiana			Brazil			
		Fishing Zones												
Year	N	69	70	71	72	73	74	75	76	77	78	79	80	81
1976	154	6	9	9	5	8	7	21	23	1	3	4	3	0
1977	420	17	21	18	3	3	3	13	11	2	3	3	2	1
1978	418	34	33	19	2	3	1	4	4	0	0	0	0	0

Table 4.4.3 Species compostion of sampled shrimp landings in Georgetown, Guyana. Occurrence is expressed in percent; N indicates the number of landings sampled; each sample consists of 250 randomly selected specimens.

Species	Percent by number 1976	1977	1978
P. subtilis (brown)	66	69	50
P. brasiliensis (pink-spotted)	24	23	41
P. notialis (pink)	9	7	7
P. schmitti (white)	1	1	2
	N = 105	N = 233	N = 181

Table 4.4.4 Size composition of sampled shrimp landings from Georgetown, Guyana, 1976-1978. Shrimp represent all species combined and were machine graded to the shown categories. N represents number of landings sampled.

		Size Category (Number of headless shrimp per pound)									Total
Year	N	50	41-50	36-40	31-35	26-30	21-25	16-20	10-15 10	pieces	poundage sampled
		- Percent by Weight -									
1976	105	12	13	11	11	15	12	11	10	6	590 493
1977	236	20	15	11	9	12	11	8	5	9	1 619 218
1978	195	21	16	10	9	11	11	7	4	12	1 468 303
Total	539	19	15	11	10	12	11	8	5	10	

Contribution 4.5

A Technique to Obtain Information for Shrimp Management in the Western Central Atlantic Ocean

by

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Table of Contents

1. Introduction

The shrimp fishery off the Guiana-Brazil continental shelf of South America originated in 1959. Annual landings reached about 8 000 t by 1965 and fluctuate between 11 and 14 000 t.

Although the distribution of shrimp is generally continuous along the northeast South America coast from Brazil to Panama, specific stock boundaries are undefined. At present unit fisheries are generally assumed to be National Fisheries. Specific information relating to biological stock boundaries are presently unavailable.

To date, resource assessment studies have been restricted to general analysis based upon catch and fishing effort data from the commercial fisheries and oceanic surveys (Jones and Dragovich, 1977); Wise, 1976; Naidu and Boerema, 1972, and Dragovich, Jones, and Boucher (1980). The specific biological parameters, growth, mortality, and migration, have not been investigated to date nor has the distribution of juveniles. These data are required to develop sophisticated yield models. Herein the National Marine Fisheries Service Gulf of Mexico Shrimp Research Programme is presented as a template for a research programme to provide technical information for shrimp fisheries management for the Guiana-Brazil area.

2. Current Research in the Gulf of Mexico

2.1 Background

The Gulf of Mexico is the major U.S.A. shrimp fishery. Approximately 80 percent of the total value of shrimp landed is caught from the Gulf. Landings have fluctuated from 61 000 t in 1961 to 127 000 t in 1977. Brown shrimp, *Penaeus aztecus*, accounts for 53 percent of the landings, white shrimp, *P. setiferus*, for 26 percent, and pink shrimp, *P. duorarum*, for 15 percent.

Management-oriented shrimp research was initiated by the Gulf coastal states and the Galveston Laboratory of the Bureau of Commercial Fisheries (now the National Marine Fisheries Service NMFS) in the late fifties. The Gulf states have continued since, to provide information for management of the shrimp resources. Each state's research programme was funded separately by state legislators so that programmes were tailored to each state's need for information for management. The Federal Government provided biological, landings and fishing effort, and some economic information to the Gulf states. In the early sixties, high seas surveys by the NMFS provided information on the life history of the major shrimp stocks. These findings were summarized by Lindner and Cook (1970), Cook and Lindner (1970) and Costello and Allen (1970). In the late sixties that research was significantly decreased.

In 1976, the U.S. extended fisheries jurisdiction from the edge of state territorial waters offshore to 200 mi. Regional management councils were created and charged with developing management plans for all of the

U.S. fishery resources within the conservation zone excluding tuna. As a result of this action, emphasis was again placed on providing scientific information for the management of the shrimp resources. This accelerated activity was exemplified by the role of the NMFS Southeast Fisheries Center's Galveston Laboratory in expansion of shrimp research to provide basic scientific information to the appropriate management entities.

Brown, pink, and white shrimp are distributed throughout the northern and western Gulf of Mexico (Osborn, Maghan, and Drummond (1969)). The center of abundance of brown shrimp is found off Texas, white shrimp off Louisiana, and pink shrimp off southern Florida with highest concentrations off Dry Tortugas. The number of stocks included nor their boundaries have as yet been documented.

Initial mark-recapture experiments indicated that white shrimp resources are continuous from the northern Gulf and into Mexico (Lindner and Anderson, 1956), with records of marked white shrimp moving across the U.S.-Mexican border. There appears to be two separate stocks of pink shrimp, one on the Campeche Bank off Mexico and the other off South Florida on the Tortugas and Sanibel grounds. Although shrimp resources have been investigated for the last two decades in the Gulf of Mexico, information required to identify and document stock boundaries is not yet available.

Christmas and Etzold, (1977), reviewed the available fishery data and summarized information on growth, mortality, and length-weight relationships for the major shrimp stocks in the Gulf of Mexico. The growth of pink shrimp has been described off Tortugas (Berry, 1965), brown shrimp off Texas (Parrack, 1978) and off Tampico (Chavez, 1974), and white shrimp off Louisiana and Texas (Lindner and Anderson, 1956) (Klima, 1974). These studies indicate that shrimp growth rate differences do exist between seasons and locations and that those differences are large. Results of several investigations of mortality rates differ greatly indicating probable death rate variations of great magnitude (Table 4.5.I).

Table 4.5.1 Weekly Instantaneous Mortality Rates, F, M, and Z, for Three Commercially Important Shrimp Species (Sexes Combined) (from Christmas and Etzold 1977)

Shrimp Species	Fishing Mortality F	Natural Mortality M	Total Mortality Z
Brown	0.06	0.21	0.27
	.020-0.315	---	---
	---	---	0.993-1.243
	0.206	0.364	0.571
White	---	---	0.46
	0.06-0.19	0.08	0.14-0.27
	0.104-0.131	0.041-0.121	0.164-0.226
Pink	0.09	0.27	---
	0.96	0.55	0.76-1.51
	0.160-0.227	0.024-0.061	0.22-0.27
	0.03-0.07	0.08-0.11	0.11-0.18
	0.09	0.02	0.11
	0.337	0.280	0.612
	---	---	0.317-0.350

Each stock may be subjected to extremely different rates of exploitation and to vastly different rates of natural mortality at different times. In general, present estimates of growth and mortality are not extensive enough to develop realistic yield models.

2.2 Objectives

The goal of the Present National Marine Fisheries Service Research Programme is to provide scientific information for management to the Regional Fishery Management Councils. Four major identified research areas are: (1) delineate stocks in the Gulf of Mexico, (2) obtain complete catch statistics, (3) predict biological and economic yield under various long-term fishing strategies, (4) develop quantitative estimates of current surplus production which account for environmental influences on recruitment abundances.

2.3 Surplus Production Model

Klima (1980) described the current Gulf of Mexico shrimp statistical survey initiated in 1956. Current outputs from this survey are published reports of ex-vessel shrimp prices and summaries of annual and monthly shrimp landings and effort statistics. Unfortunately, the amounts of shrimp caught and discarded at sea or that are sold but not landed at fish houses are unmeasured. In the northern Gulf of Mexico vessels catch either brown or white shrimp or both on a given trip. Landings and fishing effort information recorded from interviews of fishermen and from fish buying houses is being analysed by individual trip to standardize fishing effort directed at each species. These adjusted data will then be used to develop a preliminary model of the relation between fishing intensity and surplus production for each shrimp species. Data from this statistical survey collected over the past 20 years have already been used (Klima and Parrack, 1977) to develop a preliminary surplus production model of the total shrimp resource in the northern Gulf of Mexico. In addition, the Fishery Management Councils have utilized these basic data to develop the shrimp fishery management plan.

2.4 Mark-Recapture Experiments

To obtain information on stock boundaries, migration, growth and mortality, a major mark and recapture study was initiated in 1977 and continues through 1979.

The objectives of this research programme are (1) to define the cohort and environmentally specific growth of shrimp from a single estuarine system, (2) to determine the extent and direction of shrimp migration, (3) to estimate mortality of brown and white shrimp associated with specific estuaries, and (4) to provide specific distributional information on the transboundary brown shrimp resource which occurs from Corpus Christi, Texas, to Tampico, Mexico.

In past shrimp marking experiments, several different marks have been used, including biological dye and Petersen disk tags. Dyes cannot be detected after about three to four months and the Petersen disk tag, even when scaled down to a small size, is known to cause extremely high mortalities when placed in juvenile shrimp. Marullo and Emiliani, 1976, perfected a polyethylene streamer tag for our experiments. The numbered ribbons are 4-6 mil thick, 95 mm long, and 3 mm wide. They are placed through the tail of the shrimp so that half of the ribbon protrudes from each side.

Over 36 000 juvenile white shrimp were tagged and released from July through October 1977 in Caillou Lake area of southern Louisiana. Concurrently, 8 388 white shrimp were tagged and released offshore of this estuary from August through September. Approximately 9.3 percent of those released were recovered from July through December 1977 (Table 4.5.2). This recovery rate is high in comparison to previous mark and recapture experiments conducted in the Gulf of Mexico (Clark _et al._, 1974). We believe that the new monetary incentive system for return of recaptured shrimp contributed to the high recovery rate.

Table 4.5.2 Number of tagged white shrimp released in Louisiana waters from July to December 1977 and number and percent recovered

Location	Released	Recovered	Percent
Inshore	36 639	3 807	10.4
Offshore	8 336	383	4.6
Total	44 975	4 190	9.3

Several different forms of incentive systems have been used in past mark-recapture experiments to motivate fishermen and processors to return marked shrimp. In past instances, awards of US$ 0.50 to US$ 5.00 have been offered for returned shrimp, although the standard reward was US$ 2.00 in the northern Gulf. Some shrimp fishermen stated, however, that it was not worth their time to return shrimp for only US$ 2.00. Conversely, many fishermen return shrimp without monetary reward. To increase the return rate of recaptured shrimp, we established awards ranging from US$ 50.00 to US$ 500.00 (Fig. 4.5.1). These prizes were awarded every 45 days during major recovery periods. We awarded prizes of US$ 500, US$ 200, US$ 100, and US$ 50, respectively each time. Winning mark numbers were randomly preselected by computer before the release. If the first chosen mark selected was not recovered, then the second chosen was selected, and so on until four winners were identified. Marked shrimp were returned to personnel located in the major ports. These agents who normally collected catch and fishery effort statistics were given the responsibility of receiving marked shrimp and verifying the recapture area and date.

The generalized movement of white shrimp tagged and released in Caillou Lake are described by Klima (1980). Most of the shrimp migrated westward from the Caillou Estuary release point, although a small contingent did move eastward (Fig. 4.5.2). Movement out of the estuary to the offshore area and then back into other estuaries both near and far from the release point was observed. In 71 days one tagged shrimp migrated into Galveston Bay, a distance of 220 n mi. Several shrimp were recaptured in nearby Vermilion Bay. Some individuals were also observed to move inland from the release point. We believe that we obtained extensive new migration information because we marked and successfully released extremely small shrimp (50 mm total length). Previous to this study, the smallest marked shrimp released in the Gulf of Mexico were usually larger than 80 mm total length (Clark, _et al._, 1974). A previous study in Louisiana waters (Lindner and Anderson, 1956) showed offshore movement directions similar to those observed in this study, however, long distance migrates were not observed.

The analysis of growth patterns from the recaptured shrimp show striking results. Preliminary growth models fit separately to each group of released shrimp (Fig. 4.5.3) show drastically different growth rates of the individual monthly cohorts.

Growth was very rapid in July, almost as rapid in August, slower in September, and very slow in October. Water temperatures are high in July and decrease thereafter, thus we believe the growth rate is associated with that environmental variable. A temperature-associated asymptotic growth model for white shrimp accounts for 81 percent of the variation between release size (length) and recapture size; whereas time-dependent asymptotic growth models that do not employ temperature data fit to the same data set accounted for but 70 percent of the variation (Phares, MS). A linear growth model was found inadequate and the asymptotic (Richards, Logistic, and von Bertalanffy) models fit the data almost equally well. Preliminary estimates of death rates from several separate experiments indicate that the fishery mortality rate is but a small portion of the total in all months both inshore and offshore.

Instantaneous Weekly Death Rate

		Total	Fishing	Other Causes
Inshore	July	.39	.03	.36
	August	.39	.09	.30
	September	.31	.03	.28
	October	.51	.04	.47
Offshore	Sept.-Dec.	.29	.01	.27

- Brown Shrimp

During the spring, summer, and fall of 1978, the Galveston Laboratory in cooperation with the Louisiana Department of Fisheries and Wildlife, the Texas Parks and Wildlife, and the Instituto Nacional de Pesca of Mexico initiated a major brown shrimp mark-recapture experiment. The objectives of this experiment were the same as those described previously, and an additional objective was to delineate the stock boundaries in the U.S.-Mexican border area. Experiments were initiated in May in Louisiana and continued throughout the summer and fall. A total of 81 266 shrimp were marked and released in inshore areas and 26 894 in offshore areas (Table 4.5.3 and Fig. 4.5.4). In September U.S. and Mexican biologists aboard the research vessel, OREGON II, marked and released 9 000 shrimp from Brownsville, Texas, to Tampico, Mexico.

Migration information from these experiments indicate that the brown shrimp resource is not composed of isolated stocks, but rather a single population of very mobile adult individuals exists from Tampico, Mexico, to the Mississippi River (Fig. 4.5.5). Adult shrimp released offshore appear to undergo extensive movement both in an easterly and westerly direction. Juvenile shrimp released in the Caillou Lake estuary move offshore and generally westerly, although the majority were recovered close to the release point thus indicating an intensive juvenile fishery immediately adjacent to this estuary.

Shrimp released off Texas moved in a northward direction parallel to the coast toward Galveston and southward toward the Mexican border (Fig. 4.5.6). Three shrimp released off Port Aransas, Texas, migrated across the U.S.-Mexican border. The distribution of recoveries of shrimp released off Port Aransas indicate a significant southward movement toward the Mexican border. Shrimp released off Mexico tended to move northward during the first few months after release with a smaller component moving to the south toward Tampico (Fig. 4.5.7). Four animals released in Mexico migrated into Texas offshore waters. The seven transboundary migrations coupled with the general directed movement from Mexico toward the U.S. border and the movement of brown shrimp released off of Texas southward, toward Mexico show the brown shrimp resource from Corpus Christi to Tampico is indeed transboundary in nature. These results clearly indicate that brown shrimp from Corpus Christi to Tampico should be managed as a single unit and not as two independent separate resources occurring on either side of the border.

Table 4.5.3 Number of Tagged Brown Shrimp Released in 1978 and Number and Percent Recovered

1978—79 TAGGED SHRIMP STUDY

BROWN SHRIMP	RELEASE	RECAPTURE	PERCENT
INSHORE			
LOUISIANA	39,086	3,743	9.6
TEXAS	42,180	7	—
OFFSHORE			
LOUISIANA	13,540	463	3.4
TEXAS	4,330	320	7.4
MEXICO	9,024	1,499	16.6
TOTAL	108,160	6,039	

Since marked shrimp are still being recaptured at this time, modelling of growth and mortality rates have not begun. We expect marked brown shrimp to be returned for two or three years after release.

3. Proposed Programme

The shrimp fishery off of northeast South America is based on four species: pink-spotted shrimp *Penaeus brasiliensis*, brown shrimp *P. subtilis*, pink shrimp *P. notialis*, and white shrimp *P. schmitti*. White shrimp are found inshore and are of minor importance in the catch. The shrimp fishery operates on a single year-class with very large year-to-year fluctuations in abundance (Jones and Dragovich, 1977). Monthly catch rates peak in March and April and decline gradually thereafter. The catch rates off Brazil are greater than off the Guianas. Juvenile shrimp appear to recruit in March, April, and October from French Guiana, Brazil, and Guyana. The status of the shrimp stocks off of northeastern coast of South America have been investigated and the U.S. National Marine Fisheries Service has been involved in extensive oceangoing surveys; however, a lack of basic information needed for management exists. Such information includes:

(1) continuous catch and effort statistics

(2) distributional boundaries of the major stocks, and

(3) growth and mortality parameters for the major shrimp resources.

We therefore recommend: (1) establishing an accurate and continuing statistical survey to provide catch and effort information for industry and resource managers and (2) initiating mark and recapture studies on recruiting juvenile shrimp to obtain information on migration, growth, and mortality.

Juveniles can evidently be found in the inshore areas off of French Guiana Guyana, and Brazil during the Spring and Fall months (Jones and Dragovich, 1977 Information generated from marking these juveniles will provide distribution and movement patterns and data on growth rates as well. After some experience has been gained in mark and recapture procedures, specific studies can be successfully carried out to estimate mortality rates. Concurrently, it will be necessary to establish a reliable collection system for catch and effort information and a central data management file. In addition, an adequate incentive system must be established so that marked shrimp will be recovered. Fishermen must be advised of the programme and an adequate incentive system be developed so that recaptured shrimp with appropriate information, as date or recapture and location, will be returned. Since fishermen will not likely immediately become familiar with the programme, study objectives for initial experiments should not be set too high.

It can be expected that shrimps tagged off of one country's coast will be recovered off of another country's coastline. Therefore, a coordinated international programme within the WECAF area is essential. The degree of cooperation will determine the eventual success of the programme and thus the ability of the fishery industry to achieve maximum long-term utilization of the resource. We recommend an international programme be established and that each country be an active participant within this programme.

In summary, we recommend the following efforts be undertaken to construct the necessary data base:

(1) establish international cooperative infrastructure to conduct mark and recapture experiments with juvenile shrimp in the Spring and Fall to estimate growth rates and migration patterns.

(2) develop an accurate and continuing survey system to collect and distribute catch and effort statistics, and

(3) devise and carry out specific studies to estimate mortality rates.

This data can be used to devise models that will predict the status of the resource under various long-term fishing strategies and define methods to achieve maximum long-term utilization of these shrimp resources.

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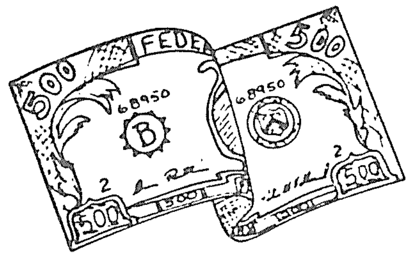

AWARDS FROM $50.00 TO $500.00 !
OUR SHRIMP FISHERY NEEDS YOUR HELP !

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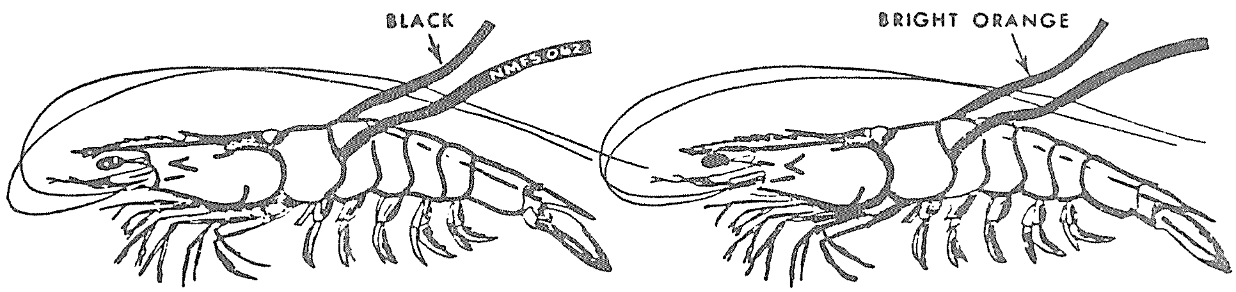


Awards will be randomly selected from tagged shrimp that are returned. To qualify as an entry, the tag must be in the shrimp and the date and location the shrimp was caught must be given. Sets of awards will continue into 1979. Any tag number that hasn't been chosen remains eligible in the later drawings.

AWARDS OF $500 -- $200 -- $100 -- AND $50 WILL BE AVAILABLE IN EACH SELECTION.

Dates for making awards will be announced.

THIS STUDY IS BEING CARRIED OUT JOINTLY BY THE TEXAS PARKS AND WILDLIFE DEPARTMENT, TEXAS A&M UNIVERSITY, THE NATIONAL MARINE FISHERIES SERVICE AND THE INSTITUTO NACIONAL DE PESCA OF MEXICO.

If you have caught a tagged shrimp or know someone who has please contact:

AGENCY	ADDRESS	PHONE NUMBER

Figure 4.5.1 Poster Advertising Shrimp Incentive System

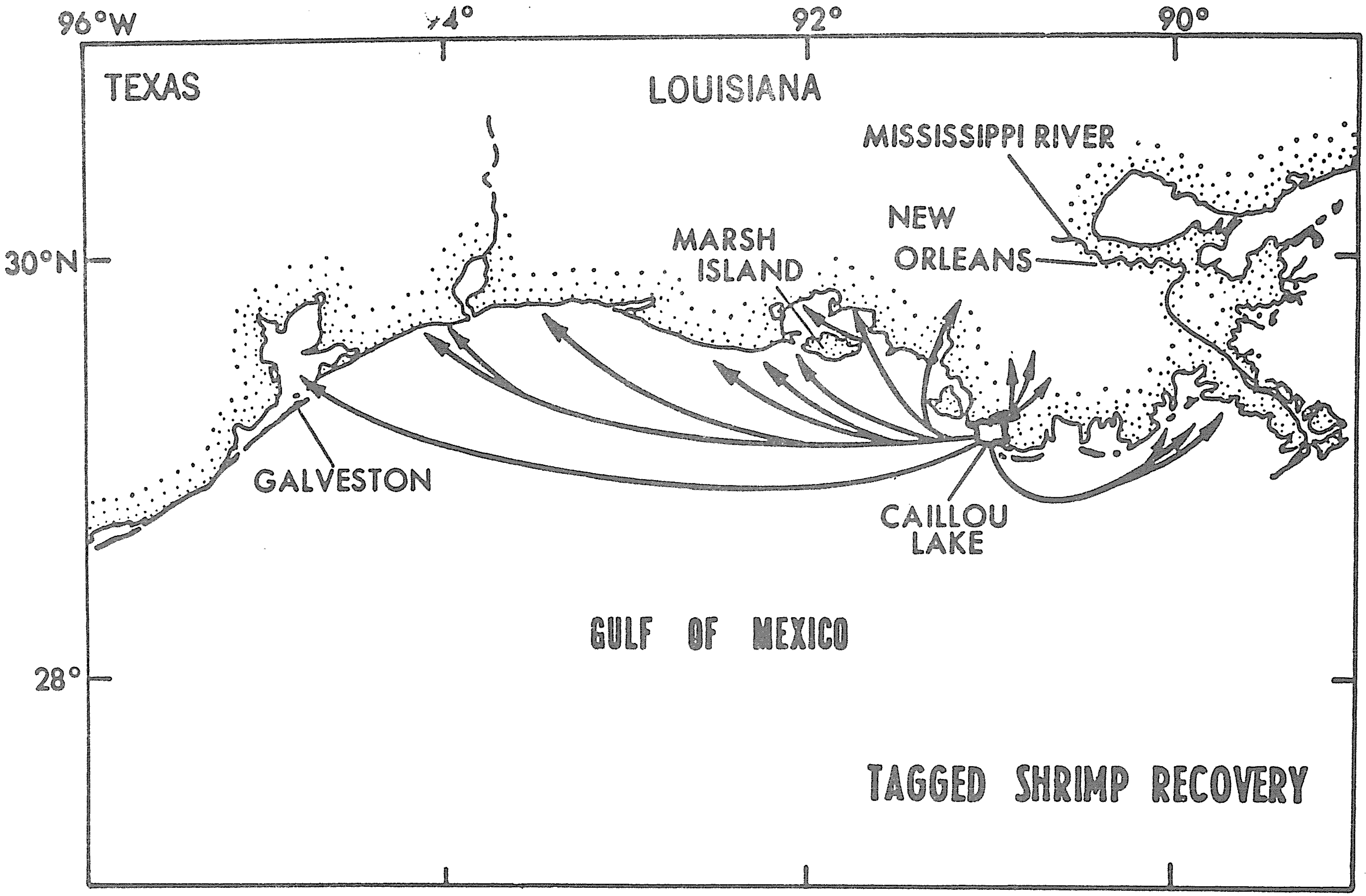


Figure 4.5.2 General Movement Patterns of White Shrimp Released in Caillou Lake, LA from July to October 1977

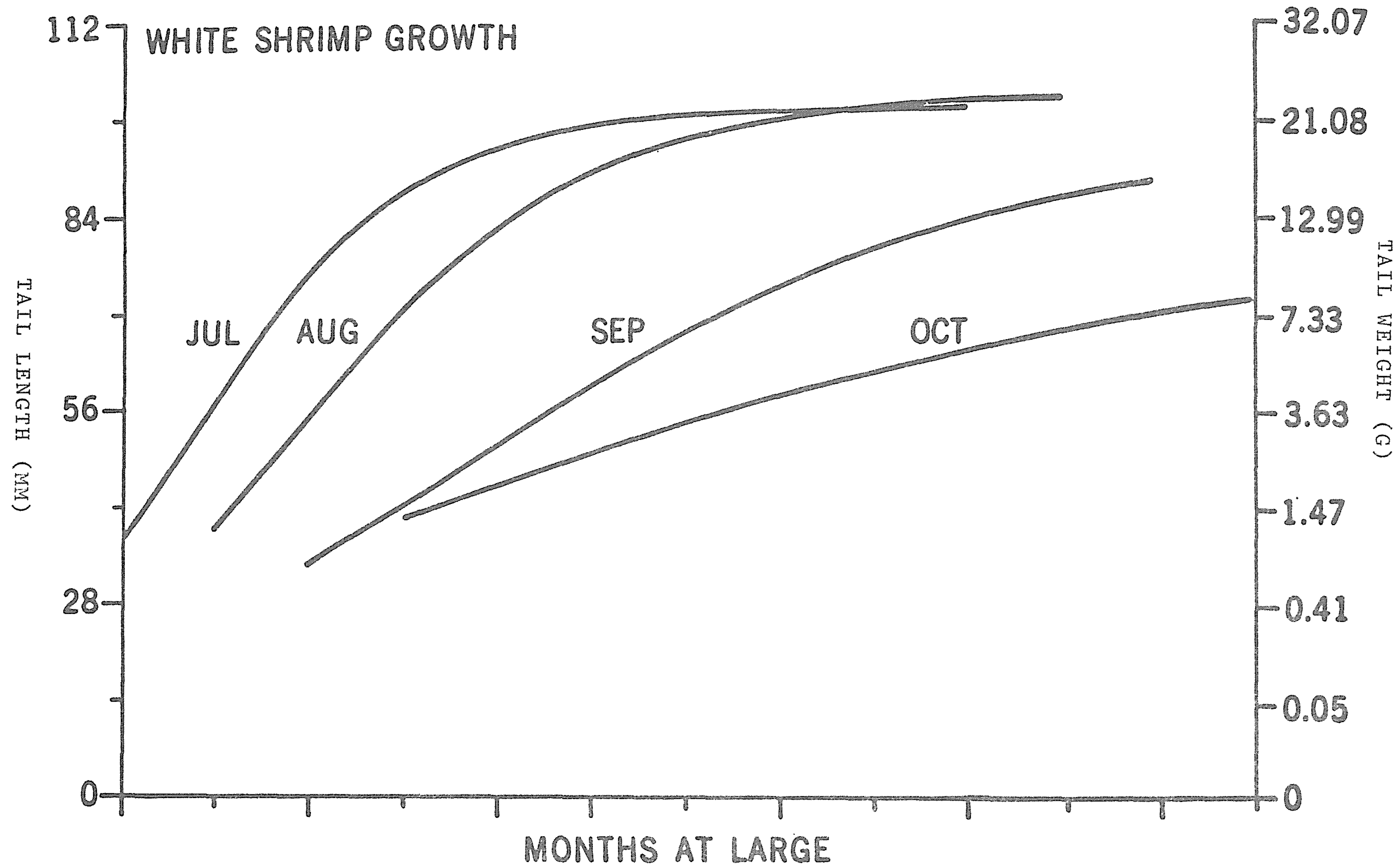
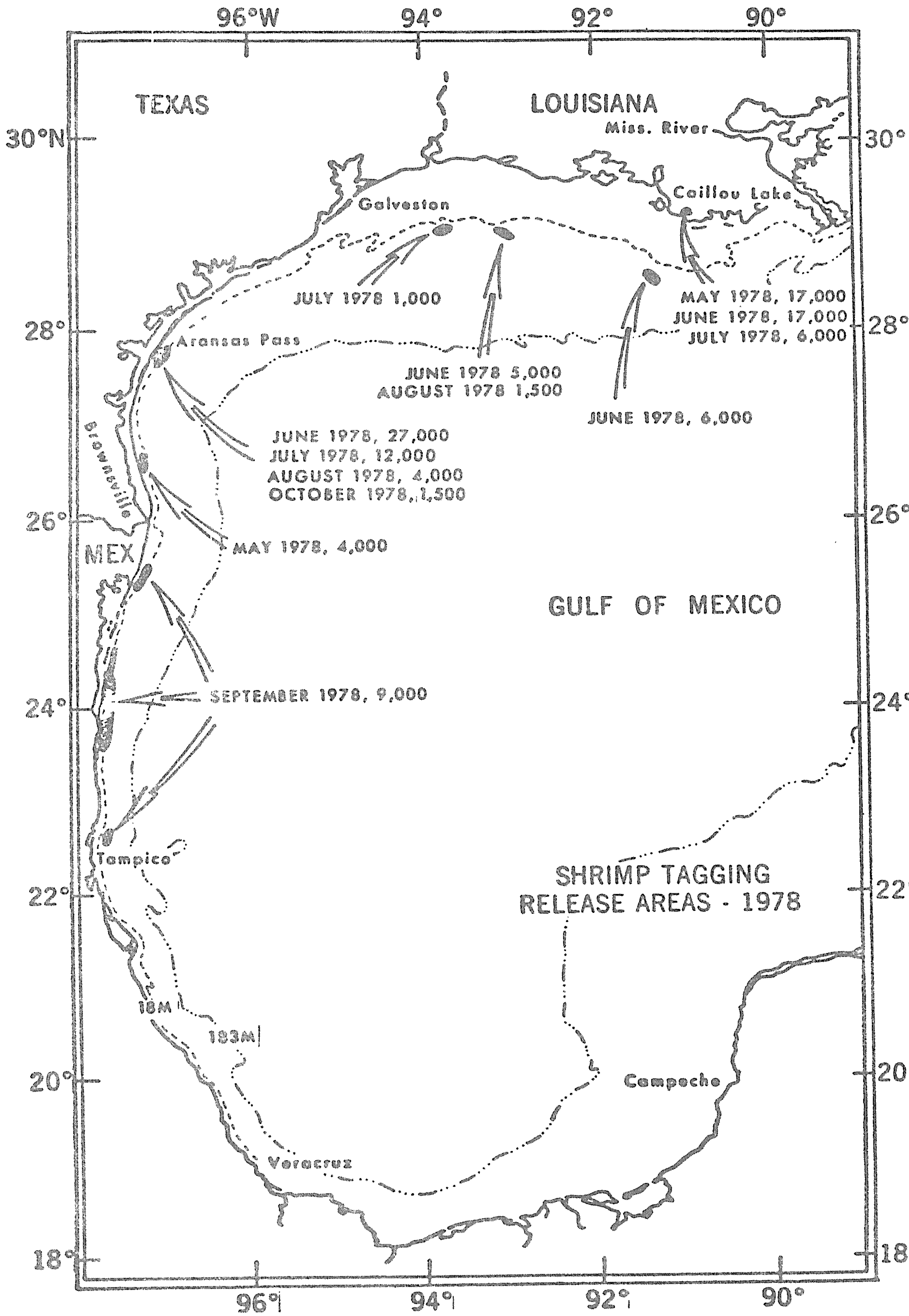


Figure 4.5.3 Comparison of Growth Curves Between July, August, September and October White Shrimp Cohorts



4 Location and Numbers of Brown Shrimp Released in 1978 in the Gulf of Mexico

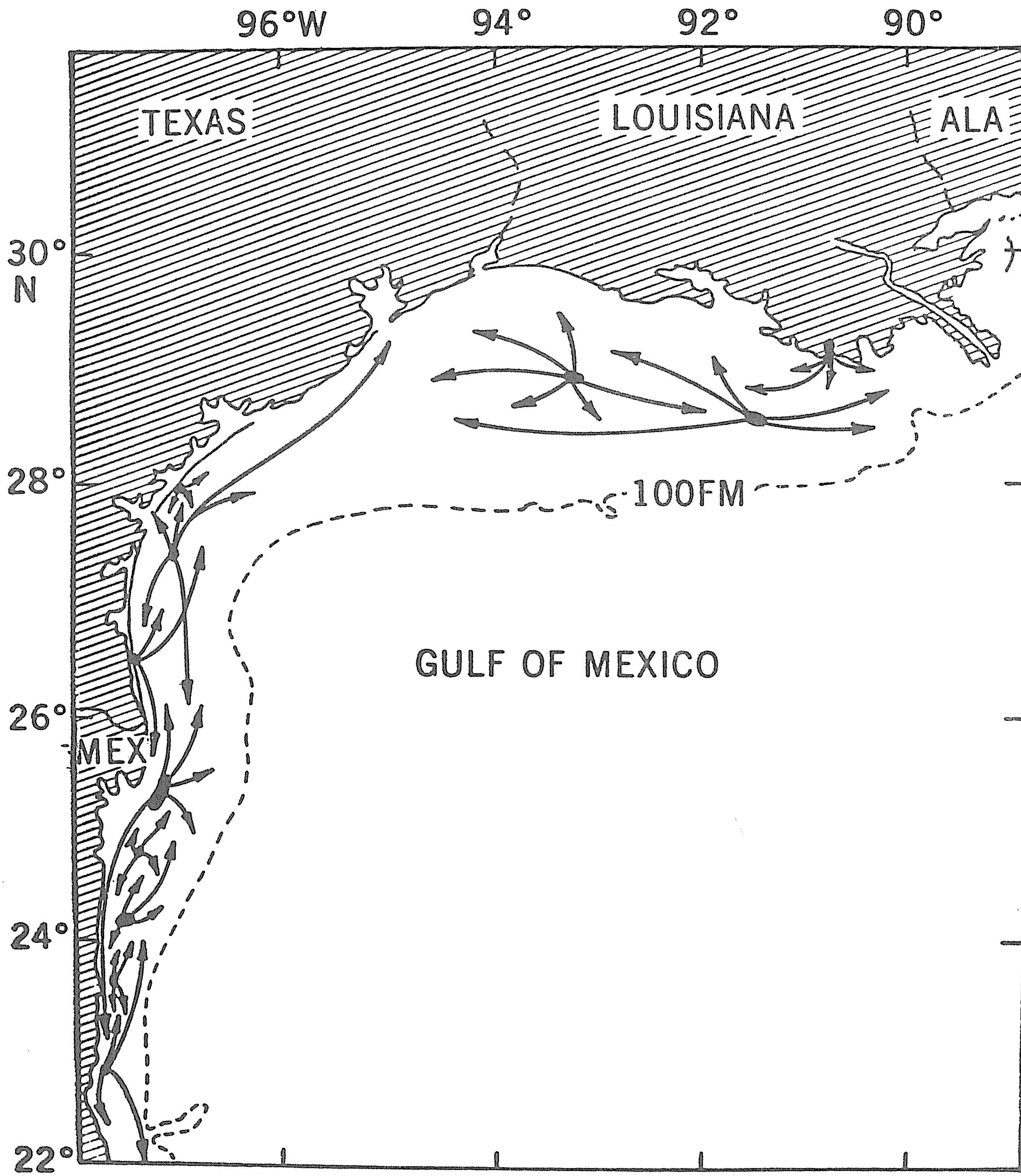


Figure 4.5.5 General Movement Pattern of Brown Shrimp Released in 1978 in the Gulf of Mexico

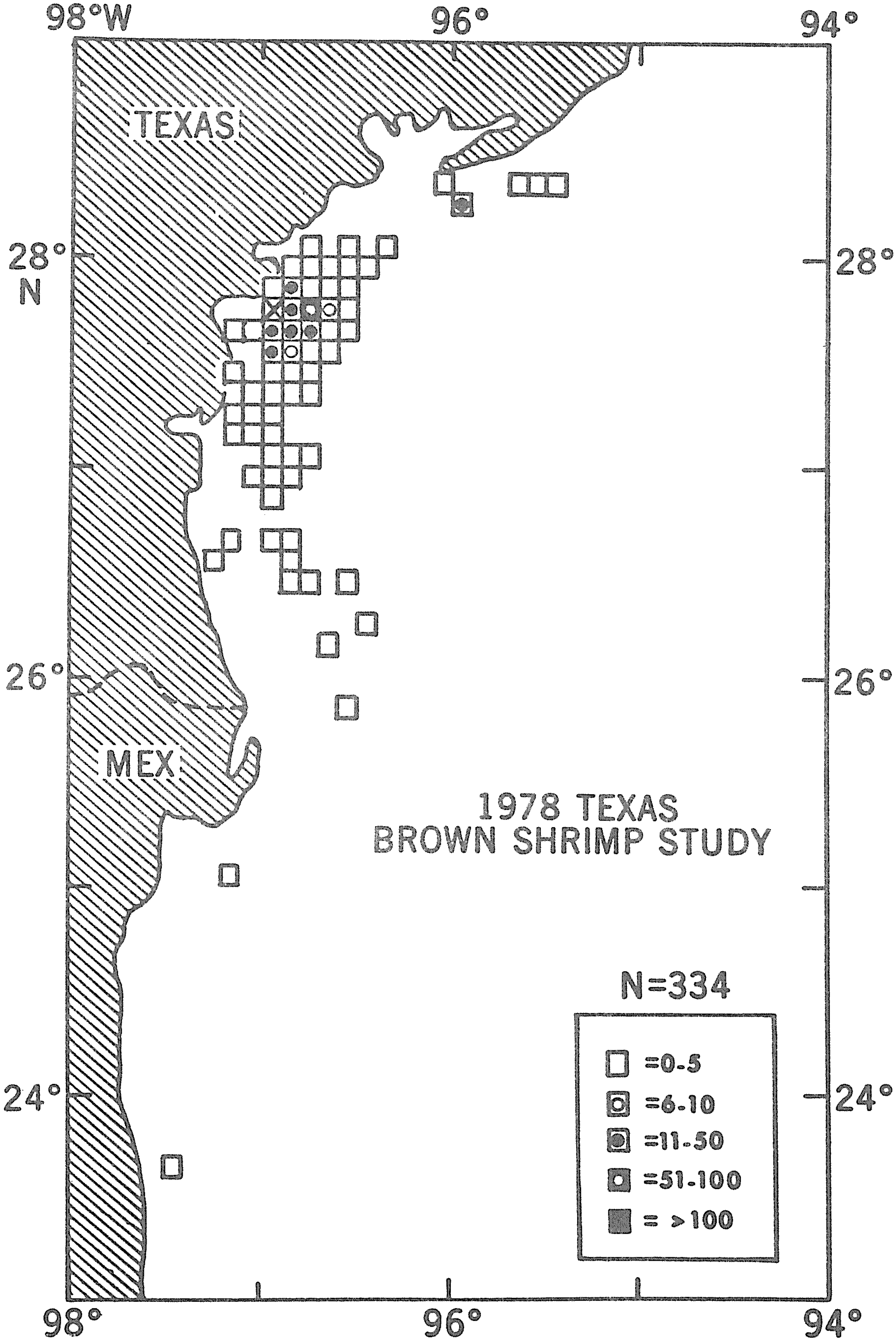


Figure 4.5.6 Density Distribution of Brown Shrimp Recoveries by Six Nautical Square Miles (Texas)

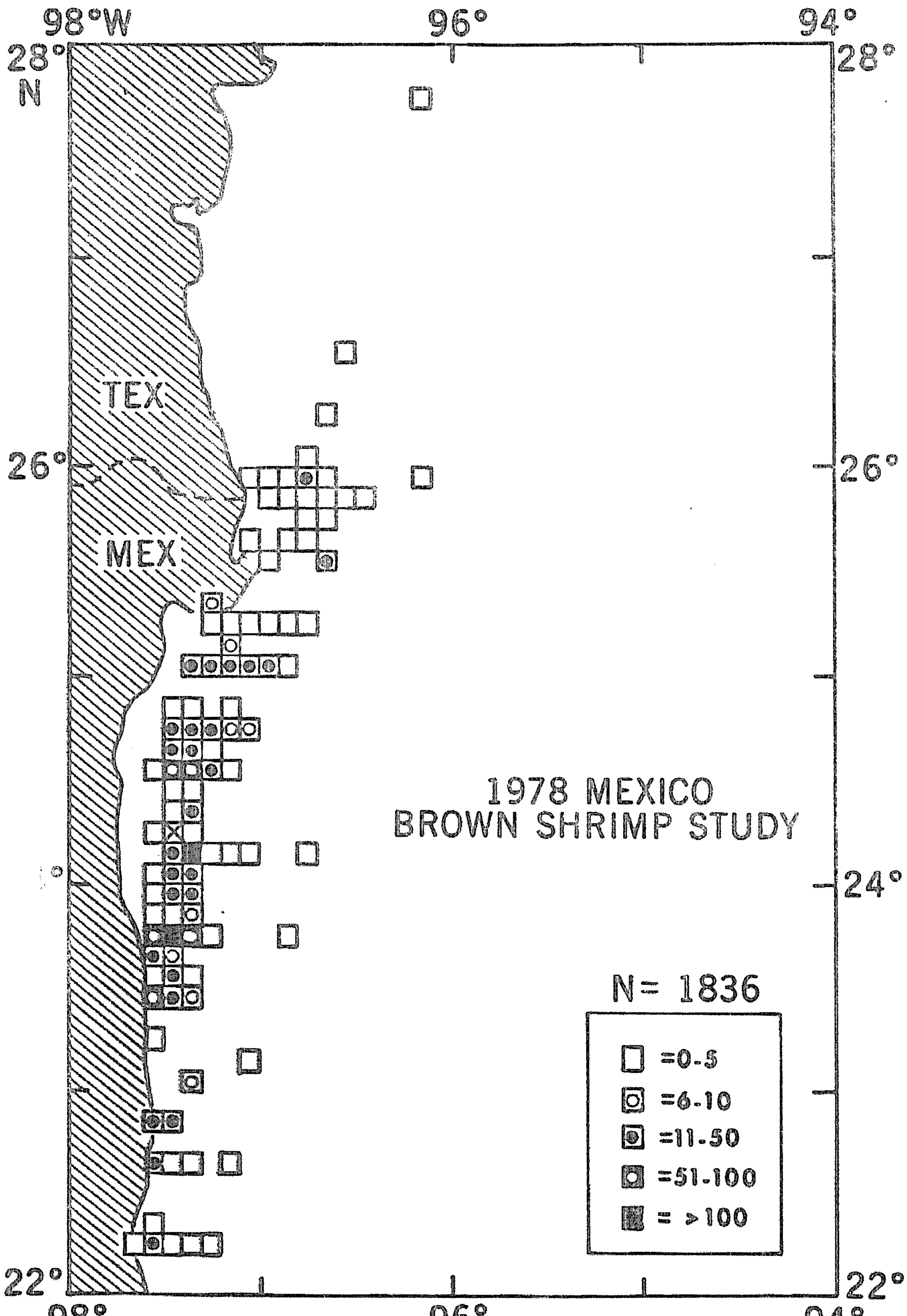


Figure 4.5.7. Distribution of Brown Shrimp Recoveries Off Mexico

Contribution 4.6

Catch Statistics - Data Needs of the Southeastern South America Shrimp Populations

by

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Table of Contents

1. Introduction

The U.S. Gulf of Mexico Shrimp Fishery is the most valuable fishery in the United States. Shrimp fisheries in other parts of the world are also recognized as being of great importance to their countries. Systematic collection of pertinent information on shrimping activities can provide important information for both industry and resource managers. Continuing statistical surveys provide the fishing industry with timely information on trends and shrimp production and marketing of shrimp products; it also furnishes the resource manager information on the distribution and magnitude of the shrimp catch and fishing effort which are the basis of formulating management decisions. The National Marine Fishery Services (NMFS), formerly the Bureau of Commercial Fisheries, initiated in 1956, a continuing survey of commercial shrimping activities in Gulf of Mexico. This paper describes the present survey and recommendations for establishing of a continuing statistical survey on shrimp activities to provide information to the shrimp industry and resource managers in the WECAF area.

2. U.S. Commercial Shrimp Fishery Statistics

Accurate statistics of U.S. shrimp trawling operations and production in the Gulf of Mexico were not collected prior to 1956. Presently, statistics describing the extensive U.S. commercial shrimp fisheries in the Gulf of Mexico are routinely collected by the NMFS. A major continuing statistical survey was initiated in 1956 and continues to the present time. Data from these surveys are published monthly in periodicals entitled Gulf Coast Shrimp Data by Area, Depth, Species, and Size, as well as annually in a periodical entitled Gulf Coast Shrimp Annual Summaries. These publications include corresponding information on number of fishing trips by commercial trawlers, the total amount of time spent fishing, and the dockside value of total landings.

The present survey, however, only permits full statistical coverage of that fishery centering on the commercial utilization of shrimp for human consumption. Operations and production of recreational fisheries have not been recorded. It should be pointed out, therefore, that the available statistics give an incomplete picture of the total shrimp harvest in the Gulf coast area and allow appraisal of only those portions of the population supporting what is commonly defined as the commercial fishery. In addition, illegal size shrimp occur in trawl catches during certain seasons and within certain areas, and as a result, a portion of the catch may be discarded at sea. Therefore, the catch statistics represent only a fraction of the total amount of shrimp actually caught and/or killed.

2.1 Identification of Fishing Grounds

To facilitate geographical assignment of commercial trawling effort and hence, classification of shrimp landings as to origin, the continental shelf of the Gulf of Mexico has been subdivided coastwise into 40 statistical subareas. These zones have been further subdivided by depth from the shoreline out to the edge of the continental shelf. Catch and effort information is reported by these statistical areas and depth zones.

2.2 Distribution of Shrimp Fishing Effort

One of the two important variables involved in measuring shrimp populations is the time spent trawling or, more commonly referred to, as fishing effort. Estimates of fishing effort are obtained by interviewing ship captains and projection to the unsampled portion of the fleet.

The number of trawler captains each port agent is able to interview per week may vary from none to as many as a hundred or more, depending on his other duties, the likelihood of contacting captains during the hours set aside for this purpose and the cooperations of the captains themselves. Special studies such as mark-recapture experiments may require a higher level of interview information in such cases, extra port agents are hired for a specific time period, to obtain such information. Through the shrimp trip interview form, data on areas and depth fished as well as time spent trawling at each fishing position are recorded.

To obtain information on the distribution of total fishing effort, it is then assumed (1) that all trawlers landing in a given port operate in the same general area(s) and at the same depths of those interviewed, and (2) that for all craft a simple linear relationship exists between amount of trawling time and size of corresponding catch. Fishing effort for non-interview vessels is estimated by expanding effort data collected through the interview process. The quantity of effort expended is calculated by merely dividing their known catches by a projection factor derived from catch effort ratios of the vessels actually sampled or interviewed. Effort is recorded to the nearest tenth in terms of days trawling time, or more precisely, the total number of hours trawled divided by 24. "Day" then does not refer to a calendar day, but merely represents 24 hours of fishing effort.

Two major biases which have been identified by Kutkuhn, 1962 affect the usefulness of effort data for biological assessment. These biases are (1) estimating non-productive fishing effort. During certain seasons considerable amounts of searching and fishing time are expended with negligible results. Under the present system, such activities go unaccounted for since effort is estimated for and assigned only to vessel-trips for which a shrimp sale is recorded. Exclusion of this effort obviously leads to underestimates of individual vessel and fleet trawling time. The second bias relates to the assumption that all vessels operating out of or landing at a particular port fish in close proximity may not always be valid. It should be pointed out, however, that portions of a fishing fleet fishing a specific locale usually tend to aggravate on shrimp concentration occurring in that area. In addition, the question how fishing positions and efforts are assigned to vessels operating in periods during which fishing interview data is not obtained presents another problem with the data. To resolve this problem, one must increase the interview level to a substantial level to assure that a significant portion of the fleet is interviewed.

2.3 Port Agents

Port agents record the day-to-day operations and production of the U.S. commercial shrimp fleet. These agents are located strategically at landing ports around the Gulf in each of the respective States, they canvass fishermen and processors for detailed information on location and amount of fishing, volume and composition of shrimp landings, and current market conditions. This information is correlated, coded and punched onto cards and then entered into the Data Communication Network. The data is processed with the Honeywell 66/80 located at Macon, Georgia. Final products from this information consist of assembling the data on a monthly basis and publishing them in Tables entitled Gulf Coast Shrimp Data by Area, Depth, Species, and Size.

3. Landings

Of equal importance to estimating fishing effort, is estimating catch. The present statistical survey attempts to account for all commercial landings through a daily or weekly canvass of processing plants. From dealers' receipts, port agents transcribe the details of landings for each vessel trip on forms entitled Shrimp Purchase Dealer Schedule. It is estimated that almost 100 percent of all Gulf shrimp landings which are sold through normal commercial channels are reported each year. Again, it should be pointed out that the recreational and non-commercial as well as discard catch are not surveyed, therefore, the landings on catch data represent only a portion of the total amount of shrimp which are killed by some form of shrimping activity.

3.1 Location

Each landing recorded by interview is coded according to its known origin.

Pro-rating landings by depth of capture is one procedure here that could lead to misrepresentation of tabulating data. If a captain states that he trawled in several depth zones but cannot specify how his trawling time and catches were apportioned among them, his total effort and corresponding catch will be coded respectively as having been expended in and taken from the zone of greatest depth fished.

3.2 Species Composition

Most dealers are very familiar with the species compositions of shrimp landed since shrimp are sold either as white, browns, or pinks (i.e., *Penaeus setiferus*, *P. aztecus*, and *P. duorarum* respectively). A breakdown by species for each landing is obtained automatically when transcribing landing data from dealer records.

In some areas, however, closely related species are not differentiated by price. An example is a non-differential price between brown and pink shrimp along the Texas, Louisiana, Mississippi coast. Most landings are recorded as brown, when, in fact, at certain times of the year, there may be a large percentage of pink shrimp distributed among the catch.

3.3 Size Composition

Ex-vessel sales are prorated on the basis of each landing size composition as well as its species composition with larger shrimp bringing higher prices. Landings are recorded according to the size as purchased from the fishermen. Accurate information concerning this size composition of catch cannot, however, be obtained from the landing information since various biases enter into these data. They are (1) different grading methods between producers, (2) changing prices, (3) differential dealer and gear selectivity, and (4) varying minimum size laws between States.

3.4 Conversion Factors

The current survey has provided the fishing industry commercial catch statistics in weight in terms of headless (or "heads-off") shrimp. Unfortunately, biologists find this in certain instances difficult to deal with, and therefore, require conversions to whole shrimp. Kutkuhn, 1962 provided conversion factors for brown, pink, white, and sea bob 1.61, 1.60, 1.54, and 1.53 respectively. Klima, 1969 provided conversion for royal-reds (*Hymenopenaeus robustus*) (i.e., 1.83).

4. Regional Data Management

The regional data management system is a network of computer devices and communications equipment designed to provide for storage, manipulation, and retrieval of information by users anywhere in the system.

The SEF Center, its laboratories, and the Southeast Regional Office are tied together, utilizing the Civil Service Commission's Honeywell computer at Macon, Georgia. It is possible to transmit, store, manipulate, and exchange scientific and statistical data among all sites. Expanded analytical and graphics capability is available at three major laboratories for both local and regional applications.

4.1 Data Volume

(1) Approximately 12 000 schedules per year are generated which results in about 48 000 80-character (card-image) records per year.

(2) Approximately 3 400 telephone reports are made each year followed by unformatted hard copy which is not further processed.

(3) Approximately 1 100 telephone reports are made each year followed by hard copy which is not further processed.

(4) Monthly landings data requires an estimated 3 000 schedules to be generated per year which are processed into approximately 60 000 card-imaged records.

(5) Approximately 3 000 vessel description changes are submitted for processing each year. In addition, boat numbers and employment data require approximately 50 forms per year.

(6) Maintaining data on wholesale and processing establishments require approximately 200 unformatted submissions per year.

(7) Cold storage holdings data are reported on about 600 schedules per year.

Data are entered into the system via terminals at any site in the region. Edit and update programmes check for certain errors before accepting the data for storage. Data can also be visually reviewed by persons familiar with the data by using cathode ray tube terminals. In this operation, the person can recall data previously entered into the system for validation or change if an error is recovered. Once validated, data are stored in permanent computer files for rapid retrieval and use by authorized personnel with the region.

5. Output

5.1 Gulf Coast Shrimp Data (1960-1978)

These published data are reported by month, area and depth of capture, shrimp species and size, number of trips, and days fished. These tabulations contain data on shrimp catch landed by U.S. craft at U.S. ports along the Gulf of Mexico for trips completed during each month. "Days fished" represents actual fishing time in number of days, a day of fishing being equivalent to 24 hours of fishing time. No distinction is made between time spent fishing at night vs. day-time in these records. A single trip is reported for each voyage. For a craft which has a portion of its catch transported to port by another vessel, the trip is assigned to the area and depth last fished by the craft. For a craft landing its entire catch, the trip is prorated to the areas and depths fished. Shrimp size is expressed in number of shrimp ("heads-off") per lb.

5.2 Shrimp Operating Unit Data File

These data, obtained from U.S. Coast Guard records and annual surveys are characteristics of fishing craft and gear including name of fishing craft, registry number, type of engine(s), horsepower, length, gross tonnage, year built, control port, crew, number of trawling units and total quantity of fishing gear (measured as total yards along the "leadline" or "foot-rope" of the trawls.

5.3 Shrimp Trip Interview Data File

These data, obtained from interviews of fishermen upon completion of fishing trips, include name and registry number of fishing craft, catch by species and size, area and depth fished, days fished (in 24-hour units), shrimp dealer number, port of landing, date of landing, method of shrimp size grading (box grading, machine grading), and value of catch by species and size.

5.4 Shrimp Dealer Data File

These data, obtained from shrimp dealer records, include port of landing, type of fishing craft, month of landings, number of trips, method of shrimp size grading (box grading, machine grading), dealer number, total landings, species and size composition of landings, and value by species and size.

6. Suggested System

We recommend a similar statistical collection system be initiated in the WECAF area. One might consider subdividing the area into statistical zones from Mexico to Brazil as a continuation of the statistical system established in the U.S. A diagram of a proposed system is included for consideration[1/]. The Statistical Area should be 1° by 1° quadratic with a similar numerical system to the Gulf of Mexico system starting at Statistical Area 40 and continuing through to Statistical Area 75 off of French Guiana. We further recommend the same depth stratification be used as is used in the Gulf of Mexico and that catch be reported on a monthly basis in terms of area, size, and depth distribution. Port agents should be located at the key ports throughout this area where a majority of the landings are known to occur. Port agents should collect the information from the processors so that the total catch landed be reported on a monthly basis and further, that port agents be responsible for interviewing shrimp fishermen so as to determine origin catch and that appropriate techniques be developed for your area to allocate fishing effort and catch to statistical areas by depth zone.

We recognize that there will be major differences in the shrimp fisheries of this area as compared to the Gulf of Mexico, therefore, a rigid system is not proposed at this time, but one in which flexibility will be permitted to adapt to the local conditions of the area. The main point that we wish to make is that collection system be established in which shrimp catches are reported on a monthly and annual basis throughout the area and that all nations participate in development and maintenance of the survey. A central data bank should be established for the collection coding and correlation of the catch statistics for the entire WECAF region. Finally the catch data should be made available to all interested parties within a reasonable time period. A Regional Data Management System will be required to process and distribute these data to the industry and resource manager.

We are presently reviewing our statistical collection system and hope to be able to develop an improved design within the next year.

1/ Not received at the time of publication.

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Contribution 4.7

Subspecific Stock Identification of Northeastern South America Shrimp Fishery

by

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1. Introduction

The shrimp fishery along the northern and eastern coasts of South America is reportedly based on four species of Penaeus: brasiliensis, schmitti, subtilis and notialis (Jones and Dragovich, 1977). Unlike the Penaeus species supporting the United States' shrimp fishery, the shrimp species being harvested off South America have not been the subjects of intensive scientific investigation. Very little information is available on the location and timing of spawning in these species. Also, data on the utilization of nursery areas by each species are very limited. Conversely, there is considerable information on the distribution of adults of each species and these data suggest associations between depth and/or substrate type and the presence of adults of each of the four species. Proper management procedures based on assessments of unit stocks will require the future development of a larger data base.

In order to provide a baseline for future studies of these shrimp stocks, research should be conducted to determine the genetic nature of these four shrimp "species". One should be certain of the number of species involved both in the offshore catches and in the nursery areas and the number of separate populations within each species before attempting to model the population dynamics of this entire shrimp fishery.

Three important questions about these penaeid species could be answered by applying the techniques used in my study of Penaeus aztecus, P. duorarum and P. setiferus in the Gulf of Mexico. First, how many species of Penaeus are, in fact, present in any area?

Although there is no apparent reason to doubt the description of Perez Farfante, this question would be answered as a routine part of a detailed genetic study of the four morphotypes of Penaeus in the area. In addition, biochemical techniques permit reliable species identification of juveniles of sizes at which morphological distinction is very difficult. Second, are any of these species subdivided into genetically differentiated populations? If isolated populations exist, they should be treated as distinct fishing stocks. Third, what are the patterns of gene flow within each species? If genetic differences exist across the range of a species, a study of rare alleles can be used to define gene flow patterns. These patterns are indicative of the movement of larval and adult shrimp between areas.

2. Methods

Of the techniques currently available for answering questions on systematics or population genetics, the one most often applied is electrophoresis of enzymes. This technique was employed in a study on the penaeid species of the Gulf of Mexico (Lester, 1979). It is a method of visualizing the proteins produced by a set of gene loci. A homogenate of one or more tissues is obtained from live or freeze-killed shrimp. A gel is made by boiling starch in a buffer and allowing it to solidify. Small pieces of filter paper are moistened with the shrimp extract and placed side by side in the gel.

This starch gel is then placed as a bridge between two buffer reservoirs and a current is passed through it. Proteins have charges on their surfaces and will migrate in an electric field. If an organism has two alleles at a single gene locus which produce proteins that differ in the number of charges exposed on their surface, then they will migrate different distances in the electric field. When the run is terminated, the position of the proteins produced by a gene locus is visualized by applying a staining solution which reacts only at the point of the enzyme reaction catalyzed by that protein. Using histochemical stains which are specific for different enzyme reactions it is possible to examine individual shrimp for protein variation at more than 20 gene loci.

If all of the enzymes from a single gene locus have migrated the same distance from their point of origin, that locus is designated as monomorphic (i.e., the gene products do not indicate the presence of different alleles). If the enzymes produced by a single gene locus migrate different distances, then the locus is polymorphic. (Fig. 4.7.1).

3. Previous Results on Penaeid Species

In my study of Penaeus aztecus, duorarum and setiferus, I used enzymes produced by 24 loci, and about 30 percent of these loci were polymorphic (Table 4.7.1). If a locus is polymorphic, some individuals will be heterozygous (i.e., have two different gene products from a single locus). In these three species, the average individual is heterozygous at 7 percent to 9 percent of the gene loci studied.

The different charge states of proteins produced by a gene locus can be considered to be alleles, although they will only represent a subsample of the alleles that are actually present. Nevertheless, populations of the same or different species can be compared by using these charge classes (alleles) at a set of loci. For example, Penaeus aztecus and P. duorarum have different common alleles at about 30 percent of their loci (Table 4.7.2). The difference between P. setiferus and either of these species is slightly greater. These differences make it simple to distinguish the electrophoretic profiles of individuals from these species (Fig. 4.7.1). The same would be true of any set of species that had been genetically isolated from each other for evolutionary time. Genetic isolation means that the populations are not capable of interbreeding or are not exchanging any individuals, either larvae or adults, so that interbreeding cannot occur. In marine organisms with planktonic larvae, such as penaeids, isolation is dependent on the pattern and speed of the currents which carry the larvae and the migration patterns of the adults.

4. Species Identification

Any genetic study of the penaeid stocks off northeastern South America, should consider at least two problems related to the genetic identification of species. First, how many genic differences can be detected among the shrimp species in South American waters and between the stocks of brown, pink and white shrimp in the North American and South American fisheries? Second, what are the most reliable and cost-effective biochemical methods that will permit the differentiation of all species at all post-larval stages?

Only recently have subtilis and notialis been elevated to the level of full species (Perez Farfante, 1978). Formerly, they were recognized as subspecies of P. aztecus (subtilis) and P. duorarum (notialis) each having a related subspecies in the Gulf of Mexico. This distinction between subspecies and true species is an arbitrary judgment based upon an evaluation of morphological characters which has always been the stock in trade of taxonomists. However, classical methods of differentiating species have not always been reliable and are not as sensitive as biochemical techniques that are currently available (e.g.,electrophoresis of enzymes). There are numerous cases of unrecognized species being detected through the use of biochemical genetics. This has happened in my own laboratory (Bell and Lester, manuscript). Fewer cases of the reverse have occurred, morphological types that were thought to be species, but proved to be the result of morphological polymorphism. Several cases have been documented in a variety of organisms (e.g.,fish: Sage and Selander, 1976; snails: Woodruff, 1978).

It is curious that the distributions of P. notialis, P. schmitti and P. subtilis are so similar and each of them shows an affinity to one of the penaeid species in the Gulf of Mexico, P. duorarum, P. setiferus, and P. aztecus, respectively, all of which have very similar distributions. It is possible that these species pairs are still genetically connected by limited interbreeding in the area of the Florida Keys (P. notialis and P. duorarum) or the Bay of Campeche (all three pairs). Despite such a connexion, limited differentiation could still occur if the level of successful interbreeding were low. The similarity of these distributions implies that all three cases of differentiation (or speciation if no gene flow is occurring) resulted from the same cause.

In the case of brown, pink, and white shrimp, the stocks off the coasts of North America and South America are obviously separate for fishery management purposes. However, the description of genetic connexions between these related stocks would be valuable as an indication of life cycle and ecological similarity between the North American shrimp stocks and the South American one. If the Gulf of Mexico shrimp stocks are representative of the level of genic differentiation between penaeid species, the shrimp stocks in the Guianas-Brazil area should exhibit striking differences at about 30 percent of the loci examined. Many fewer of the gene products which show mobility differences in the pairwise species comparisons will have different mobility patterns for all of the species. It is possible that the most reliable and cost effective method will involve the analysis of gene products from several loci for the discrimination of species. This could be particularly true of a method to be applied to adults, juveniles and postlarvae because of developmental changes in the loci which are active and in the functioning form of the enzyme.

5. Stock Differences within Species

Isolation of stocks in species with planktonic larvae appears to be related to the movement of the larvae on currents and the migrations of the adults. Shrimp larvae have a greater potential for long distance dispersal than the adults; even though the adults can move many miles during their lifetime (Klima, 1980). The movement of adults can be directly evaluated by tagging studies (Klima and Parrack, 1980). However, the movement of specific larvae is not a reasonable research objective and genetic techniques which track genes over long time periods are the simplest approximation. Let us examine the currents off northeastern South America to determine whether there is probable cause to suspect isolation of stocks due to patterns of larval transport.

5.1 Current Patterns

If one compares the currents of the Central Atlantic region (Fig. 4.7.2) and the distributions of the shrimp species in the region a pattern of possible genetic differentiation emerges. As the South Equatorial Current nears the coast of South America it splits into two currents which follow the coast to the northwest and southwest of Cabo de Sao Roque. The southwestern branch is the Brazil Current and the South Equatorial Current continues northwest to join with the North Equatorial Current off French Guiana and Suriname. This current flows through the Caribbean into Straits of Yucatan. In the Caribbean Sea, the movement of the water mass is rapid and very constant in direction, except for the gyres which develop in the Golfo de los Mosquitos and the Gulf of Honduras. As the current moves past the Yucatan Peninsula it splits again and part of it loops north of Cuba and through the Straits of Florida. The remainder circulates in the western Gulf of Mexico in a clockwise gyre or in a fan-like pattern toward the Texas coast. Some of this water rejoins the main current north of Cuba and sweeps up the east coast of Florida to become part of the Gulf Stream.

5.2 Results of Isolation Studies on Gulf of Mexico Stocks

The effect of the mixture of water masses in the Gulf of Mexico was apparent in the genetic study of *Penaeus aztecus*, *duorarum* and *setiferus*. Collections were obtained from localities up to 1 500 km apart; the genetic constitution of these collections was compared within each species over 24 loci. Genetic similarity can be described by a single statistic, genetic identity (Nei, 1972), which sums all of the differences in gene frequencies at a set of loci. Between species the genetic identity is usually less than 0.75. But between populations of a single species the level of genetic identity is usually 0.90 or greater. However, for *P. aztecus*, *duorarum*, and *setiferus*, the genetic identities which obtained when comparing collections within each species is greater than 0.99. Based on the genetic information obtained by electrophoresis, one may conclude that each of these species is genetically homogeneous within the Gulf of Mexico, and therefore constitutes a single population or stock. However, additional genetic data on *P. setiferus* from the Atlantic obtained by another population geneticist (Wyatt Anderson, personal communication), shows that this species is genetically subdivided or is composed of at least two stocks, one in the Gulf of Mexico and one in the Atlantic Ocean.

5.3 Hypotheses on Isolation in South American Stocks

Let us examine distribution of the four Penaeus species being considered

(Fig. 4.7.3) and see whether the current patterns and the distributions provide us with reasonable hypotheses about the genetic subdivision of these species into semi-isolated stocks. Penaeus brasiliensis is distributed from approximately 30° S latitude along the coast of Brazil to approximately 35° N latitude, and it is very abundant on the Guianas-Brazil fishing grounds (Jones and Dragovich, 1977). Penaeus schmitti occurs in the inshore habitat from about 30° S latitude to the north coast of Cuba. It has a taxonomic affinity to P. setiferus and they are parapatric, that is, their ranges join but do not overlap. P. notialis ranges from 20° S latitude to the northern coast of Cuba, while P. duorarum is found in the Gulf of Mexico and up to 35° N latitude in the Atlantic. A very similar pair of species' distributions exists for P. subtilis and aztecus. P. subtilis ranges from the Tropic of Capricorn to the north coast of Cuba, while P. aztecus is distributed from the Gulf of Mexico to Cape Cod, Massachusetts. On the Guianas-Brazil fishing ground, the likelihood of isolated stocks of any species is very low. If the migration of adults counter to the current is not extensive, the species should show a clinal pattern of gene frequencies. Thus, new genes arising by mutation will always tend to move with the current and may be absent upstream from their site of origin. If this pattern exists, it means that recruitment is based on shrimp produced upstream from the location and counter current movement is rare. It appears that mobility of the adult shrimp should be sufficient to break down a clinal pattern based on larval dispersal.

Outside of the fishing area, all four species may show genetic differentiation north and south of Cabo de Sao Roque where the South Equatorial Current splits (Fig. 4.7.2). The strength and constancy of the current may be sufficient to maintain separate avenues of larval dispersal to either side of the Cape. Patterns of adult migration in this area are unpredictable. In addition to the potential isolation caused by the splitting of the South Equatorial Current, there may be some genetic isolation of the stocks off Nicaragua, Costa Rica, Panamá and northern Colombia, and in the Gulf of Honduras, because of the circulation patterns in these areas. Again these current patterns would circumscribe larval dispersal, but could be overcome by adult migration.

P. schmitti may also show genetically different stocks north and south of Cabo de Sao Roque. Because it appears to be restricted to near-shore waters where current flow is restricted by water depth and tides, this species is more likely to show genetic differentiation across its range. In particular, the the occurrence of P. schmitti in bodies of water with limited oceanic access, such as Lake Maracaibo, could lead to the development of local stocks.

6. Conclusions

Two patterns of differentiation have been identified for investigation. The first exists at the level of interspecific separation and requires a study of the biochemical genetic differences among Penaeus brasiliensis, P. notialis, P. schmitti, and P. subtilis, and between the South American species and the congeners to which they show affinities (*P. duorarum*, *P. setiferus* and *P. aztecus*).

If they are true species which have existed as isolated genetic systems for evolutionary time, they should demonstrate genetic differences similar to those described among *P. aztecus*, *duorarum* and *setiferus* (Lester, 1979). Should any of the "species" pairs prove to be connected by interbreeding, one could make certain assumptions about the ecology and physiology of the South American shrimp stocks based on information available on the related stock in the Gulf of Mexico. Studying the genetic characteristics of these species will permit the development of reliable methods for biochemically identifying any species among this group at any post-larval stage.

At another level, there are patterns of differentiation which could exist within each of the penaeid species off the South American coast. Each species could be subdivided at the easternmost point of South America by the effect of the splitting of the South Equatorial Current. It is also possible that the movement of shrimp could be impeded by the gyres in the Gulf of Honduras or the Caribbean north of Panamá, and that genetic differences could arise in these and smaller bodies of water (e.g.,Lake Maracaibo) which have limited water exchange with the main currents. Also, the distribution of gene frequencies, particularly for rare alleles, can provide information on the pattern of recruitment in these shrimp stocks. Nevertheless, in the region of the Guianas-Brazil fishing grounds, it is improbable that genetically differentiated stocks exist within any of the penaeid species.

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Table 4.7.1 Summary of the loci scored in *Penaeus aztecus*, *P. duorarum*, and *P. setiferus*.

Locus[a]	Species		
	aztecus	duorarum	setiferus
Alcohol dehydrogenase	NA[b]	NA	M[c]
Aldolase	M	NA	NA
Esterase-2	P[d]	P	P
Esterase-5	P	P	M
Glutamate dehydrogenase-2	NA	M	M
Glutamate-oxaloacetate transaminase-1	M	M	NA
Hexokinase-2	P	NA	P
Isocitrate dehydrogenase	NA	M	M
Leucyl aminopeptidase	P	M	M
Malate dehydrogenase-2	M	P	NA
Mannose-6-phosphate isomerase	P	P	P
Peptidase (leucyl-alanine substrate)-2	M	M	P
Peptidase (leucyl-alanine substrate)-3	P	P	M
6-Phosphogluconate dehydrogenase	M	P	P
Phosphoglucose isomerase	P	P	P
Phosphoglucomutase	P	P	P

[a] Loci monomorphic in all species: Acid phosphatase, Aldehyde oxidase-1, Aldehyde oxidase-2, Glycerate-2-dehydrogenase, Glyceraldehyde-3-phosphate dehydrogenase, Hydroxybutyrate dehydrogenase, Hexokinase-1, Malate dehydrogenase-1, Peptidase-1, Protein (Coomassie blue stain)-2, and Protein (Coomassie blue stain)-3.

[b] NA = locus not analyzed because, due to species differences, it could not be resolved with the techniques developed.

[c] M = monomorphic locus, i.e. no population has the common allele in a frequency < 0.95.

[d] P = polymorphic locus, i.e. one or more populations have the common allele in a frequency < 0.95.

Table 4.7.2 Loci having different mobilities of most frequent alleles in *Penaeus aztecus*, *P. duorarum* and *P. setiferus*

Loci	Species: aztecus	duorarum	setiferus
Acid phosphatase	M	M	F_1
Aldehyde oxidase-2	M	F_1	M
Esterase-5	S_2	M	F_1
Glutamate oxaloacetate transaminase	S_1	M	M
Malate dehydrogenase-1	M	M	S_1
Malate dehydrogenase-2	M	M	F_1
Mannose-6-phosphate isomerase	M	F_2	M
Peptidase-1	M	S_1	M
Peptidase-3	M	M	F_1
Phosphoglucose isomerase	S_1	M	M

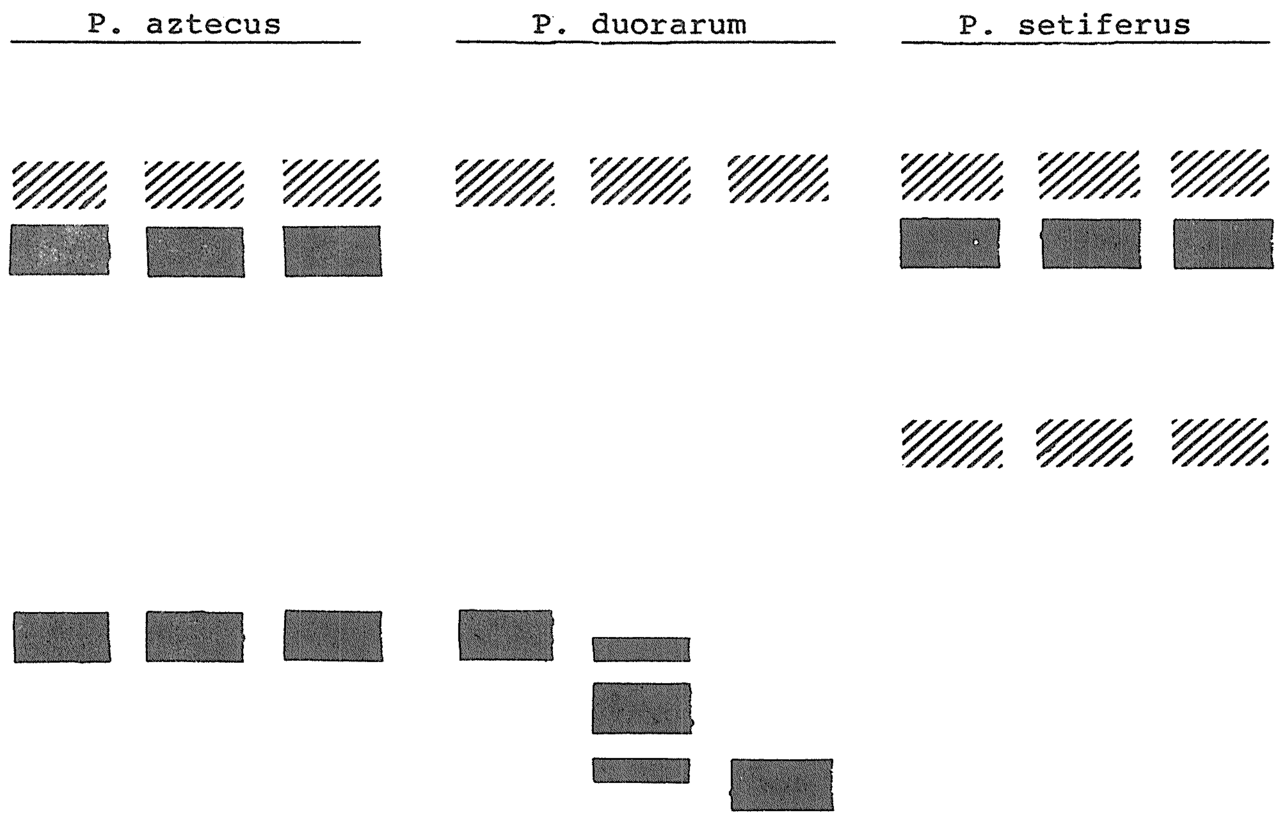


Figure 4.7.1 Staining Patterns of Enzymes Produced by Malate Dehydrogenase Loci in the Three *Penaeus* Species from the Gulf of Mexico

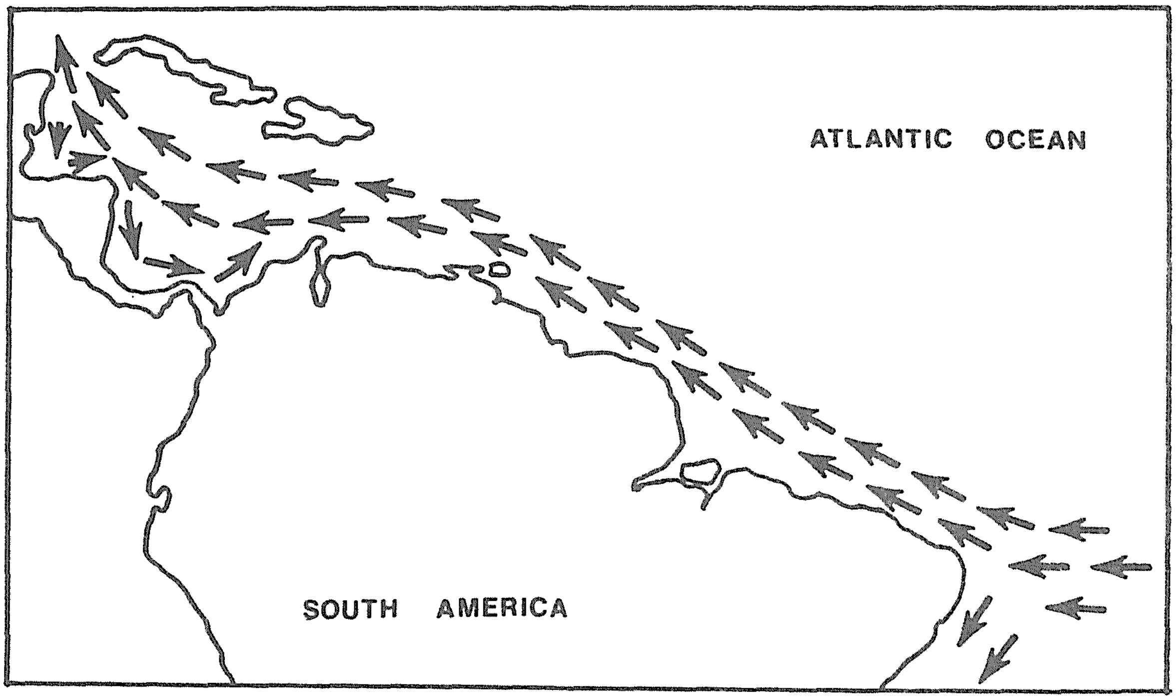
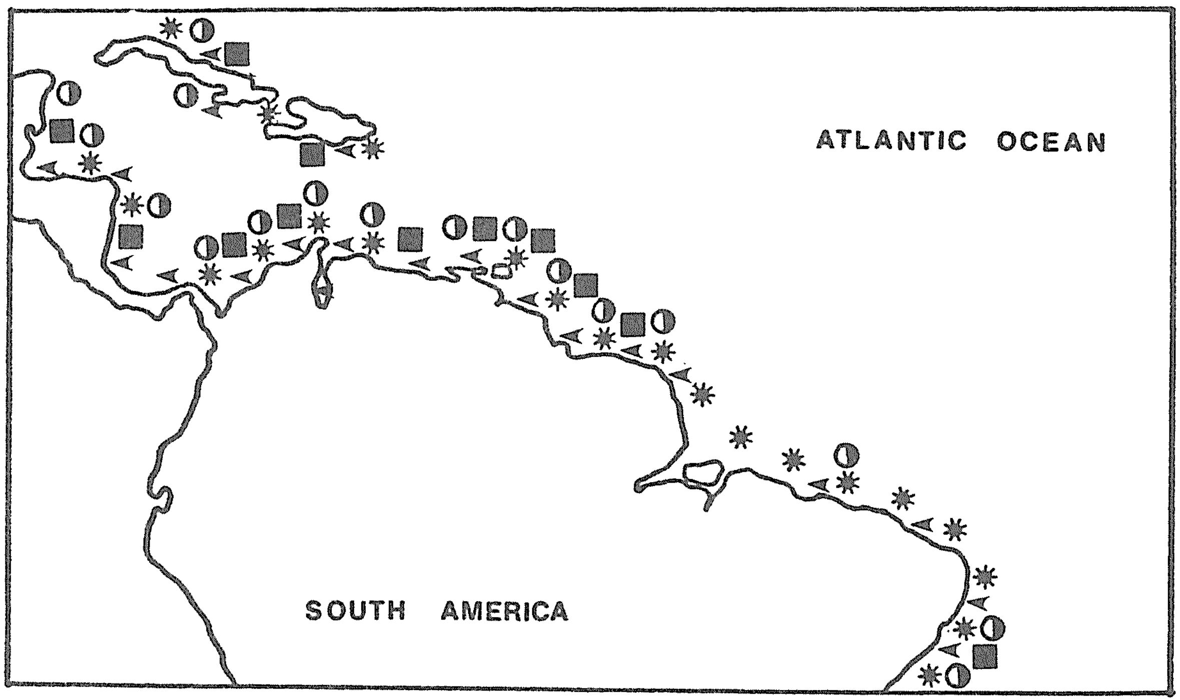


Figure 4.7.2 Major Current Patterns Off the Coast of Northeastern South America



◐ *P. braziliensis*

■ *P. notialis*

≺ *P. schmitti*

✳ *P. subtilis*

Figure 4.7.3 Distributions of the Four *Penaeus* Species in the Guianas-Brazil Fishery Along the Coast of Northeastern South America

Contribution 4.8

Expected Effects of Possible Regulatory Measures in the Shrimp Fishery with Special Reference to Fisheries of the Guianas and Northern Brazil

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1. Introduction

The report of the meeting of the WECAFC Working Party on Stock Assessment of Shrimp and Lobster Resources, held in Cartagena, 18-23 November 1977 indicated that the total fishing effort on the shrimp stocks exploited by the industrialized fisheries in the Guianas-Brazil area was in recent years probably at, or slightly above, that required to obtain their maximum sustainable yield. The question therefore arises whether management of these fisheries is needed, and what kind of management measures might be required. The present note discusses some of the expected effects of possible management measures and the information required to determine the most appropriate measures.

2. The Need for Management

Experience has shown that in several tropical shrimp fisheries the yield curve is flat-topped and that often the right-hand side of the curve shows only a slow decline when effort increases substantially above the level giving the maximum yield. In other words, above that level, the catch per unit effort declines nearly proportionally with the increase in effort. The profitability of the fishery is often such that it is still worthwhile for a boat owner to join the fishery or add another boat when the stock is already exploited much above its optimum level. This means that very substantial investments often continue to be made in these fisheries after they have reached a level where these investments do not lead to any increase in total catch.

In some shrimp fisheries the yield curve is clearly dome shaped, and overinvestment and the consequent overfishing has led to a very serious drop in the total catch. In both cases, suitable fishery regulations would appear to be desirable.

As has been stated in the introduction, the fishing effort has been estimated to have been in recent years (observations for 1973-1976) at, or slightly above, that required to obtain the maximum sustainable yield. This conclusion was based on an analysis of the total catch and effort data for the whole area. It is known, however, that the fishery was originally started off Guyana and has gradually spread more eastward, until the whole area off the Guianas and northern Brazil became exploited. That means that the stage of development of the fishery has differed between different parts in the area. Also, the recent changes in the fisheries regime of the seas will have led to different developments in the fishery in different parts of the area. All this would not affect the Working Party's general conclusions if all shrimp in the whole area belonged to the same stock, and moved freely throughout the whole area. It is more likely, however, that the shrimp movements are more limited, and that there exist a number of more or less independent stocks along the coast. In that case, fishing off Guyana would not affect the stocks of northern Brazil, and vice versa, and hence the fishery on each stock would have to be studied and managed separately. Taking the history of the fishery into account, it may perhaps be expected that if separate stocks exist, proper analysis will show that, for instance, the stocks off Guyana have been more and those off northern Brazil less heavily fished than the overall analysis suggest.

Knowledge is therefore required on stock identity and stock separation, and on the distribution and migration of each stock. In addition, catch and effort statistics are needed by sub-divisions of the total area. Unfortunately, no statistics on catches by sub-division are available for the earlier years of the development of this fishery, and even in later years the existing detailed data may cover only part of the fleets fishing in the area. It is, however, important that efforts are made to estimate the catches and the effort in sub-divisions of the area over as many of the past years as possible. As a consequence of the emerging new fisheries regime of the seas, countries can now have the authority to ensure collection and reporting of statistics of the fishery in their national waters, and this sub-division by national waters may be a useful first division of the area into smaller units even though it is unlikely that stock distribution limits will coincide with national boundaries. It should be realized, however, that for a proper analysis of the effects of fishing, and of the state of exploitation of each stock, the catches of all fleets fishing the same stock should be taken into account whether a stock is distributed in the waters of only one or of more than one country. Whereas there is no direct evidence of the existence of stocks shared by two or more countries, it has been suggested that for instance the shrimp of northern Brazil might carry out substantial migrations across the Brazil-French Guiana border during their life cycle. In the case of such shared stocks, fishing in the waters of one country will affect the same stock in the waters of another country. For this reason, also the management of shared stocks can only be effective if the countries concerned coordinate their management measures, which requires consultation and agreement on these measures.

Even though there is urgent need for information on stock identity and on the state of exploitation of each individual stock before more definite conclusions can be drawn, the fact that it is likely that at least in parts of the area the stocks are already fairly heavily exploited indicates that management measures may be desirable.

3. Methods of Regulation of the Shrimp Fishery

The decline of the catch rates when fishing increases are due, in the first place, to the fact that at higher levels of fishing more shrimp are caught when they are still young, soon after they move onto the fishing grounds or reach a size which is retained in the nets. As a consequence, less and less shrimp survive to grow up and be caught at larger sizes. Thus, the abundance in the sea decreases, in particular of the larger sizes. This is a normal consequence of fishing, and does not prevent the total catches to rise with increases of fleet size up to a moderate level. If fishing becomes too heavy, however, these effects become so important that the total catch by weight does not increase further, and may even decline. In such a case we speak of "growth overfishing". Because of the lower price of smaller shrimp, the optimum value of the catch is already obtained at a level of effort lower than that giving the optimum catch by weight. If the decline of the abundance of the larger shrimp, the breeding stock, is so serious that also the number of young produced which will recruit to the fishery in the next season is significantly reduced, we have a case of "recruitment overfishing". Recruitment overfishing is the cause of substantial decrease in the total catch at high levels of fishing, but such decreases have only been observed so far in shrimp fisheries in special areas and are perhaps unlikely to occur in the shrimp fisheries of the WECAF region at the levels of effort to which the fishery, if unregulated, might expand.

In both cases the overfishing has resulted from too heavy fishing, and an obvious remedy therefore is to reduce the amount of fishing. As growth overfishing is due to catching too many shrimp when they are too small, another measure to improve the catches is by selective protection of the small shrimp. This will also allow more shrimp to reach maturity and hence reduce the recruitment overfishing. Reduction of recruitment overfishing by selective measures to protect only those shrimp which are at or approaching breeding age may not be very effective, if the catches of smaller shrimp are so large that few approach breeding age. Thus, in both types of overfishing the most effective measures to manage shrimp fisheries tend to be either selective protection of small shrimp, or general reduction in the amount of fishing. The balance between these two will depend on the conditions in the fishery; where growth overfishing only is important, more emphasis may be placed on protection of young shrimp, and where recruitment has been affected, a general reduction in the amount of fishing may be more important. Both seem likely to be valuable for the shrimp fishery in the area.

3.1. Protection of Young Shrimp

There are various ways to protect small shrimp. These include:

3.1.1. Increase in the mesh size of the nets: This can be especially effective for species in which nearly all the animals below a certain size, and few above that size, can escape through the meshes. Experiments have shown, however, that often the selective action of the meshes is not very good for shrimp, and that fairly large meshes through which some large shrimp escape, still do retain a substantial quantity of small shrimp. This may limit the usefulness of mesh regulation in the shrimp fishery.

3.1.2. Minimum size limits for landed shrimp: These may have the effect that the ships will avoid areas such as nursery grounds where mainly undersized shrimp are caught, but also that the small marketable shrimps caught together with the legal sized shrimp will have to be discarded. Most of the discarded shrimp will have died and will therefore not contribute to the recovery of the stocks. Thus, minimum size limits alone may only have a limited beneficial effect and may even be harmful if the losses from discarding of small, dead shrimp exceed the beneficial effect of avoiding nursery grounds.

3.1.3. Closure of the fishery during the recruitment season: Recruitment of young shrimp usually takes place throughout the whole year, though certain seasons may show higher recruitment than others. Older and bigger shrimp, however, are caught throughout the year. Closure of the fishery during the peak recruitment periods will give the young shrimp recruited during these periods the opportunity to grow. However, a certain amount of the older and larger shrimp, which otherwise would have been caught, will die during this period and will therefore be lost. The net benefit of the closed season depends on the balance between these effects. Studies of the possible benefits require more information on the seasonality of recruitment in the area, as this seasonality varies between regions.

3.1.4. Closed areas: Juvenile shrimp is distributed in shallow, coastal waters, but the industrial fisheries take place mainly outside the nursery grounds. The main fishery in the shallow areas is carried out by the artisanal shrimp fisheries which are important in parts of the WECAF area, often mainly fishing for Xiphopenaeus kroyeri, a coastal species not fished for by the industrialized fleet. The artisanal fishery will, however, also catch young specimens of the Penaeus species fished by the fleet. Closure of the inshore areas will greatly affect the artisanal fisheries, and thereby is likely to increase the recruitment of small shrimp to the stocks fished by the industrialized fisheries, but will have less effect on saving any small shrimp caught by the latter fisheries which fish in deeper waters. Not enough is known about the distribution of the small, medium-sized and large shrimp of the species caught in the industrial fisheries and of the mortality caused on this shrimp by the artisanal fisheries to determine the effect of the closure of the coastal areas. It may, however, be undesirable for socioeconomic reasons to put too many restrictions on the artisanal fisheries.

In summary, it appears that most measures for protecting small shrimp have some drawbacks, although it is expected that most of them will lead to some net benefit. The magnitude of these benefits cannot be calculated until more is known about recruitment seasonality, the growth and mortality rates and the distribution of the shrimp of different sizes and ages, and on the gear selectivity.

3.2. Regulation of the Amount of Fishing

The amount of fishing can be regulated through limitation of the catch, closed seasons, or limitation of the number of boats fishing.

3.2.1. Limitation of the catch: If the allowable catch is restricted to the production potential of the shrimp stocks, in theory decline of these stocks is prevented. (In practice, the allowable catch should be set somewhat below the production potential in order to prevent the amount of fishing to increase to higher levels, when fishing is close to the flat top of the yield curve.) An allowable catch, lower than the production potential of overexploited stocks, will permit these stocks to recover. Regulation of the catch (catch quotas) therefore provide a means to maintain a fishery at, or restore it to, its most productive level. A quota system requires that the production potential of the stock is fairly precisely known each year, which implies considerable research on the annual variations in yearclass strength of the shrimp, and necessitates annual agreement between the countries concerned about the quota level. Notwithstanding these disadvantages, quota systems are used in several fisheries in other parts of the world as a basis for division of the allowable catch between countries fishing the same fish stocks. These deal, however, mainly with fisheries or species with a longer lifespan than shrimp, and hence usually with smaller year-to-year variations in stock size.

3.2.2. Closed season: Closure of part of the fishing season reduces the fishing pressure on the stocks and will thereby lead to recovery of overexploited stocks. Closed seasons will, of course, have little effect when the closure is limited to periods in which fishing would have been light anyway for other reasons, and thus the effectiveness depends on the period chosen for the closure. Additional benefits can be obtained if the closure period is timed to coincide with specific phenomena of the shrimp biology. Closure during the shrimp recruitment period will combine the effects of reduced fishing with that of protecting the small shrimp. Closure during the main spawning period, however, has less specific advantage than closure in an earlier period which would allow more shrimp to grow up and reach breeding age.

The length of time of closure of the fishing season which will give the optimum benefits of a shrimp stock, depends not only on the period of the year chosen but obviously also on the degree of overfishing of that stock and will therefore be different for different stocks in the area, and any closure for reduction of fishing effort is undesirable for stocks which are exploited about or below their optimum level.

3.2.3. Limitation of the number of boats fishing: The most direct way of preventing or restoring the effects of too heavy fishing is by regulation of the number and type of boats involved in the fishery. Ideally, the total fishing effort employed in the fishery might be such that it would give the optimum benefits without restrictions on the activity of the fleet other than those concerning the protection of small shrimp. This would require a system of licencing of the boats allowed to take part in the fishery. One practical problem is related with the question how to allow for differences in size and efficiency of the boats in determining the number of boats required, in particular when more than one country participate in the fishery on the same stocks. Also, ways need to be found to adjust the system to changes in the efficiency of the boats through increased engine power and improvements in the gear and fishing methods. On the other hand, this type of regulation would not require such detailed adjustments to annual fluctuations in yearclass strength, and hence there is less need for collection of detailed and accurate information on this yearclass strength each year before the start of the fishing season, and for annual revision of the regulation measures.

4. General Considerations on Regulation of the Shrimp Fisheries

In considering the introduction of management measures to reduce or prevent overexploitation, the problem that arises first of all is the relation between the catches of industrialized and artisanal fisheries for the same species. The latter fisheries usually catch the younger and smaller individuals. If the industrialized fisheries cause recruitment overfishing, regulation of these fisheries will improve nor only their own catches, but also the artisanal catches of the species involved. The catch of young shrimp by artisanal fisheries on the other hand will reduce the catch of these species by the industrialized fleet, although the extent of this reduction is unknown in most fisheries. In view of the lack of quantitative knowledge, and of the important socioeconomic aspects of the artisanal fisheries in many countries, it may be decided for the time being to only consider regulation of the industrialized fisheries.

Protection of small shrimp in the latter fisheries will give benefits, if any, to the fisheries of all shrimp stocks which are heavily exploited and could therefore probably be introduced universally for the whole area. On the other hand, limitation of the amount of fishing will have to be done on a stock by stock basis, if such stocks are fished independently, and would therefore require more specific control. In practice, such limitation will be done on a country basis, but it requires cooperation between countries fishing shared stocks.

Another aspect which needs consideration is that any regulation which lead asto a substantial improvement in the catches and thus to a more profitable fishery, other than through regulation of the number of boats, will in practice attract more boats into the fishery until it becomes unprofitable again, thereby largely invalidating the benefits of the regulation. Therefore, regulation of the number of boats would appear to be indispensable in any shrimp fishery if it is desired to keep the fishery at a profitable level. As a consequence, such regulation may well be taken as the measure to be considered in the first place. In doing so, it should be noted that regulation of fleet size has several socio-economic aspects which should be taken into consideration. The countries will have to decide on their management objectives which could be, for instance, optimum catch, optimum economic benefits, or optimum employment, but should also consider to whom should accrue the possibly considerable benefits to be obtained from fleet regulation if this was introduced. Should the full benefits go to the relatively few privileged people who remain to be involved in the shrimp fishery, or should a considerable part of these benefits be creamed off, through taxation or high licence fees, to be used for public purposes, or e.g., for the development of fisheries for other marine resources? Problems may arise if countries fishing a shared stock have different management objectives, requiring different stock levels.

For the area as a whole it has already been noted that the total fishing effort was in the period 1973-1976 about and perhaps somewhat above the level giving the optimum catch, and that whereas in parts of the area fishing has probably been rather heavier than required to obtain the fishery policy objectives, in other parts of the area some increase in fishing may have been possible. Even though the fleet size and its distribution has changed substantially since that time as a consequence of the extended jurisdiction, it is clear that it is timely for the countries in the area to start to consider the kind of action to be taken in order to reach the national shrimp fisheries development and management objectives. In view of the likelihood that the distribution of at least some of the individual shrimp stocks cuts across national borders, these considerations require international consultation. Further scientific advice is needed before the effects of specific management actions can be evaluated. There is therefore need for speeding up the scientific investigations on the shrimp stocks in the area.

5. Research Needs

It would appear from the above discussions that the most important problem for rational exploitation and management of the shrimp resource in the area is that of stock identity, distribution and migration, and of the state of exploitation of each of the stocks. The stock identity studies are particularly relevant to determine which stocks lie wholly within national waters and can be regulated nationally, and which stocks are shared between countries and require joint analysis and agreement between these countries for their management. The best method for studying the stock identity problems would appear to be through a large-scale, well designed tagging experiment. Because of its prime importance, WECAFC should consider to make such an experiment as a major WECAFC initiative. If properly designed, such an experiment might also provide reasonable estimates of mortalities, and may thus help to determine the state of exploitation of each stock. In addition, it will be important to attempt to obtain time-series of estimates of catch and effort on each stock for as many years as possible for catch/effort analysis.

At the same time, there is need for investigations which will provide additional information required to make more quantitative estimates of the effects of the various possible methods of regulation of the shrimp fishery described in Section 3. These may include mesh experiments, growth studies, periodicity of recruitment, distribution at different shrimp sizes, nursery areas, annual variations in yearclass stength.

Clearly, such investigations take time, and it has been argued that it is timely to start consideration of management action. Reporting on the scientific results cannot, therefore, wait until the investigations are concluded, and the task of the scientists will include to report at intervals on the trend in the fisheries on the various stocks, and on the best available estimates of the state of exploitation of these stocks, thereby providing basic information on the urgency of management measures, or the prossibilities for further expansion of the fisheries, and including estimates of the expected effects of the various possible management measures.

Contribution 4.9

Industrial Sampling and Estimated Length Composition of the Landings in Belém (1969-1978)

by

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1. Introduction

The biological sampling system for the industrial landings in Belém was started in 1975. The object of the system is to collect data on composition by species, size and sex of the catch on the north coast of Brazil.

The sampling was designed to develop a new methodology to obtain the catch composition by length and sex, through a direct conversion from the total weight of each commercial size category, so that it could be applied to the data collected from the industries since 1969.

The commercial catch is composed primarily of the following species: Penaeus subtilis and P. brasiliensis. The first is dominant and makes up about 90 percent of the total catch. The sampling will consider only this species.

2. Material and Methods

After capture the shrimps are headed and stored in ice till landing. Afterwards they pass through a special tank for washing and cooling, and are then conducted by belt conveyors to a machine that classifies them by sizes.

The classification by commercial size category represents the number of tails per pound and it is made through the diameter of the first abdominal segment. Landings are classified in nine commercial size categories: U -15; 15 - 20; 21 - 25; 26 - 30; 31 - 35; 36 - 40; 41 - 50; 51 - 60; 61 - 70 tails per pound.

The small or damaged shrimps, that are not suitable for export are removed by hand during the transport from the special washing tank to the selection machine and forms class "A"

The present analysis is based on 20 samples obtained in the industries of Belém, covering a 12-month period with one to three samples per month. It records data on sex and tail weight to the nearest decigram. The sampling design requires a sample of about 200 shrimp to be taken during transport to the industry. Afterwards a sample of 150 individuals is taken from each size category mechanically classified and also 200 individuals of class "A" are sampled.

The length distributions of carapaces for males and females were determined for each size category through the relationship length of carapace and weight of tail determined by Barbosa and Rocha (1978):

$$Y = 6\ 577 \ .\ 10^{-4}\ x^{2\ 886} \quad \text{for males } (r = 0.961)$$

$$Y = 9\ 903 \ .\ 10^{-4}\ x^{2\ 732} \quad \text{for females } (r = 0.976)$$

From the length frequency distribution of carapace, the overall composition was obtained dividing the weight landed by size category by the mean weight of the corresponding sample and multiplying such value by the frequency determined for size category to obtain the number of individuals in each category.

Afterwards, the standard normal distributions for each category were obtained calculating means and standard deviations and the percentage composition by each length of carapace was determined.

From this it was possible to conclude that having the landing classified by the weight or number of individuals landed in each category and weighting them by the corresponding percentage indeces, the length frequency distribution of the landing can be obtained.

The methodology developed involves difficult and tedious work to determine if the standard tables of 1976 are valid for the other years, utilizing the data of 1976 and 1977.

3. Estimate of the Length Composition of the Landings (1969-78)

The landing data by weight category are available for the period October to December 1976. Due to the lack of samples before November 1975 and considering that the work of convertion has not yet finished, the standard tables mentioned above were used to obtain the montly size frequency distribution for the separate and combined sexes. Although the results are preliminary, there can be observed in tables 4.9.1 and 4.9.2 evidence of the recruitment period and of the greater participation of large individuals since 1977. This can be confirmed through the weight distribution of the landing categories.

The montly trend of the catch rates and the mean lengths of carapace in the period 1970-78 are presented in Figures 4.9.1 and 4.9.2. In 1978, there can be observed an increase in the catch rates accompanied by an increase of the mean length of carapace. From November to December is evident a rise in the mean lengths of carapace and a decrease in the catch rates.

Table 6.9.1 Catch Rate (kg/day at sea, heads-off) and Estimated Average of Carapace Lengths (mm) for the Belém Shrimp Landings (1970-78)

Penaeus subtilis

Month	1970		1971		1972		1973		1974		1975		1976		1977		1978	
	$\bar{X}$	CPUE	$\bar{X}$	CPUE	$\bar{X}$	CPUE	$\bar{X}$	CPUE	$\bar{X}$	CPUE	$\bar{X}$	CPUE	$\bar{X}$	CPUE	$\bar{X}$	CPUE	$\bar{X}$	CPUE
01	32.13	172	32.36	181	30.47	159	30.46	152	30.91	95	31.57	81	30.62	160	30.55	172	32.11	177
02	31.21	143	32.64	193	30.11	143	30.68	209	30.43	101	31.69	129	29.91	161	31.85	166	32.16	171
03	31.53	169	31.48	201	31.67	166	30.88	246	31.08	85	32.45	278	29.67	142	32.64	179	32.60	177
04	32.93	165	31.10	170	31.97	180	31.48	218	32.52	92	31.83	151	29.30	131	32.40	180	32.20	226
05	32.96	130	31.11	243	20.05	160	32.02	179	32.84	85	31.78	110	29.71	103	31.57	165	30.83	312
06	31.77	164	32.37	220	29.82	161	31.92	175	33.08	99	30.45	105	31.02	102	31.33	143	31.05	314
07	31.14	103	31.21	227	30.47	142	31.55	193	32.14	157	29.40	114	29.50	116	31.40	135	31.41	253
08	31.33	104	30.97	189	30.44	118	31.77	153	30.92	104	29.45	104	29.73	101	31.69	105	31.98	233
09	31.47	90	30.50	166	29.27	115	31.41	130	31.03	94	30.22	145	29.54	108	32.10	83	33.42	224
10	30.57	91	30.84	120	30.71	115	32.74	95	32.07	60	29.74	114	29.16	108	30.65	60	34.08	153
11	30.44	116	31.08	90	28.93	124	31.71	97	32.25	71	30.59	124	29.26	136	30.28	74	33.22	150
12	30.09	114	30.17	114	31.01	126	31.94	110	31.59	90	31.17	136	29.21	147	30.36	109	32.38	163
	31.46	127	31.32	184	30.41	144	31.55	160	31.74	98	30.86	130	29.72	127	31.40	132	32.29	221
s	0.90		0.77		0.88		0.63		0.86		1.03		0.57		0.80		0.96	

Table 4.9.2 Estimated Average Caparace Lengths (mm) for the Belém Shrimp Landings (1970-1978)

Penaeus subtilis

Month	Average Carapace Length (mm)																	
	1970		1971		1972		1973		1974		1975		1976		1977		1978	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
01	28.90	33.78	28.49	34.30	27.59	32.89	27.63	32.83	27.80	33.29	28.67	33.24	27.75	32.82	27.70	32.79	28.87	33.81
02	28.22	33.20	28.62	34.52	27.44	32.57	27.90	32.85	27.45	33.02	28.64	33.43	27.24	32.44	28.54	33.62	28.88	33.85
03	28.14	33.69	27.85	33.84	28.42	33.57	27.98	33.03	27.90	33.43	29.11	22.96	27.34	32.03	29.28	34.07	28.96	34.29
04	29.00	34.57	27.74	33.53	28.70	33.72	28.21	33.56	28.53	34.54	28.76	22.52	26.84	32.14	29.14	33.89	28.45	34.16
05	28.97	34.72	27.75	33.52	27.18	32.80	28.36	34.15	28.50	34.94	28.74	33.50	26.93	32.62	28.53	33.35	27.63	33.33
06	28.38	33.82	28.35	34.49	27.32	32.34	28.13	34.24	28.64	35.11	27.88	32.60	27.98	33.16	28.37	33.19	27.67	33.57
07	28.10	33.35	27.85	33.53	27.87	32.62	28.11	33.77	28.51	34.17	27.34	31.66	27.41	31.74	28.40	33.25	27.84	33.85
08	28.22	33.46	27.84	33.23	27.95	32.51	28.35	33.80	28.26	32.87	27.40	31.65	27.45	32.04	28.33	33.64	28.19	34.23
09	28.45	33.47	27.48	33.05	27.86	31.42	27.86	33.76	28.37	32.87	28.08	32.02	27.10	32.15	28.55	33.98	28.77	35.41
10	27.85	32.82	27.81	33.18	28.00	32.89	28.92	34.49	28.51	34.04	27.53	31.91	27.03	31.69	27.84	32.90	29.24	35.74
11	27.76	32.70	27.79	33.47	27.14	31.18	28.24	33.98	28.54	34.20	27.78	32.76	27.01	31.87	27.46	32.83	28.78	35.20
12	27.68	32.34	27.50	32.65	28.07	33.13	28.12	34.22	28.49	33.48	28.28	33.08	27.05	31.73	27.53	32.85	28.45	34.53
$\bar{X}$	28.31	33.49	27.92	33.61	27.75	32.64	28.15	33.72	28.29	33.83	28.18	32.78	27.26	32.20	28.31	33.36	28.48	34.33
s	0.46	0.70	0.37	0.58	0.50	0.75	0.32	0.55	0.37	0.78	0.60	0.80	0.34	0.47	0.58	0.47	0.54	0.76

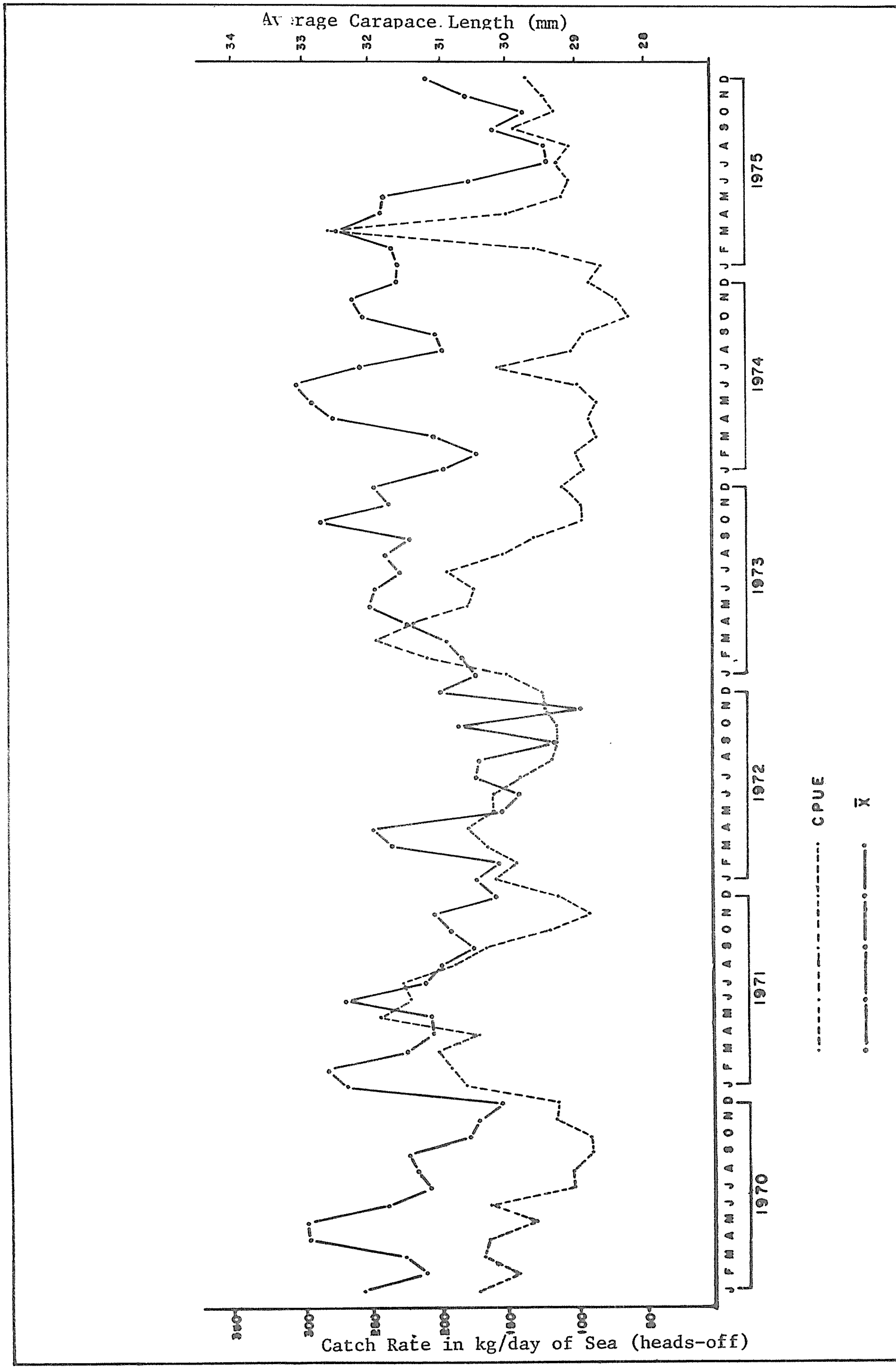

Figure 4.9.1 Catch Rate and Estimated Averages of Carapace Length for the Belém Shrimp Landings

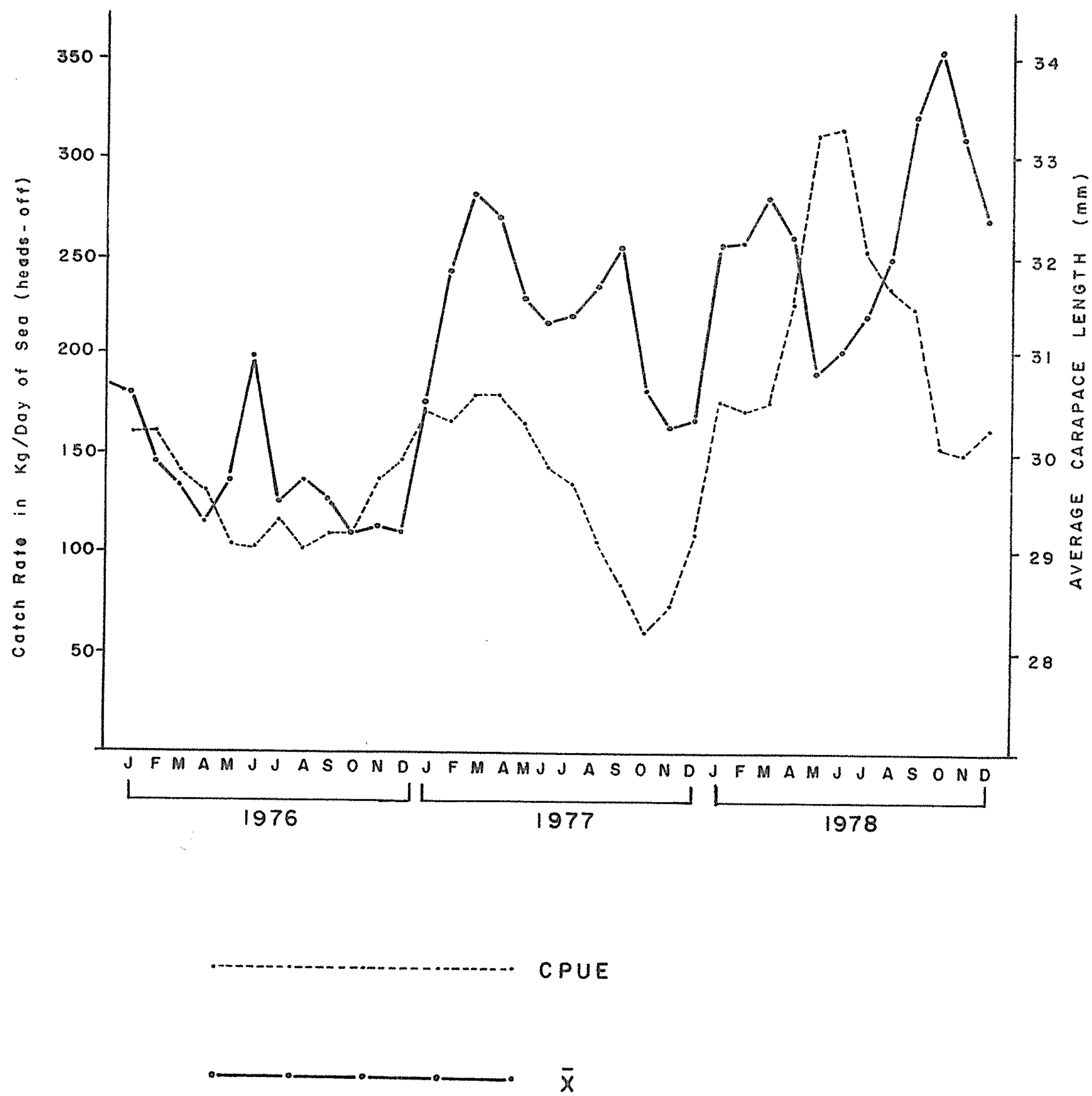

Figure 4.9.2 Catch and Estimated Averages of Carapace Lengths for the Belém Shrimp Landings

Contribution 4.10

Biological Sampling for Juveniles of *Penaeus Subtilis* In the States of Pará and Maranhao, Brazil

by

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1. Introduction

The biological sampling programme for juveniles of pink shrimp in the states of Pará and Maranhão was started in July 1976 with the object of collecting monthly information on the species composition and length distribution of the artisanal shrimp catch.

At the beginning a search was made for nursery grounds of P. subtilis on the coast of Amapá but this indicated an absence of commercial stocks of shrimp near the coast. In Pará and Maranhão shrimp grounds were found along the entire coast.

The most important nursery grounds found were the following: Curuçá, Maracaná, Salinópolis and Viteu in the State of Pará, and Turiaçu in the state of Maranhão.

2. Material and Method

Biological sampling is being carried out in the following places: Curuça, Salinópolis, Primavera and Maracanã.

A sample of 300 to 500 individuals is collected monthly from each nursery ground to obtain the proportion of species, sex and the length frequency distribution of the carapace. Generally there are some difficulties in identification of the species and sex of small individuals. In addition, the length range found is very large and this makes it necessary to sample a significative number of shrimps.

3. Discussion

In 1977 and 1978, P. subtilis contributed 80 percent of the individuals examined. P. brasiliensis, P. schmitti and Xiphopenaeus kroyeri contributed the other 20 percent.

Monthly participation of P. subtilis presented no evident trend in the various places sampled. However, in 1978, P. subtilis contributed more than 90 percent of the samples from all the places (Tables 4.10.1 and 4.10.2).

The carapace length of P. subtilis varied from 8 mm to 28 mm, in the period 1977-78. The mean length of the samples varied from 13.1 mm to 21.1 mm in 1977 and from 11.2 mm to 19.5 mm in 1978. The smallest mean lengths were observed in Curuça (Figures 4.10.1 to 4.10.4).

Table 4.10.1 - Number of Sampled Shrimp in the Nursery Grounds - Percentual Participation and Mean Length of *P. subtilis*, by Month and Municipality in 1977

Month	Municipality											
	Curuça			Maracana			Primavera			Salinas		
	No. of Individuals	% of *P. subtilis*	Av. Length (mm)	No. of Individuals	% of *P. subtilis*	Av. Length (mm)	No. of Individuals	% of *P. subtilis*	Av. Length (mm)	No. of Individuals	% of *P. subtilis*	Av. Length (mm)
January	207	24.60	16.84	-	-	-	-	-	-	-	-	-
February	225	100.00	15.18	-	-	-	-	-	-	-	-	-
March	-	-	-	500	42.40	15.74	-	-	-	-	-	-
April	249	100.00	13.44	-	-	-	-	-	-	-	-	-
May	-	-	-	-	-	-	-	-	-	-	-	-
June	-	-	-	-	-	-	-	-	-	-	-	-
July	-	-	-	-	-	-	-	-	-	-	-	-
August	249	97.99	13.71	-	-	-	-	-	-	-	-	-
September	228	4.40	-	-	-	-	-	-	-	338	82.54	13.14
October	390	100.00	15.92	-	-	-	150	2.70	-	131	14.50	21.11
November	331	0.90	-	287	0.10	-	95	0.00	-	-	-	-
December	427	1.00	-	-	-	-	146	100.00	20.08	-	-	-

Table 4.10.2 - Number of Sampled Shrimp in the Nursery Grounds - Percentual Participation and Mean Length of P. subtilis, by Month and Municipality in 1978

Month	Municipality								
	Curuça			Maracana			Sàlinas		
	No. of Individuals	% of *P. subtilis*	Av. Length (mm)	No. of Individuals	% of *P. subtilis*	Av. Length (mm)	No. of Individuals	% of *P. subtilis*	Av. Length (mm)
January	-	-	-	-	-	-	-	-	-
February	-	-	-	-	-	-	-	-	-
March	258	0.90	-	315	1.00	-	309	46.28	18.16
April	253	69.20	12.58	357	88.00	13.79	-	-	-
May	265	93.60	12.88	-	-	-	-	-	-
June	427	56.40	14.03	302	95.00	14.33	26	30.80	-
July	364	98.60	12.80	211	78.20	17.20	-	-	-
August	427	92.70	13.70	329	96.00	15.00	237	98.70	19.50
September	356	96.30	11.20	324	95.10	15.40	-	-	-
October	-	-	-	270	87.00	14.70	-	-	-
November	468	98.10	13.60	579	39.70	14.90	-	-	-
December	-	-	-	-	-	-	-	-	-

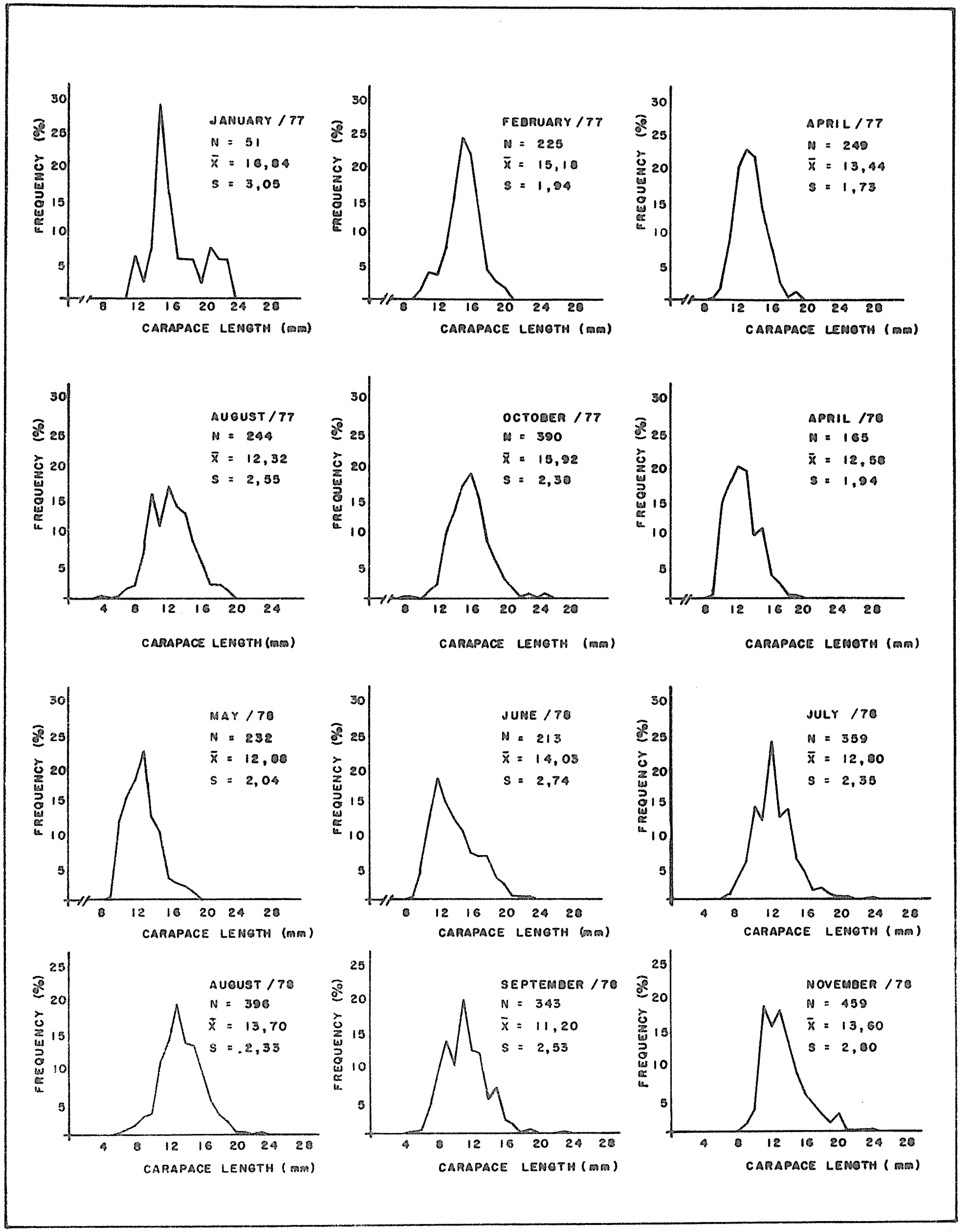

Figure 4.10.1 Carapace Length Frequency Distribution for Brown Shrimp (Penaeus Subtilis) from Nursery Grounds Landed at Curucá - Belém (PA)

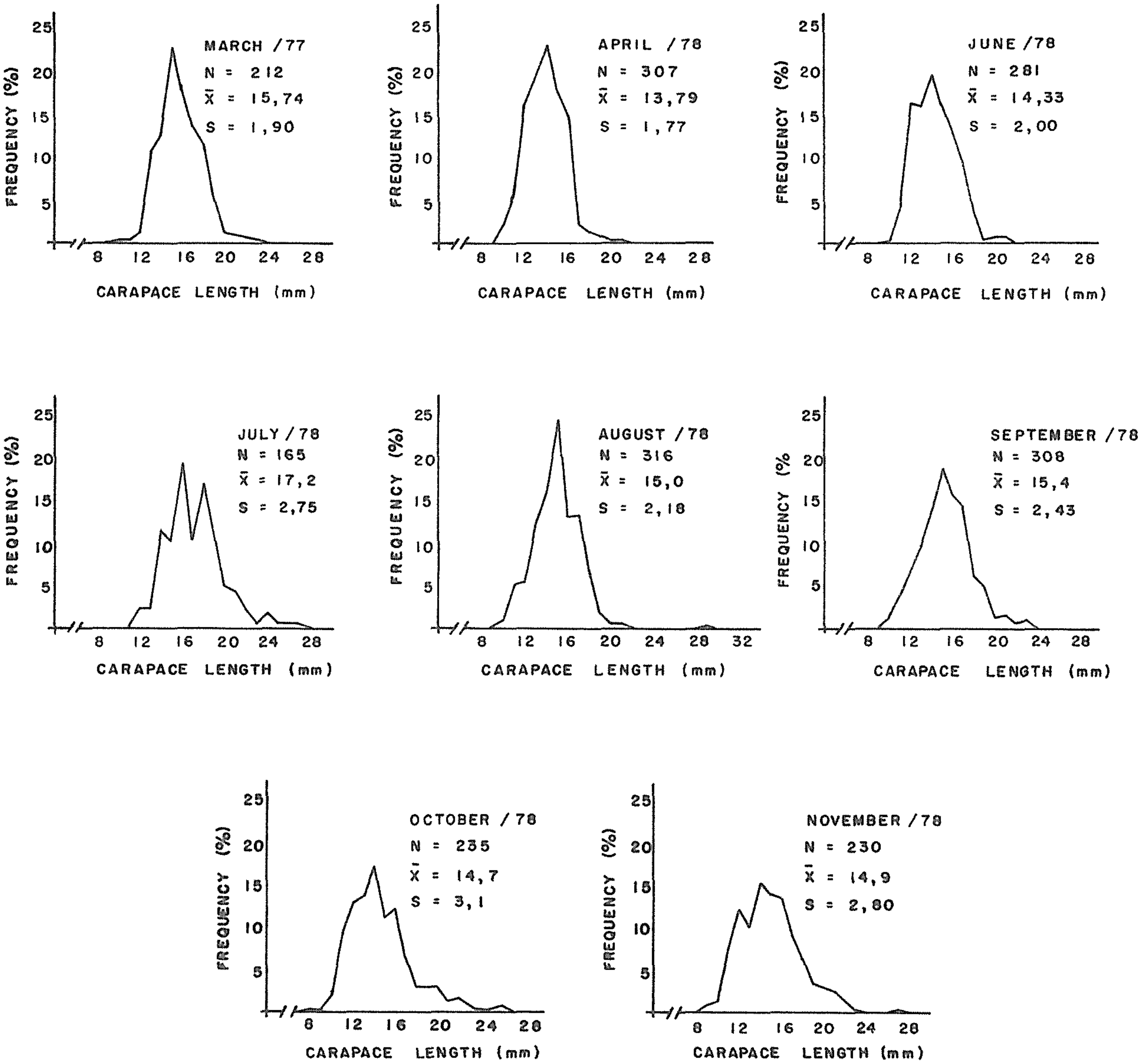

Figure 4.10.2 Carapace Length Frequency Distribution for Brown Shrimp (Penaeus Subtilis) from Nursery Grounds Landed at Maracanã - Belém (PA)

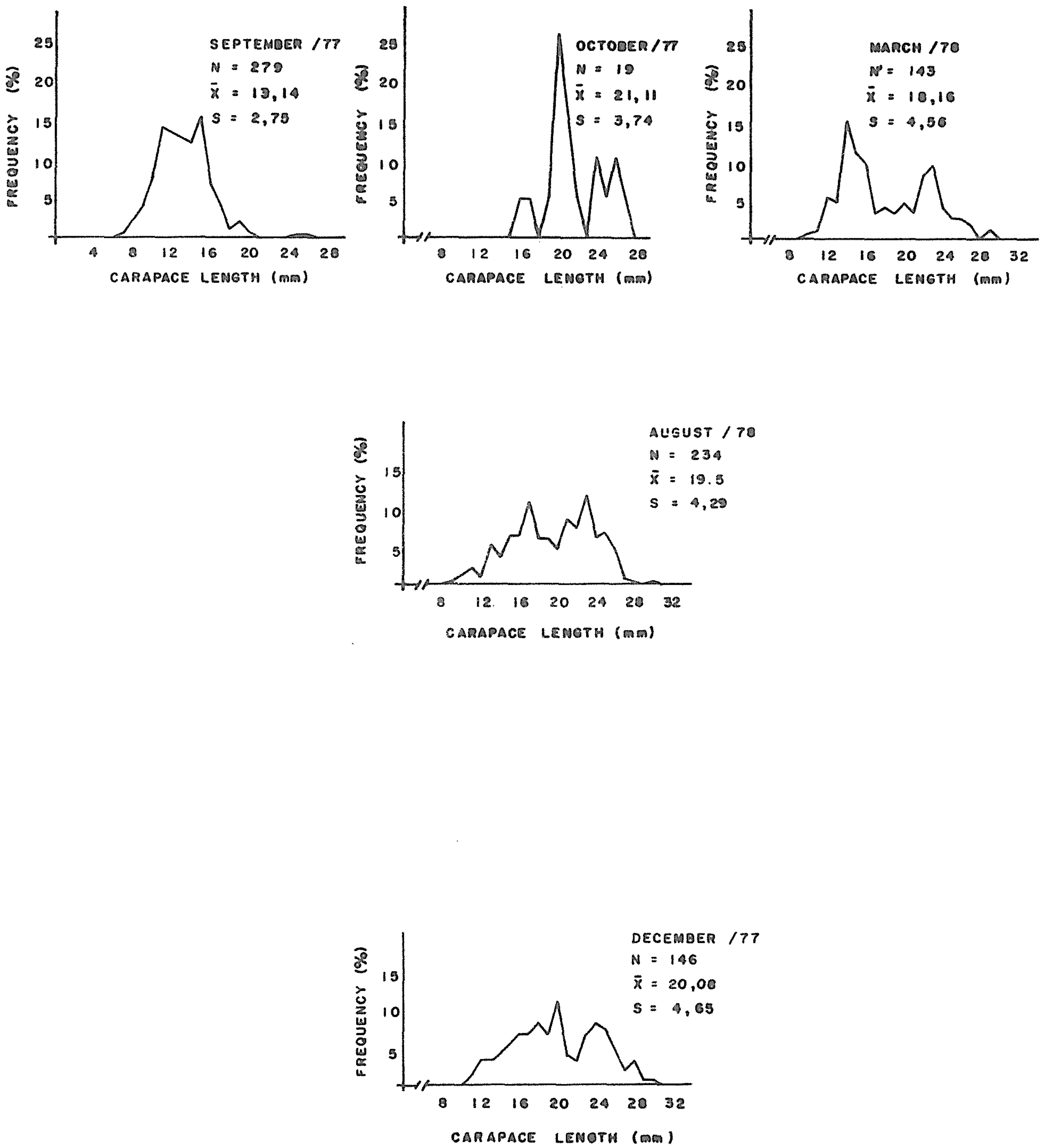

Figure 4.10.3 Carapace Length Frequency Distribution for Brown Shrimp (Penaeus Subtilis) from Nursery Grounds Landed at Salinas - Belém (PA)

Contribution 4.11

The Relative Abundance, Composition and Distribution of Demersal Finfish Off Northeast South America as Determined by OREGON and OREGON II Surveys (1957-77)

by

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1. Previous Exploratory Surveys

The study area extends from the Orinoco River to the Amazon River, an area of roughly 75 000 mi^2 of continental shelf. It includes the coastal waters of Guyana, Suriname, French Guiana and north Brazil.

The earliest published survey was that of ORSTOM II (Durand, 1959) off French Guiana. This largely provided an ichthyological assessment of that region. A two-year survey (1957-1959) off Guyana was also made by the CAPE ST. MARY (Mitchell & McConnell, 1959). It provided catch rates (per hour) and the main part of the survey was within 25 fathoms. Surveys off Suriname were made by the COQUETTE (Higman 1957. Rathjen et al., 1968) and were restricted to waters off the Suriname river mainly within 25 fathoms. The LA SALLE (Gines & Cervigon, 1968) conducted exploratory fishing during 1967 off Guyana and Suriname, largely within inshore waters. The UNDP/FAO vessel CALAMAR explored the coastal waters off the Guianas for four years, with approximately 80 percent of the effort off Suriname, and within 25 fathoms (Rathjen et al., 1968).

These surveys also provided catch rates per hour, and some analysis was done in terms of finfish composition and relative abundance by depth, time of day, and geographical co-ordinates.

2. OREGON and OREGON II Surveys

These cover a 20-year period (1957-1977) and were made using a variety of trawl gears, rigging, trawl times and collected during different times of year, day, and depth. The two vessels differ substantially in length, tonnage, and horsepower.

They complement previous surveys however by extending the area surveyed to the mouth of the Amazon River, and sampled mainly the mid-shelf zone. Some sampling was done of the continental slope fauna. None of the above surveys used random sampling to determine station locations.

3. Data Analysis

Data will be sorted by longitude into one degree block shelf areas and secondarily by depth for each cruise. This allows examination of data over the 20-year period, as well as between countries and by depth. Fishing gear was standardized to the 40 ft (Head-rope) shrimp trawl, per fishing hour (Klima, 1976).

For each standardized haul per depth zone the finfish species will be ranked to give percentage abundances by species and family.

Stations where fish trawls and directed fishing were done will be analysed separately and comparisons made.

3.1. Relative Abundance

Finfish catch rates (kg/h for standard trawl) and density estimates (kg/ha) can be determined for total catch, and selected families and species by depth zone and blocks.

3.2. Standing Stock Estimates (SS)

In blocks where bathymetric charts of sufficient detail are available these can be calculated using swept area density estimates and simulated values of the catchability coefficient. Following Gulland (1972), estimates of annual sustainable yield can then be obtained from the SS estimates. Various values of the mortality coefficient will be used in the absence of determined values.

4. Discussion

Quantitative interpretation of OREGON and OREGON II survey data must consider the various systematic (bias) and sampling errors inherent in the survey designs. Some of these may be minimized by reducing the scale of the observations, but confounding also exists in the presence of the shifting commercial shrimp fishery in some areas surveyed.

This is especially so when inferring population response to varying features of the shelf environment, trends over time, and the creation of ecological models. Strict statistical accounting of spatial distributions, relative abundance and species composition of the demersal finfish is therefore not possible using this data alone.

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Table 4.11.1 Survey Periods and Areas Surveyed by OREGON and OREGON II, Off Northeast South America (1957-77)

CRUISE	SURVEY PERIODS	SURVEY AREAS
OREGON		
# 47	3 Nov -- 19 Nov (1957)	Guyana,Surinam,French Guiana,N.Brazil
# 53	26 Aug -- 25 Sept(1958)	Guyana,Surinam,French Guiana
# 84	18 Feb -- 25 Mar (1963)	Guyana,Surinam,French Guiana
OREGON II		
# 8	25 Apr -- 17 May (1969)	Guyana,Surinam,French Guiana
# 13	15 Nov -- 27 Nov (1969)	French Guiana 1/
# 38	21 Jun -- 4 Jul (1972)	Guyana,Surinam,French Guiana
# 49	26 Jan -- 13 Feb (1974)	Guyana,Surinam,French Guiana
# 58	5 May -- 18 May (1975)	French Guiana,N.Brazil
# 66	15 May -- 28 May (1976)	Guyana,Surinam,French Guiana,N.Brazil
# 84	14 Nov -- 2 Dec (1977)	Guyana,Surinam,French Guiana,N.Brazil

1/ Only Continental slope surveyed

Table 4.11.2 Objectives of OREGON AND OREGON II Surveys as Given in Cruise Reports, and Breakdown of Trawl Stations by Day (06.00 to 18.00 hours)

CRUISE	SHRIMP		GROUNDFISH		TIME OF DAY
	Exploratory	Simulated	Exploratory	Simulated	
OREGON #47	******				D35 N29
#53	******				D43 N71
#84	******		******		D23 N32 (18) (0)
OREGON II #8	******1/		******		D41 N53 (20) (0)
#13		******2/			D14 N23
#38	******				D00 N67
#49	******	******			D8 N59
#56 3/					
#58	******				D15 N39
#66	******	******			D30 N36
#84	******				D19 N28

1/ Experimental fishing also done for Plesiopeneus (slope only)
2/ Continental slope only surveyed
3/ No fish data collected

Contribution 4.12

A Study of the Fishery Activities of Korean Shrimp Trawlers in the WECAF Area (1977-1978)

by

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1. Summary

Fishing area distribution and monthly fishing conditions are discussed, based on data collected by the captains of Korean shrimp trawlers. Information from 17 of 130 vessels in 1977 and from 24 to 124 vessels in 1978 which fished off Suriname was utilized, as well as data from all 10 of the trawlers which fished off Colombia in the period January-June 1978.

The monthly catch in the Suriname area peaked each year in April and May and declined to its lowest level in June and July. The location and area of the grounds fished off Suriname remained almost constant each month. Whilst in 1977 the index of pupulation fluctuated considerably, in 1978 it remained fairly constant around 40 units. Monthly values of the CPUE and index of density showed slight fluctuations each year.

There were distinct differences in the evolution of the CPUE and index of density between the Suriname and Colombian areas. Values for Suriname were almost always higher.

2. Introduction

The Korean shrimp trawl fishery in the western central Atlantic Ocean has been carried out since the exploratory and training operation began in 1969. Thereafter the fishery expanded rapidly. The catches were 34 t with 5 vessels in 1971, 871 t with 55 vessels in 1974, 2 447 t with 110 vessels in 1976 and 2 799 t with 130 vessels in 1977.

This paper is based on data collected in 1977-78 from Korean-flag vessels in the WECAF area and reviews the amount of fishing effort by month and by fishing ground.

3. Sources of Data and Methods

Catch data collected by the Korean shrimp vessels was provided through their companies. The data covered the activities of 17 of 130 vessels in 1977 and 24 of 124 vessels in 1978 which fished off Suriname and all 10 of the trawlers which fished off Colombia during the period January-June 1978. Information given included area of capture, fishing effort and catch by month and area of capture. Catch and fishing effort for each 1° latitude by 1° latitude block were summarized to enable and analysis to be made.

The vessels' tonnages were in the vicinity of 100 t. The catch was calculated by multiplying the number of boxes by the average weight of box. Fishing effort is expressed by the number of hours trawled. The CPUE, index of population size, index of density, effective fishing effort, effective overall fishing intensity and effectiveness of fishing effort were calculated as below:

$$\text{CPUE} = \frac{1}{N}\sum C_i/X_i$$

Index of population size, $P = \sum A_i(C_i/X_i)$

Index of density, $\not{C} = P/\sum A_i$

Effective fishing effort, $\overline{X} = C_i/\emptyset$

Effective overall fishing intensity, $f = \sum C_i/P$

Effectiveness of fishing effort, $r = \overline{X} / \sum X_i$

Were, N : number of sea blocks
i : sea block
A_i : the size of sea block i (Fig. 4.12.10)
C_i : the catch taken from block i
X_i : the effort operated in block i

4. Results and Discussions

4.1 Suriname Area (Figure 4.12.1)

The catch and effort for 1977-78 are shown in Figure 4.12.2. As fishing effort increased, catch also increased. The montly catch peaked in April and May and declined to its lowest level in June and July. The location and area of the grounds fished remained nearly constant each month (Figures 4.12.3 and 4.12.4), the area being greatest in January-March and declining gradually thereafter.

The abundance of the resources by month was obtained by calculating the CPUE, index of population size and index of density (Tables 4.12.1, 4.12.2 and 4.12.5). In 1977 the values of the index of population size fluctuated, with a tendency to decrease through the year, but in 1978 they remained fairly constant around 40. The monthly values of CPUE and index of density fluctuated slightly during the two years.

Effectiveness of effort was calculated to measure the efficiency of the effort exerted on the grounds (Tables 4.12.1, 4.12.2 and 4.12.5). The highest value is for September 1978 which shows that the choise of fishing grounds was very good during that month, the regional distribution of effort being better than the distribution of the shrimp stocks.

4.2 Colombia (Figure 4.12.1)

Ten Korean vessels fished off Colombia from September 1977, through June 1978. Only the catch data for the period January through June 1978 has been utilized. The montly catch peaked in March and declined gradually thereafter (Figure 4.12.6). The move to the Suriname area in June resulted in a decline in catch and effort in that month.

The location and size of the fishing grounds remained constant (Figure 4.12.8) but the value of the index of population size increased continuously (Figure 4.12.7), which seemed to indicate an increase in the shrimp resources.

The values of montly CPUE and the indeces of population size and density continued to increase.

The effectiveness of effort was around "1" except during May when it droped to "0.91", which indicated poor selection of fishing ground during that month (Table 4.12.3).

4.3 Comparisons Between Suriname and Colombia

It is difficult to compare two fishing grounds for as short a period as six months. However, the CPUE and index density for the Suriname area were higher than for the Colombian area (Figure 4.12.9). This seems to indicate that the fishing grounds off Suriname are more productive than those of Colombia.

Table 4.12.1 Index of population size, index of density, effective effort, and effectiveness of effort for the Korean shrimp fishery off Suriname in 1977

Month	$\sum$ Ai Size of fishing ground	Catch (Kg)	Effort (hour)	CPUE (Kg/hour)	P Index of population size	Ø Index of density	$\bar{X}$ Effective fishing effort	f Effective overall fishing intensity	r Effectiveness of effort
Jan	11.4	40 682	7 160.0	6.57	75.18	6.59	6 173.29	541.52	0.86
Feb	15.4	42 240	6 229.5	7.01	105.71	6.86	6 157.43	399.83	0.99
Mar	14.4	30 163	5 319.5	5.99	88.15	6.12	4 928.59	342.26	0.93
Apr	10.7	34 330	5 783.0	5.75	62.17	5.81	5 908.77	552.22	1.02
May	11.3	40 676	6 729.0	5.48	62.31	5.88	6 315.99	603.18	1.01
June	12.2	24 285	4 176.0	5.88	72.13	5.91	4 110.83	336.95	0.98
July	6.1	17 735	2 986.0	5.81	35.21	5.77	3 073.66	503.88	1.03
Aug	10.7	25 997	4 223.0	6.13	65.49	6.12	4 247.88	397.00	1.01
Sep	8.7	21 653	3 702.0	5.66	49.08	5.72	3 785.49	435.11	1.02
Oct	8.3	28 410	4 770.0	5.98	50.19	6.05	4 695.87	565.77	0.98
Nov	3.7	27 310	5 011.0	5.55	20.60	5.57	4 903.05	1 325.15	0.98
Dec	4.7	30 857	4 976.0	6.33	29.80	6.34	4 867.03	1 035.54	0.98

Table 4.12.2 Index of population size, index of density, effective effort, and effectiveness of effort for the Korean shrimp fishery off Suriname in 1978

Month	Σ Ai Size of fishing ground	Catch (Kg)	Effort (hour)	CPUE (Kg/hour)	P Index of population size	Ø Index of density	$\bar{X}$ Effective fishing effort	f Effective overall fishing intensity	r Effectiveness of effort
Jan	5.7	25 559	4 731	4.73	28.33	4.97	5 142.66	902.22	1.09
Feb	7.9	24 598	3 901	6.25	48.81	6.18	3 980.26	503.83	1.02
Mar	9.3	44 672	8 051	4.95	48.06	5.17	8 640.62	929.10	1.07
Apr	8.7	52 011	9 398	5.62	48.13	5.53	9 405.24	1 081.06	1.00
May	7.1	51 412	8 643	6.30	42.36	5.97	8 611.73	1 212.92	1.00
June	9.1	38 907	7 207	5.08	45.36	4.98	7 812.65	858.53	1.08
July	9.7	32 774	5 970	5.29	50.54	5.21	6 290.60	648.52	1.05
Aug	7.7	37 906	6 135	5.73	44.50	5.78	6 558.13	851.71	1.07
Sep	9.7	44 455	7 991	4.79	45.21	4.66	9 539.70	983.47	1.19
Oct	7.7	39 330	6 530	5.99	45.87	5.96	6 598.99	857.01	1.01
Nov	7.7	26 022	4 564	5.32	40.29	5.23	4 975.53	646.17	1.09
Dec	4.7	10 368	1 706	6.05	28.21	6.00	1 728.00	367.66	1.01

Table 4.12.3 Index of population size, index of density, effective effort, and effectiveness of effort for the Korean shrimp fishery off Colombia, January–June 1978

Month	Σ Ai Size of fishing ground	Catch (Kg)	Effort (hour)	CPUE (Kg/hour)	P Index of population size	$\emptyset$ Index of density	$\bar{X}$ Effective fishing effort	f Effective overall fishing intensity	r Effectiveness of effort
Jan	1.3	13 516	3 318	4.08	5.29	4.07	3 320.88	2 554.52	1.00
Feb	1.3	16 664	3 588	4.64	6.04	4.65	3 583.66	2 756.66	1.00
Mar	1.3	16 348	3 540	4.68	5.85	4.50	3 632.89	2 794.53	1.03
Apr	2.3	14 670	3 486	4.24	9.98	4.34	3 380.18	1 469.64	0.96
May	2.3	11 240	2 544	4.78	11.18	4.86	2 312.76	1 005.55	0.91
June	2.3	8 604	1 452	5.93	13.99	6.08	1 415.13	615.27	0.97

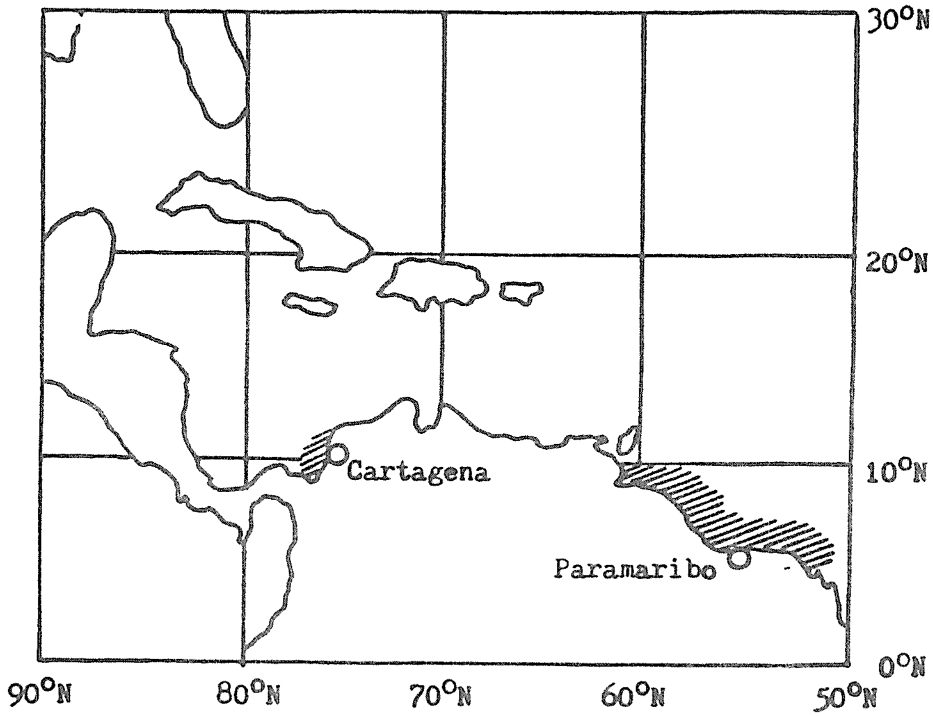


Figure 4.12.1 Location of the Sampling Area for this Study

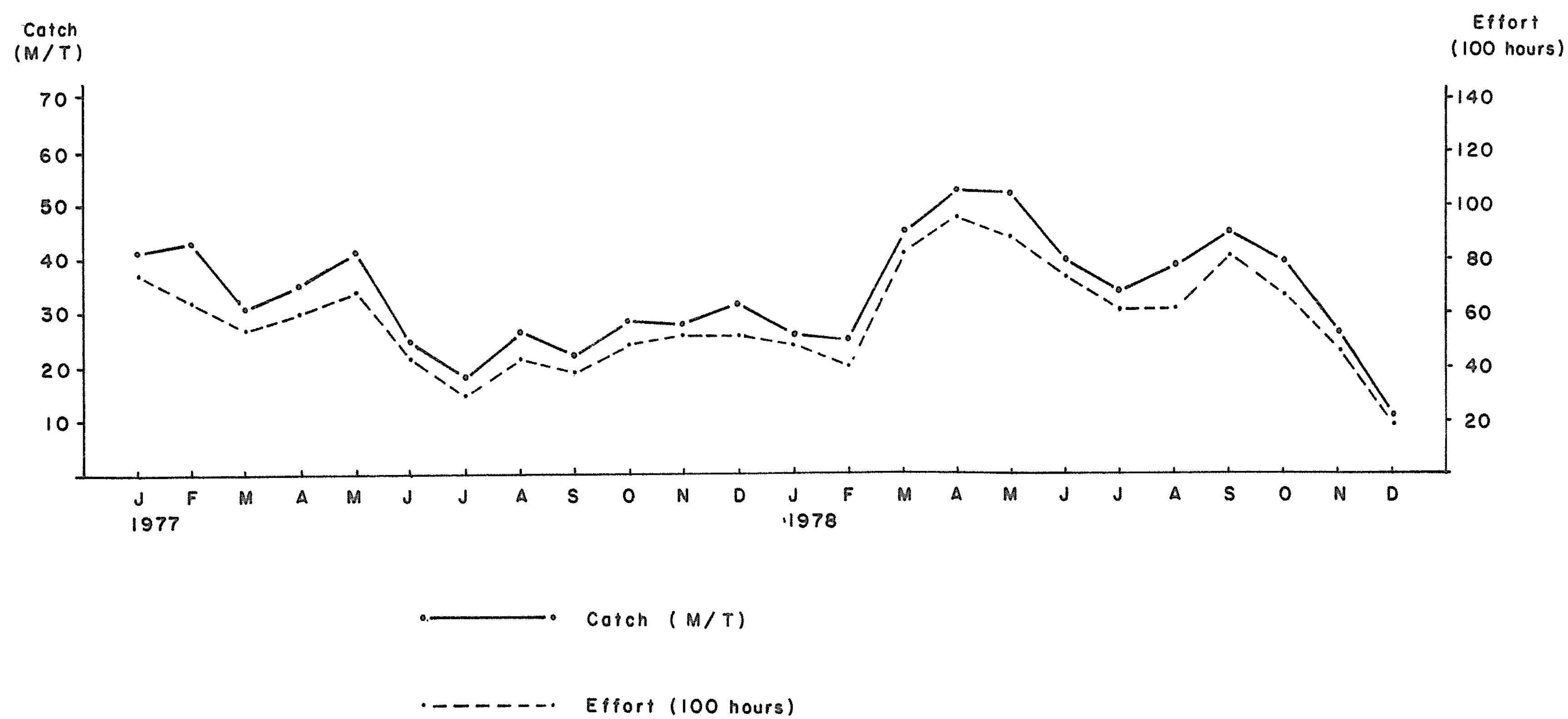


Figure 4.12.2 Montly Changes of Catch and Effort of Shrimps by Korean Shrimp Fishery off Suriname, 1977-78

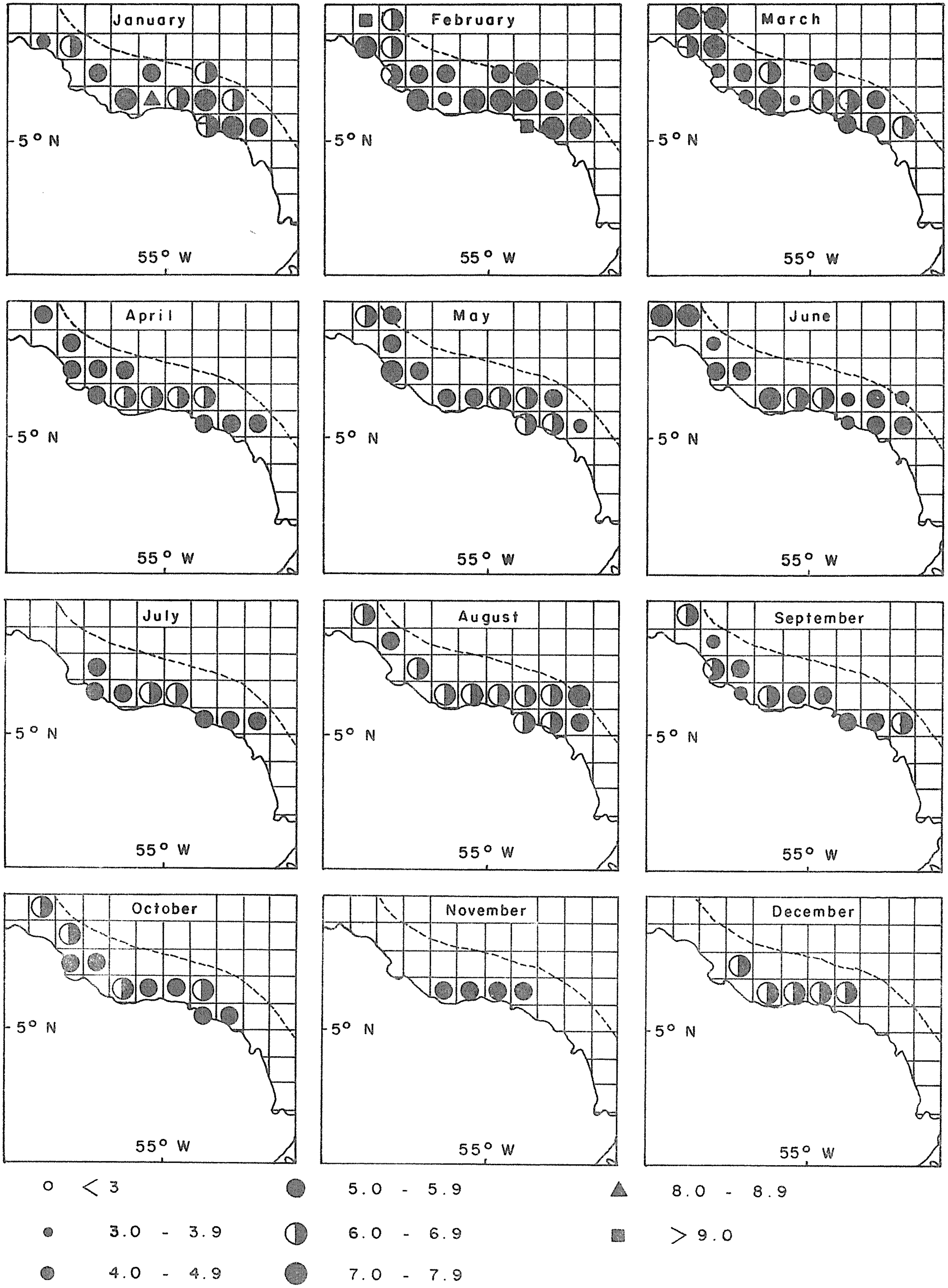


Figure 4.12.3 Distribution of CPUE of Shrimps by Korean Shrimp Fishery off

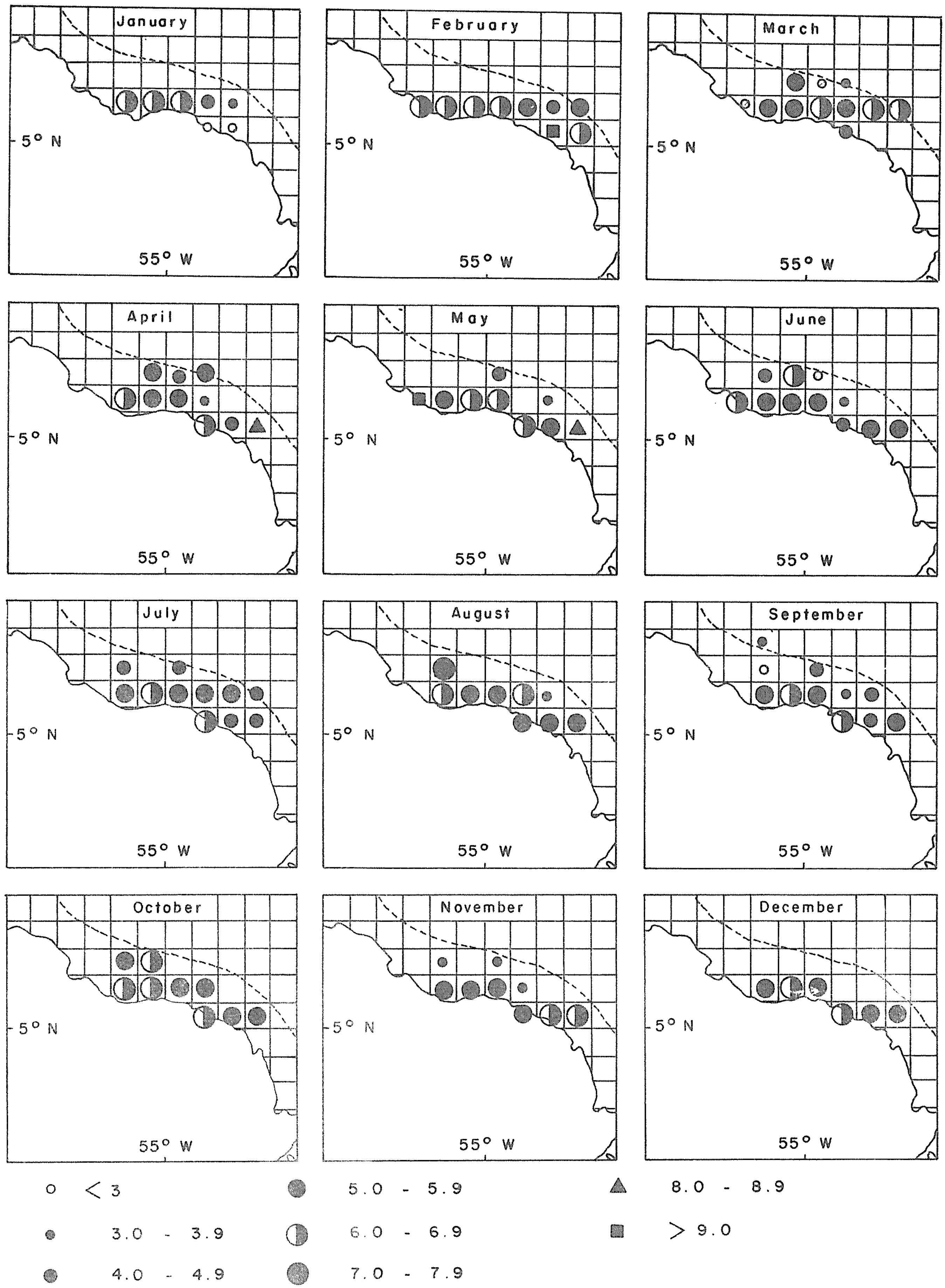


Figure 4.12.4 Distribution of CPUE of Shrimps by Korean Shrimp Fishery off Surinama in 1978

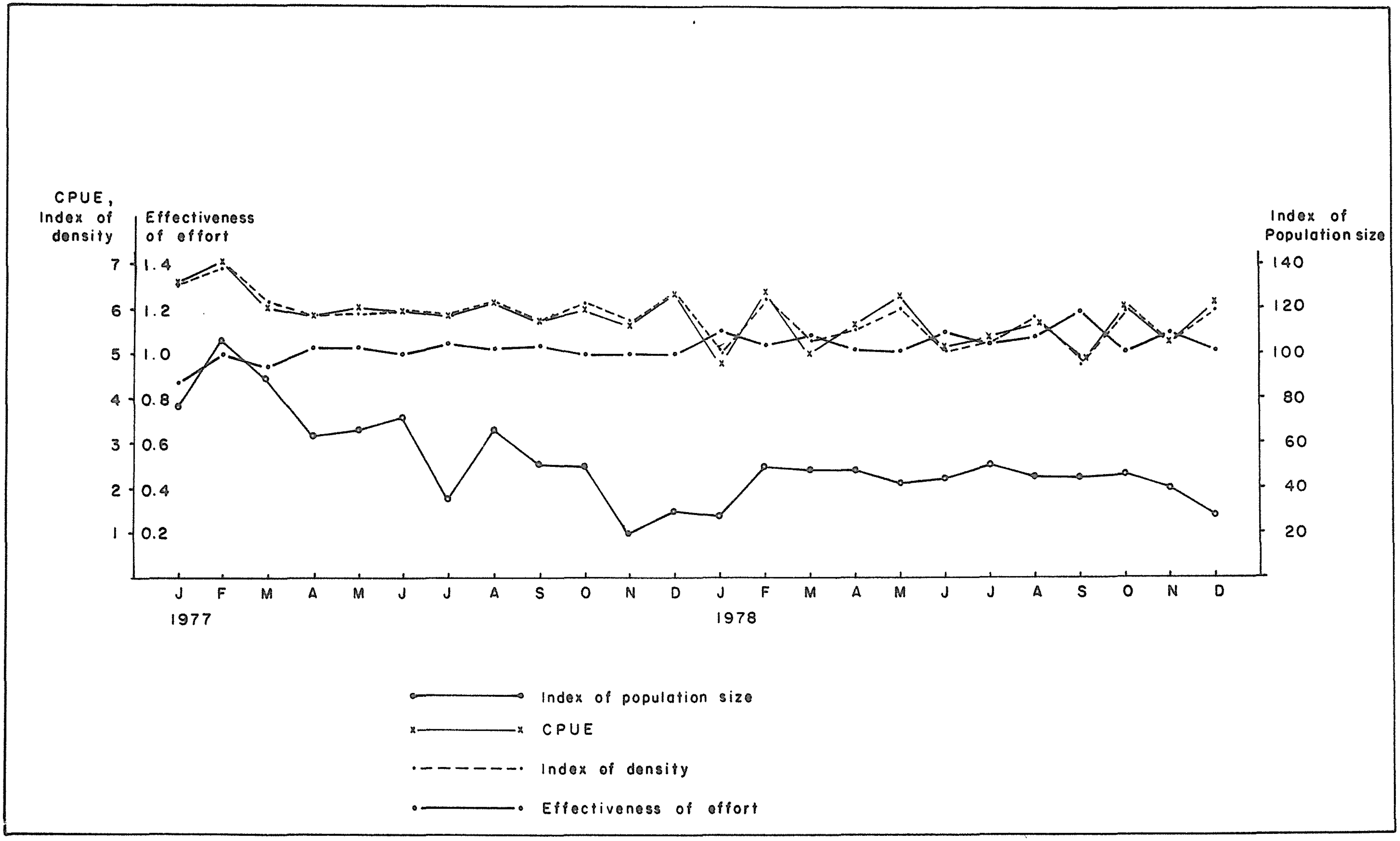


Figure 4.12.5 Monthly Changes of CPUE, Index of Population Size, Index of Density, and Effectiveness of Effort of Shrimps by Korean Shrimp Fishery off Suriname, 1977-78

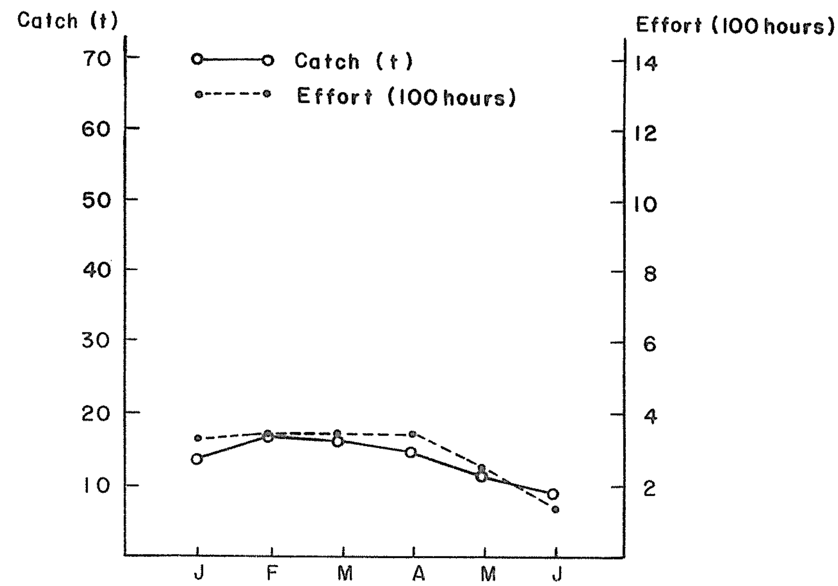


Figure 4.12.6 Monthly Changes of Catch and Effort of the Korean Shrimp Fishery off Colombia, January-June 1978

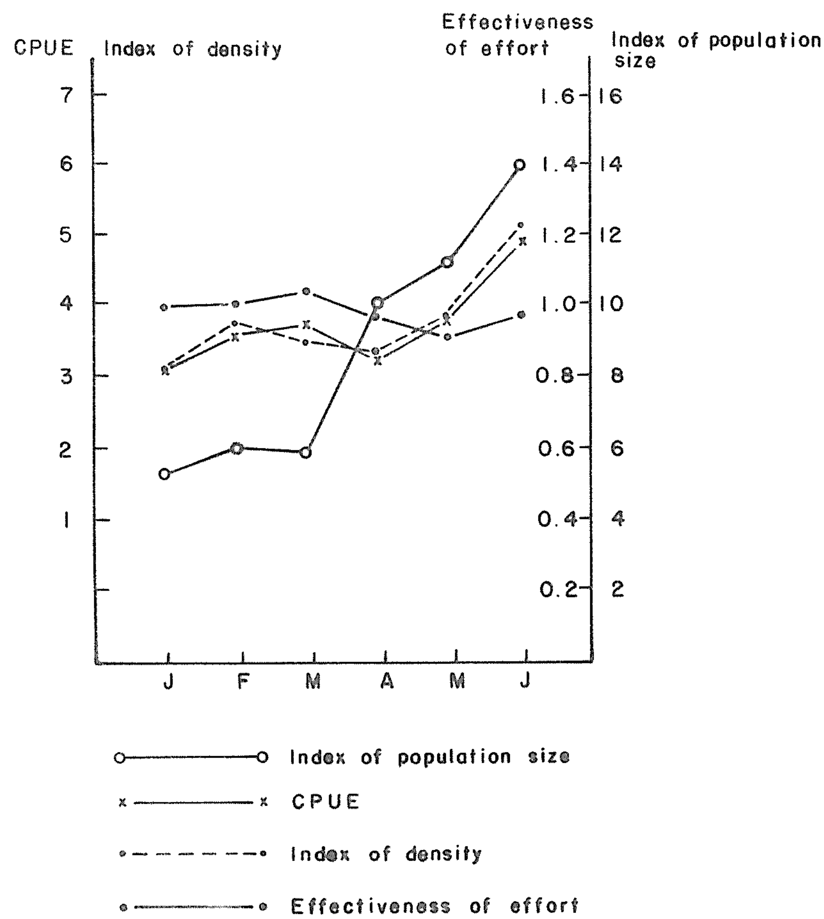


Figure 4.12.7 Monthly Changes of CPUE, Index of Population Size, Index of Density and Effectiveness of Effort of the Korean Shrimp Fishery off Colombia January-June 1978

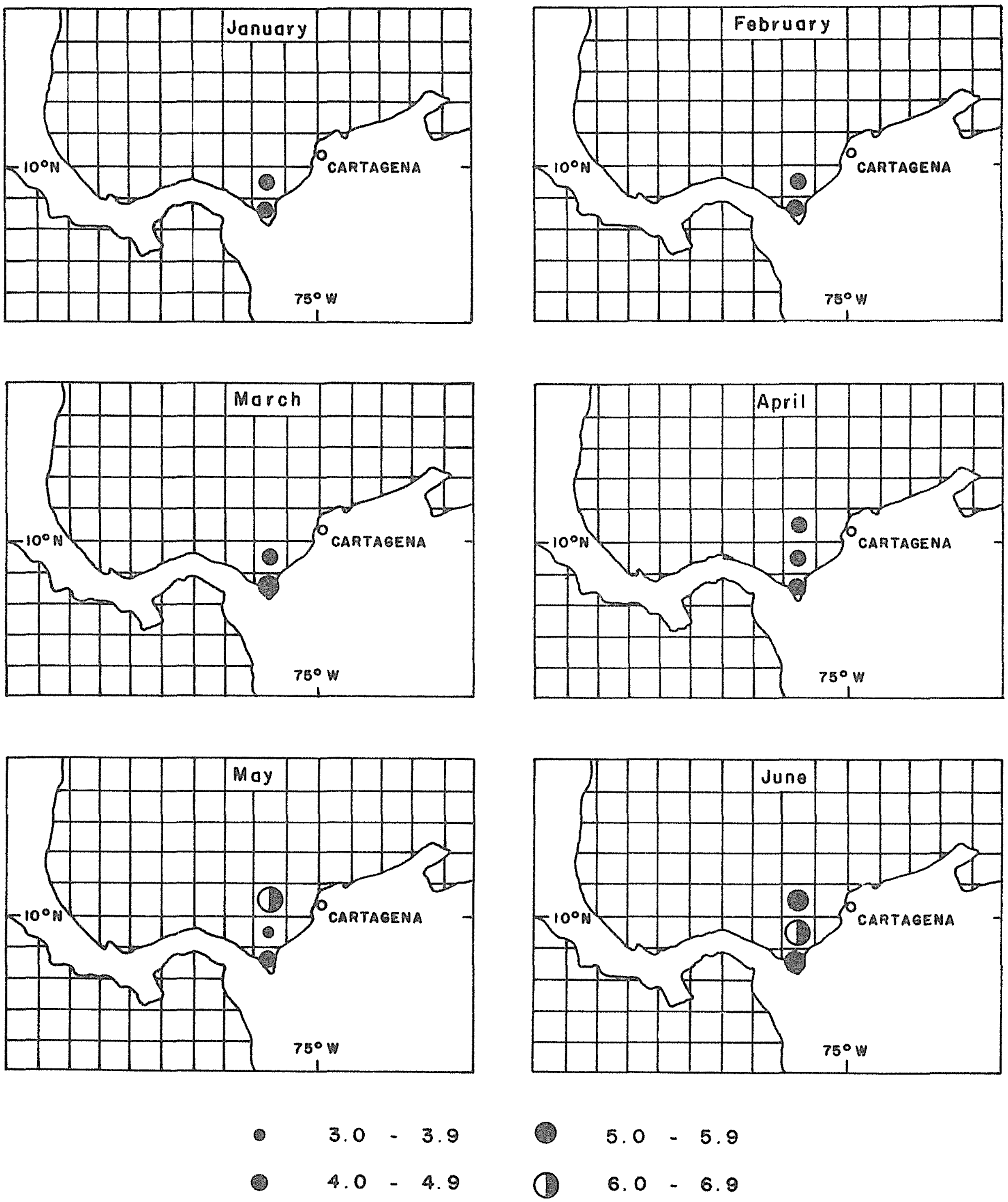


Figure 4.12.8 Distribution of CPUE of Shrimps by Korean Shrimp Fishery off Colombia, January-June, 1978

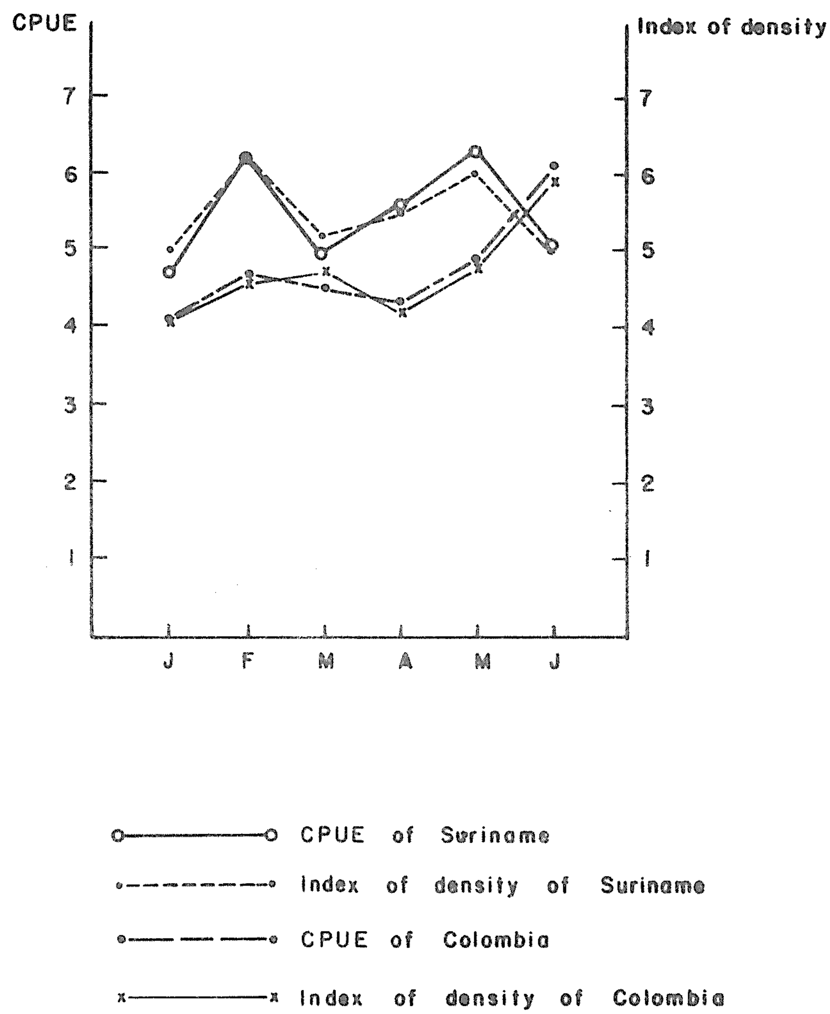
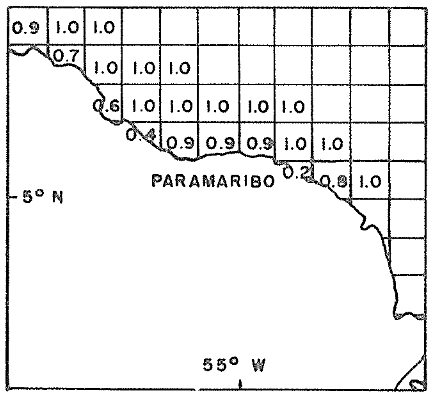


Figure 4.12.9 Monthly Changes of CPUE and Index of Density of Shrimps by Korean Shrimp Fishery off Suriname and off Colombia, Juanuary-June 1978.



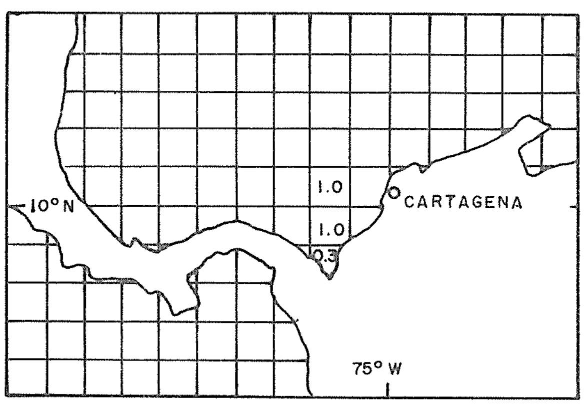


Figure 4.12.10 Estimated Size of Sea Blocks off Suriname and Colombia

Contribución 4.13

Potencial Reproductor de *Xiphopenaeus Kroyeri* (Heller) de Guyana

(Reproductive Potential of *Xiphopenaeus Kroyeri* (Heller) from Guyana)

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Indice

1. Introducción

El X. kroyeri es una especie que se encuentra ampliamente distribuida en el Atlántico Centro-Occidental desde el sur de Cabo Hetteras, Carolina del Norte hasta la Bahía de Simbras, Brasil (Pérez Farfante, 1970 a).

La talla que alcanzan estos crustáceos es pequeña en comparación con los peneidos que se explotan comercialmente en la actualidad, pero como las pesquerías de estos ya se encuentran explotadas al máximo en el Atlántico Centro-Occidental y la abundancia de X. kroyeri, llamado vulgarmente "titi", es muy grande, algunos países han comenzado la explotación debido a que cada día aumenta la demanda de camarón en el mercado mundial y el precio que alcanza va en aumento.

Casi todos los trabajos acerca de esta especie se refieren a distribución. Khandker (1965) reporta que habita en el Golfo de Paria y alrededor de la Isla Margarita (Venezuela). Burkenroad (1939) reporta que apareció en la expedición del ATLANTIC y Simpson, Ruiz (1975) lo reporta en aguas cubanas.

Hay otros trabajos sobre evaluación de potencial pesquero de esta especie como el de Naidu y Boerema (1972) y el de Bullis y Thompson (1959), que estimó el potencial en 45 000 t en la Guyana.

Muy pocos trabajos se dedican a estudiar su ciclo de vida y ninguno existe sobre el potencial reproductor, siendo este último aspecto muy importante, ya que se utiliza frecuentemente en modelos de evaluación a partir de los cuales, junto con otros parámetros, se puede estudiar el crecimiento y mortalidad de las especies.

2. Materiales y Métodos

Las muestras estudiadas provienen de dos cruceros de investigación realizados frente a las costas de Guyana en enero y marzo de 1978, en la zona comprendida entre los 06°00' N y los 57°30' W, en profundidades que oscilaron entre 12 y 24 m.

El barco utilizado fue un camaronero de la flota comercial dotada de redes simples por cada banda.

Se realizaron 30 arrastres de una hora en cada crucero, escogiéndose hembras en estadios de maduración avanzados hasta completar cinco por cada clase de largo (clases de 3 mm). En total se seleccionaron 50 hembras, las que se preservaron en formol al 10 por ciento neutralizado con tetraborato de sodio hasta su traslado al laboratorio. En éste, se midieron desde la base de la escotadura postorbital hasta el último segmento abdominal (largo cubano), expresando esta medida en centímetros y décimas. Luego se pesaron en una balanza de 0,1 g de sensibilidad, expresándose el peso en gramos y décimas y se extrajeron las gónadas, pesándose en una balanza de torsión de 1 mg de apreciación (esta medida se expresó en miligramos).

A cada gónada se le hizo un frotis varificándose los resultados mediante cortes histológicos para determinar el estadio de maduración de cada ejemplar. Las gónadas se almacenaron en formol al cuatro por ciento neutralizado con tetraborato de sodio hasta el momento de ser contadas.

De cada gónada se extrajeron submuestras con gotero, se contaron 500 huevos y el resto se eliminó. Estos 500 huevos se pesaron en una balanza de torsión de 0,05 mg de sensibilidad después de extraer el exceso de humedad. El peso se expresó en miligramos y centésimas. Se obtuvo un coeficiente de variación promedio de ocho por ciento en los conteos.

Los huevos se contaron y se midieron en un microscopio esteroscópico con micrómetro ocular, calibrado con un micrómetro de platina. El diámetro de los huevos se expresó en milímetros. Para medir el estadio II se tomaron los huevos de este estadio presentes en las gónadas maduras, a pesar que no fueron contados.

El número de huevos de la gónada se calculó utilizando la siguiente fórmula:

$$Nh = \frac{\text{peso de la gónada por 500}}{\text{peso de 500 huevos}}$$

Se utilizó el método de los cuadrados mínimos semi-logarítmico para calcular la relación entre el número de huevos y otras variables como el largo, el peso y el peso de la gónada.

3. Resultados y Discusión

(a) Diámetro Promedio de los Huevos para Diferentes Estadios de Maduración

Se calculó la media, la varianza, la desviación standard y el rango de variación del diámetro de los huevos en los estadios de maduración II, III y IV que fueron los que aparecieron en las gónadas estudiadas (estos datos se ofrecen en Cuadro 4.13.1). En él puede apreciarse cómo va aumentando el diámetro promedio de los huevos a medida que la maduración es más avanzada.

En el estadio IV se obtuvo un diámetro promedio de 0,24 mm. Si comparamos este valor con los encontrados por otros autores para otras especies, vemos que no difiere mucho del resto de los peneidos. Eldred (1958) plantea para P. duorarum un rango de 0,23 a 0,33 mm, Cummings (1961) en la misma especie encontró un diámetro de 0,37 mm; Pérez Farfante (1969) se refiere a P. aztecus y sitúa un diámetro entre 0,26 y 0,28 mm; Pearson (1939) establece 0,28 mm como promedio para P. setiferus; Guitart y Quintana (1977) determinaron que el diámetro promedio de P. duorarum y P. aztecus era 0,28 mm y el de P. setiferus, 0,29 mm.

(b) Número de Huevos Promedio en Cada Clase de Largo

Las clases de largo se agruparon en intervalos de 3 mm y se calculó la media, la desviación standard y el rango de variación del número de huevos en cada una de ellas, los que se presentan en el Cuadro 4.13.2. En la misma se observa que los mayores valores de desviación standard y rango de variación se encuentran a partir de la clase 7,4-7,6 cm por lo que creemos que este hecho está relacionado con la maduración de las gónadas y con la época en que se tomaron las muestras.

(c) Ecuaciones Determinadas para Calcular el Número de Huevos a Partir de Algunas Variables

Se estimó la ecuación que relaciona el número de huevos (Nh) con el largo cubano (Lc):

$$\text{Ln Nh} = 9{,}0639650 + 0{,}3020821\ (\text{Lc}) \qquad r = 0{,}9955$$

Se calculó además la ecuación que permite estimar el número de huevos con el peso (P) del ejemplar:

$$\text{Ln Nh} = 9{,}9539792 + 0{,}1569405\ (\text{P}) \qquad r = 0{,}9725$$

La tercera ecuación que se determinó es la que relaciona el número de huevos con el peso de la gónada (Pg):

$$\text{Ln Nh} = 10{,}3405761 + 1{,}8439791\ (\text{Pg}) \qquad r = 0{,}8877$$

Se determinó la significación de los coeficientes de correlación, encontrándose que todos eran altamente significativos para un intervalo de confianza del 99 por ciento, aunque se recomienda la que relaciona el número de huevos con el largo cubano.

Con las ecuaciones anteriores se calculó el número de huevos para algunos valores de largo, peso y peso de la gónada, los que se ofrecen en los Cuadros 4.13.3, 4.13.4 y 4.13.5. En ellos se aprecia que el número de huevos aumenta a medida que se hacen mayores el largo, el peso y el peso de la gónada.

En las Figuras 4.13.1 a 4.13.3[1/] se presentan los valores de número de huevos calculados a partir de las ecuaciones determinadas. Puede observarse en ellas que la relación entre ese número y las demás variables es exponencial.

(d) Número Promedio de Huevos a Desovar

El número promedio de huevos que desova esta especie se determinó a partir de la ecuación que relaciona el número de huevos con la talla tomándose como talla promedio la de 7,4 cm, que fue la media durante los viajes realizados. El número de huevos que correspondió a esta talla fue de 74 800.

El mayor número de huevos encontrado fue de 285 300 y correspondió a una talla de 8,0 cm. El menor fue de 25 600, que correspondió a 6,7 cm de largo.

1/ No recibidas a la fecha de publicación

El número de huevos que desova esta especie es menor que el de otros peneidos. Anderson et al. (1949) contaron los huevos de una hembra de P. setiferus de 17,5 cm de largo total encontrando que desova 860 000 huevos; Guitart y Fraga (ms) encontraron que esta misma especie desova como promedio 300 000 huevos; Rivas (ms) calculó que P. notialis desova 185 000 huevos como promedio; Pelegrín y Yong (ms) calcularon que P. aztecus desova 310 000 huevos como promedio; Pérez Farfante (1970 b), reporta que P. schmitti desova 500 000 huevos y Bendazoli (ms) informa que la misma especie desova 214 000 huevos. Guitart y Anderes (ms) calcularon que P. duorarum desova 211 000 huevos como promedio; Rao (1968) para P. indicus encontró que una hembra de 140 mm de largo total desova 68 000 y una de 200 mm desova 731 000 huevos.

Opinamos que estos resultados pueden ser buenos indicadores del potencial reproductor de esta especie ya que aunque el número de huevos que desova es menor que el del resto de los peneidos, también debe tenerse en cuenta que las tallas en ellos son menores.

4. Conclusiones

(a) El diámetro de los huevos aumenta a medida que es más avanzada la maduración de la gónada, siendo el diámetro promedio del estadio IV de 0,24 mm.

(b) Se calcularon tres ecuaciones que relacionan el número de huevos con el largo cubano, el peso y el peso de la gónada, siendo altamente significativos los coeficientes de correlación para un intervalo de confianza de 99 por ciento.

(c) La relación del número de huevos con el largo, el peso y el peso de la gónada corresponde a una relación exponencial.

(d) Se encontró que el número promedio de huevos que desova esta especie es de 74 800, con valores límites entre 25 700 y 285 300.

(e) El número de huevos crece a medida que aumentan el largo, el peso y el peso de la gónada.

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Cuadro 4.13.1 Diámetro Promedio de Huevos para Diferentes Estadios de Maduración

	Media (mm)	Varianza	Desviación standard	Número de ejemplares	Rango de variación (mm)
II	0,14	0,000289	0,017	9	0,12-0,17
III	0,20	0,000100	0,010	14	0,18-0,21
IV	0,24	0,000256	0,016	27	0,21-0,26

Cuadro 4.13.2 Número de Huevos Promedio en Cada Clase de Largo

Clase de largo (mm)	Media (x 1 000)	Desviación standard	Rango de variación (en '000 de huevos)
5,9-6,1	47,6	22,6	30,0-75,0
6,2-6,4	55,7	32,9	26,2-100,0
6,5-6,7	59,0	19,1	25,7-82,4
6,8-7,0	76,0	34,1	48,5-130,8
7,1-7,3	85,9	27,7	35,3-124,0
7,7-7,9	104,6	82,7	30,3-226,9
8,0-8,2	174,3	77,0	79,7-285,3
8,3-8,5	99,1	52,7	44,1-149,2

Cuadro 4.13.3 Valores del Número de Huevos Calculados Usando la Ecuación que los Relaciona con el Largo del Ejemplar

Largo (mm)	Huevos (en miles)
5,4	44,1
5,7	48,3
6,0	51,9
6,3	57,9
6,6	63,4
6,9	69,4
7,2	76,0
7,5	83,2
7,8	91,1
8,1	99,8
8,4	109,0
8,7	120,0
9,0	131,0

Cuadro 4.13.4 Número de Huevos Calculados para Algunos Valores del Peso del Ejemplar Partiendo de la Ecuación que los Relaciona

Peso (gr)	Huevos(en miles)
4,0	39,4
4,5	42,6
5,0	46,1
5,5	49,9
6,0	53,9
6,5	58,3
7,0	63,1
7,5	68,3
8,0	73,8
8,5	79,8
9,0	86,4
9,5	93,4
10,0	101,0
10,5	108,0
11,0	118,0
11,5	128,0
12,0	138,0

Cuadro 4.13.5 Número de Huevos Calculados para Algunos Valores del Peso de la Gónada a Partir de la Ecuación

Peso de la gónada (gr)	Huevos (en miles)
0,05	33,9
0,10	37,2
0,15	40,8
0,20	44,8
0,25	49,1
0,30	53,8
0,35	59,0
0,40	64,7
0,45	71,0
0,50	77,8
0,55	85,4
0,60	93,6
0,65	102,0
0,70	112,0
0,75	123,0
0,80	135,0
0,85	148,0
0,90	163,0
0,95	178,0
1,00	196,0
1,05	215,0
1,10	235,0
1,15	258,0
1,20	283,0

Contribución 4.14

Observaciones Biológicas Sobre el *Xiphopenaeus Kroyeri* (Heller) en la Plataforma de Guyana

(Biological Observations on *Xiphopenaeus Kroyeri* (Heller) from the Guyanese Shelf)

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Indice

1. Introducción

Las capturas de X. kroyeri en Guyana forman parte de las pesquerías dirigidas a la explotación de otros peneidos de mayor talla.

Aunque esta especie se caracteriza por su pequeña longitud, su gran abundancia ofrecería muy buenas perspectivas de explotación (Lindner, 1971), especialmente en la actualidad en que su carne ha sido reconocida como de gran calidad en el mercado mundial.

En la Figura 4.14.1 se muestra la distribución de este crustáceo en el Atlántico centro-occidental. Se localiza desde la costa sureste de los Estados Unidos hasta el norte de Brazil (Pérez-Farfante, 1970 a).

Esta especie ha sido poco estudiada, la mayoría de los autores se han dedicado a la sistemática y el resto de los trabajos como los de Bullis y Thompson (1959) y Naidu y Boerema (1972), son evaluaciones preliminares obtenidas con los pocos datos biológicos disponibles.

El presente informe forma parte de los estudios que se iniciaron en el Centro de Investigaciones Pesqueras en 1977 y contribuye a ampliar el conocimiento del ciclo de vida de X. kroyeri y consecuentemente a lograr una explotación más racional de la pesquería.

2. Materiales y Métodos

Se realizaron tres viajes de investigación a la zona de Guyana; el primero en agosto de 1977 y los restantes en enero y marzo de 1978, a bordo de barcos comerciales, habilitados con redes dobles por cada banda.

Se diseñó un sistema de muestreo de 25 estaciones de 60 minutos de duración cada una.

El tamaño de la muestra por estación fue aproximadamente de 50 ejemplares tomados al azar y fijados en formol al 10 por ciento neutralizado con tetraborato de sodio. Posteriormente esos ejemplares se trasladaron al laboratorio para su procesamiento.

En cada camarón se determinó el sexo y se midió el largo cubano (desde la escotadura postorbital hasta el último segmento abdominal) utilizándose una regla de acrílico graduada en milímetros. El peso de los camarones enteros se obtuvo en una balanza eléctrica de 0,1 g de sensibilidad; ambas medidas se expresaron en centímetros y gramos respectivamente. Se extrajeron las gónadas y se pesaron en una balanza de torsión de 1 mg de sensibilidad, expresando el peso en miligramos.

En cada crucero se seleccionaron 10 hembras de cada clase de largo (con 5 milímetros cada una para realizar un estudio histológico de las gónadas. Estas se fijaron en Bouin después de observar la coloración que presentaban y se procesaron por el método de parafina; los cortes se hicieron de 8 a 10 micras de espesor y se colorearon con la fórmula tricrómica de Mallory. Seguidamente se clasificaron por estadios de maduración utilizándose un microscopio biológico con micrómetro ocular.

Se determinó el índice gonadosomático (IG) de cada ejemplar utilizando la siguiente fórmula:

$$I.G. = \frac{\text{peso de la gónada x 100}}{\text{peso del camarón entero}}$$

Se estableció la relación existente entre este índice y los estadios de maduración gonadal determinados mediante cortes histológicos. Se consideraron maduras las hembras que presentaban valores de índice gonadosomático iguales o mayores de 7,0.

3. Resultados y Discusión

(a) Proporción de Sexos

Cuando se va a realizar una evaluación de su potencial pesquero, es necesario determinar la proporción de sexos de cualquier especie. En la Figura 4.14.1 se muestra la proporción entre hembras y machos en todas las isobátas de cada crucero. Se encontró que las hembras siempre eran más numerosas que los machos y las pruebas de hipótesis realizadas arrojaron que existían diferencias significativas entre ambos sexos en todos los meses estudiados. Creemos que esto se debe a que los machos presentan tallas menores que las hembras y son menos susceptibles de ser capturados por la red.

Los estudios realizados sobre este aspecto en otras especies ofrecen resultados diferentes. Eldred *et al.* (1961) y Pérez-Farfante (1961) entre otros, aseguran que la proporción entre hembras y machos es 1:1 en el *Penaeus duorarum* y Pérez-Farfante (1969) señala esta misma proporción en otras especies de peneidos.

(b) Distribución de las Tallas

Las frecuencias de longitud en todos los cruceros realizados, se agruparon en clases de 5 milímetros.

En la Figura 4.14.3 se presenta la composición por talla en cada sexo. Se observa que en el mes de agosto las hembras presentan las modas mayores; los machos mantienen el mismo valor modal en todos los cruceros. Esto probablemente se debe a la selectividad del arte que no retiene a los individuos pequeños, siempre los más abundantes.

En el mes de marzo las estaciones fueron más numerosas que en el resto de los viajes por lo que muestra fue mayor en número y la forma de la curva se acercó a la distribución normal.

En la Figura 4.14.4 se puede apreciar también que los machos siempre poseen una talla promedio menor que las hembras.

Se puede observar una diferencia de las tallas promedio en el transcurso del año; en los primeros meses se registraron las tallas promedio menores y en el mes de agosto las mayores.

Para determinar si existía algún tipo de relación entre la talla y la profundidadse hicieron correlaciones en todos los viajes; se obtuvo en todos un coeficiente de correlación que no fue significativo para el 95 por ciento de significación. Algunos autores como Iversen et al. (1960) y Pérez-Farfante (1970 b) plantean, para otros peneidos, una distribución diferencial según la profundidad encontrándose los mayores en las isóbatas más profundas. Se piensa que el comportamiento de X. kroyeri difiere de los tros peneidos debido a que habita en un rango de profundidad muy restringido, ya que la mayoría de los individuos se encuentran entre los 10 y 20 m.

(c) Factor de Condición

Se calculó el factor de condición por clase de largo de cada viaje y los resultados aparecen en la Figura 4.14.5. Se puede apreciar que los valores más altos se presentan en las clases de largo menores, que es cuando los camarones presentan un crecimiento más rápido.

Este factor varía en los diferentes meses del año, los valores más grandes se encuentran en el mes de agosto que, como veremos posteriormente, es el que presenta mayor cantidad de hembras maduras. Se debe a que el peso de los ovarios en este estadio puede llegar hasta tres gramos e influye mucho en el peso total.

Existen diferencias entre hembras y machos, las primeras presentan valores más altos. Estas diferencias se acentúan a partir de la clase de 5,6 a 6,0 cm, que es la talla en que las hembras comienzan a madurar.

Aunque el valor del factor de condición varía en los distintos viajes, el patrón de las curvas es similar; las hembras presentan altos valores en las clases de largo menores y pequeños en las clases mayores, manteníendose más o menos constante en las clases intermedias.

En los machos los valores van decreciendo a medida que las clases de largo son mayores excepto en enero en que aumenta bruscamente en las clases mayores; esto se debe a que la cantidad de machos fue pequeña en las clases citadas.

4. Reproducción

(a) Descripción de los Estadios de Maduración Gonadal de las Hembras

1. Las gónadas son transparentes y finas. En el microscopio se observa el ovario formado por numerosas columnas de oogonias, situadas en el centro del órgano; parte de ellas se desarrollan y se convierten en

oocitos que poseen grandes núcleos, los que contienen hasta 5 nucléolos, muy desarrollados y situados en el centro del núcleo (Figura 4.14.6).

(2) La coloración de las gónadas es amarillo-verdoso pálido, intensificándose el color a medida que la gónada va madurando. La estructura microscópica presenta oocitos de mayor tamaño, en los que la relación desproporcionada que existía en el estadio anterior entre el tamaño del núcleo y del citoplasma disminuye; el número de nucléolos aumenta, no se observan agrupados en la región central del núcleo y disminuyen de tamaño (Figura 4.14.7).

(3) Los ovarios presentan una coloración verde pálido, oscureciéndose a medida que madura. Igual que en el estadio anterior, son más anchos y ocupan gran parte del cefalotórax. En la estructura microscópica puede observarse que los oocitos presentan el citoplasma granuloso y el núcleo es pequeño en relación con el tamaño del citoplasma; los nucléolos pueden llegar a 20 y migran hacía la periferia, reduciéndose considerablemente de tamaño, semejando pequeños puntos (Figura 4.14.8).

(4) La coloración de las gónadas es verde olivo intenso, los lóbulos anteriores ocupan todo el cefalotórax. En el microscopio se observaron unos círculos en toda la periferia de los óvulos, que son los llamados cuerpos periféricos (Figura 4.14.9).

(5) Gónadas de color blanco grisáceo. Son fláccidas y acintadas. En el microscopio se observa el ovario desorganizado, con restos de vitelo diseminados por toda la gónada y óvulos en reabsorción dentro y fuera de las lamelas. También se observan espacios vacíos (Figura 4.14.10).

(b) Talla de Primera Maduración

Para calcular este valor se graficó la frecuencia acumulada del por ciento de hembras que tenían un índice gonadosomático mayor de 7,0 cm, en cada clase de largo.

Se asume como largo de primera maduración el punto en que la pendiente de la curva crece rápidamente, caso en que coincide con la clase de 6,1-6,5 cm, como puede verse en la Figura 4.14.11.

Se determinó que el 50 por ciento de las hembras maduras correspondía a la clase de 6,6-7,0 cm.

La talla más pequeña en la que se encontró una hembra madura correspondió a la clase de 5,6-6,0 cm.

(c) Indice Gonadosomático

Se determinó el por ciento de hembras en cada clase de largo con un índice gonadosomático mayor de 7,0 cm. Estos valores se presentan en la Figura 4.14.12 donde se distingue que el porcentaje mayor correspondió a la clase de 7,1-7,5 cm.

En la Figura 4.14.13 se presentan los valores de este índice por clase de largo en cada crucero. En ella puede apreciarse que los valores más altos corresponden al mes de agosto y los más bajos a marzo. Basándonos en estos resultados se plantea que la época de mayor desove en esta especie es el mes de agosto. En este mes se presentan valores muy altos de índice gonadosomático en dos clases de largo que son: 6,1-6,5 y 8,1-8,5 cm. Este hecho podría indicar que la primera corresponde a los individuos que desovan por primera vez y la otra incluye a los que desovan por segunda y tercera vez.

En enero y marzo los valores de índice gonadosomático son bajos, detectándose sólo valores altos en las clases de largo mayores. El mes donde se presentó el índice promedio más bajo fue marzo.

(d) Area de Desove

Para determinar la zona de desove se escogieron las estaciones que presentaban altos valores de índice gonadosomático y se tuvo en cuenta que estos valores se repitieron en todos los cruceros. Las estaciones seleccionadas presentaban más del 50 por ciento de las hembras con índices mayores de 7,0 cm. Esta área está localizada entre los 6° 10' a 6° 30' N y de 56° 50' a 57° 30 W.

En el resto de las estaciones realizadas se encontraron hembras maduras en porcentajes muy bajos y solamente en tallas superiores a 7,0 cm.

5. Conclusiones

(a) Se determinó que existía diferencia significativa en la proporción de sexos, siendo siempre las hembras más numerosas que los machos.

(b) Las hembras son siempre mayores que los machos.

(c) En el mes de agosto se presentan las mayores tallas promedio en ambos sexos.

(d) Se observó que no hay relación entre la talla y la profundidad.

(e) Las hembras presentan un factor de condición más elevado que los machos.

(f) Los valores más altos del factor de condición se registraron en el mes de agosto y siempre son mayores en las clases de largo menores.

(g) El largo de primera maduración coincide con la clase de 6,1-6,5 cm., aunque el 50 por ciento de las hembras maduras se observó en la clase 6,6 a 7,0 am.

(h) Se encontró en el mes de agosto el mayor porcentaje de hembras maduras.

(i) Se determinó que el área de desove de esta especie en la plataforma de Guyana está ubicada entre 6°10' y 6°30' N y los 56°50' y 57°30' W.

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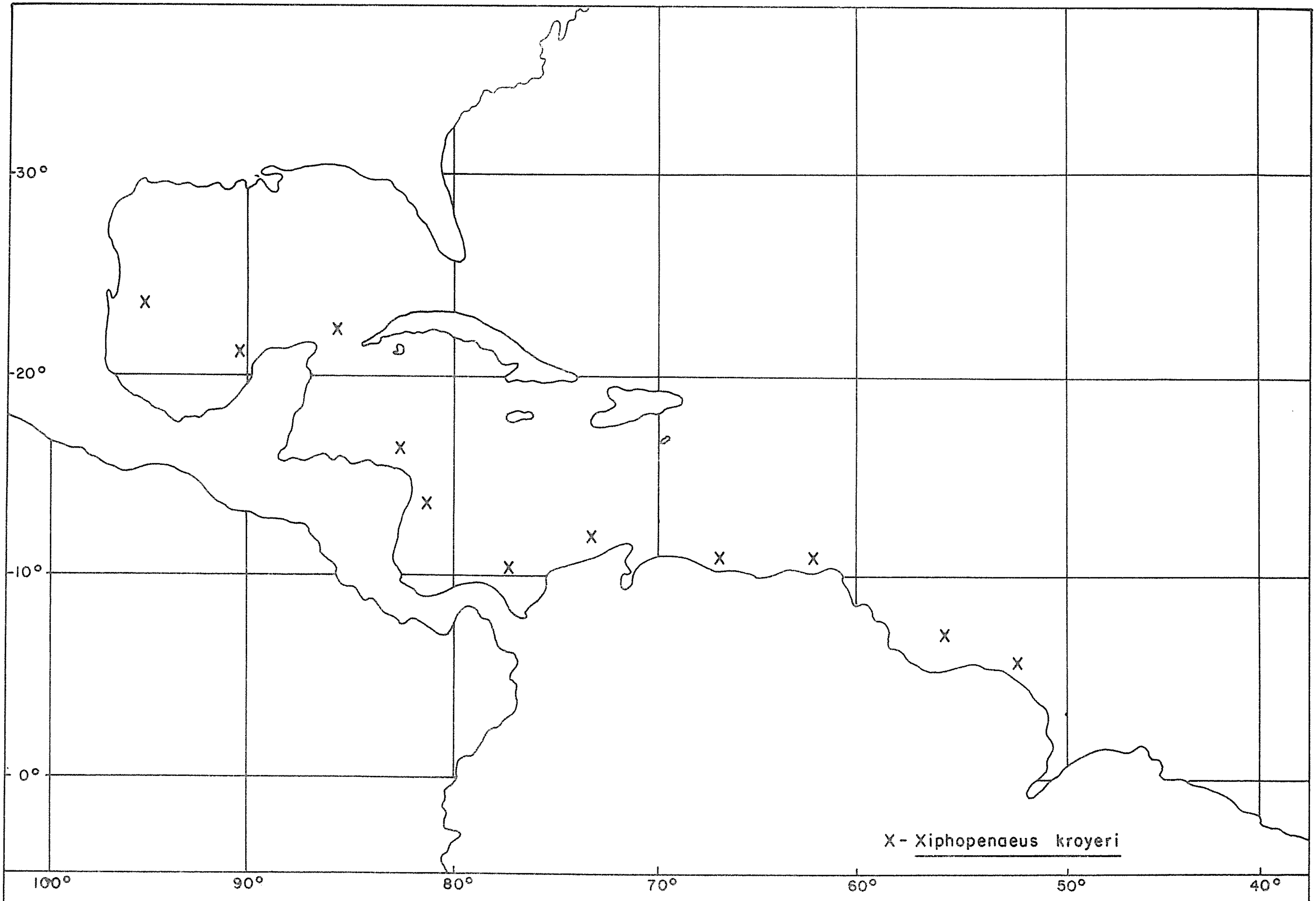

Fig. 4.14.1.- Distribución del Xiphopenaeus kroyeri en el área del Caribe.

X. kroyeri

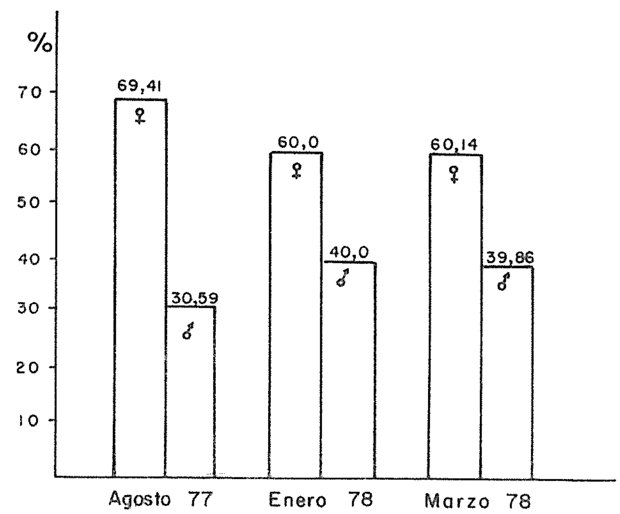

Figura 4.14.2 - Proporción de sexos en los distintos cruceros realizados.

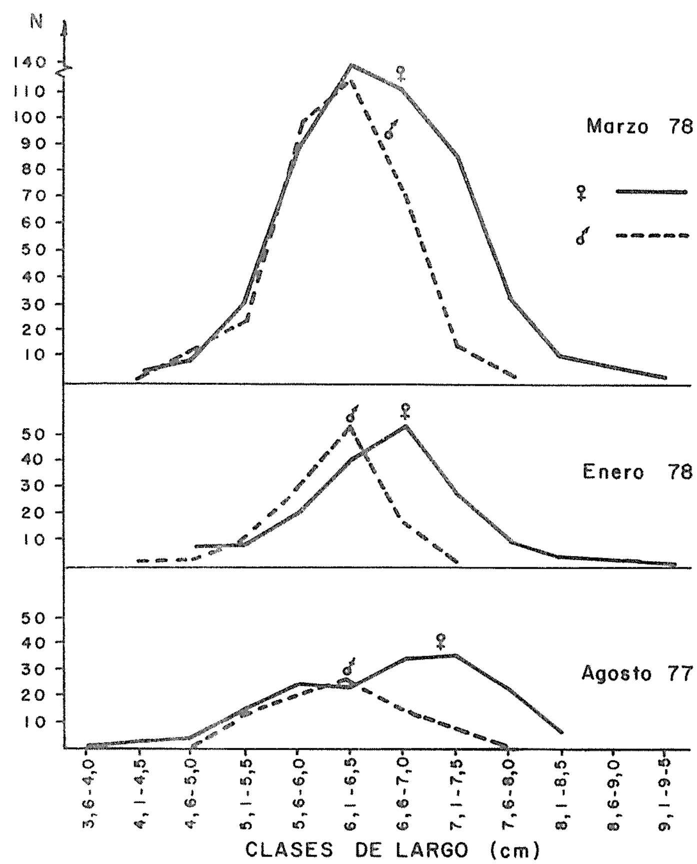

Figura 4.14.3 - Composición por tallas de hembras y machos en los distintos cruceros estudiados.

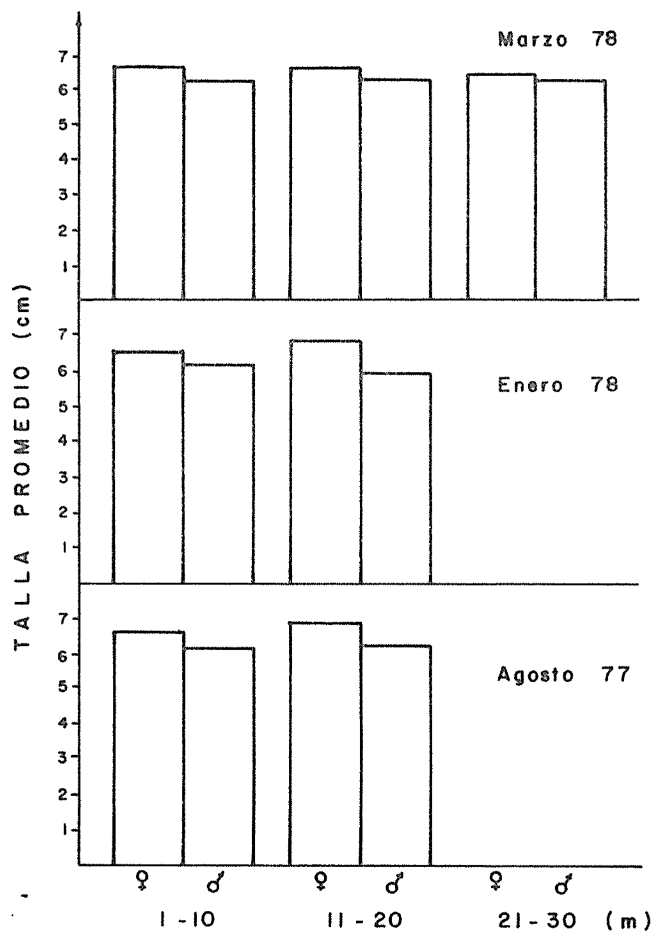

Figura 4.14.4 - Talla media por isóbatas de X. kroyeri en los tres viajes realizados a Guyana.

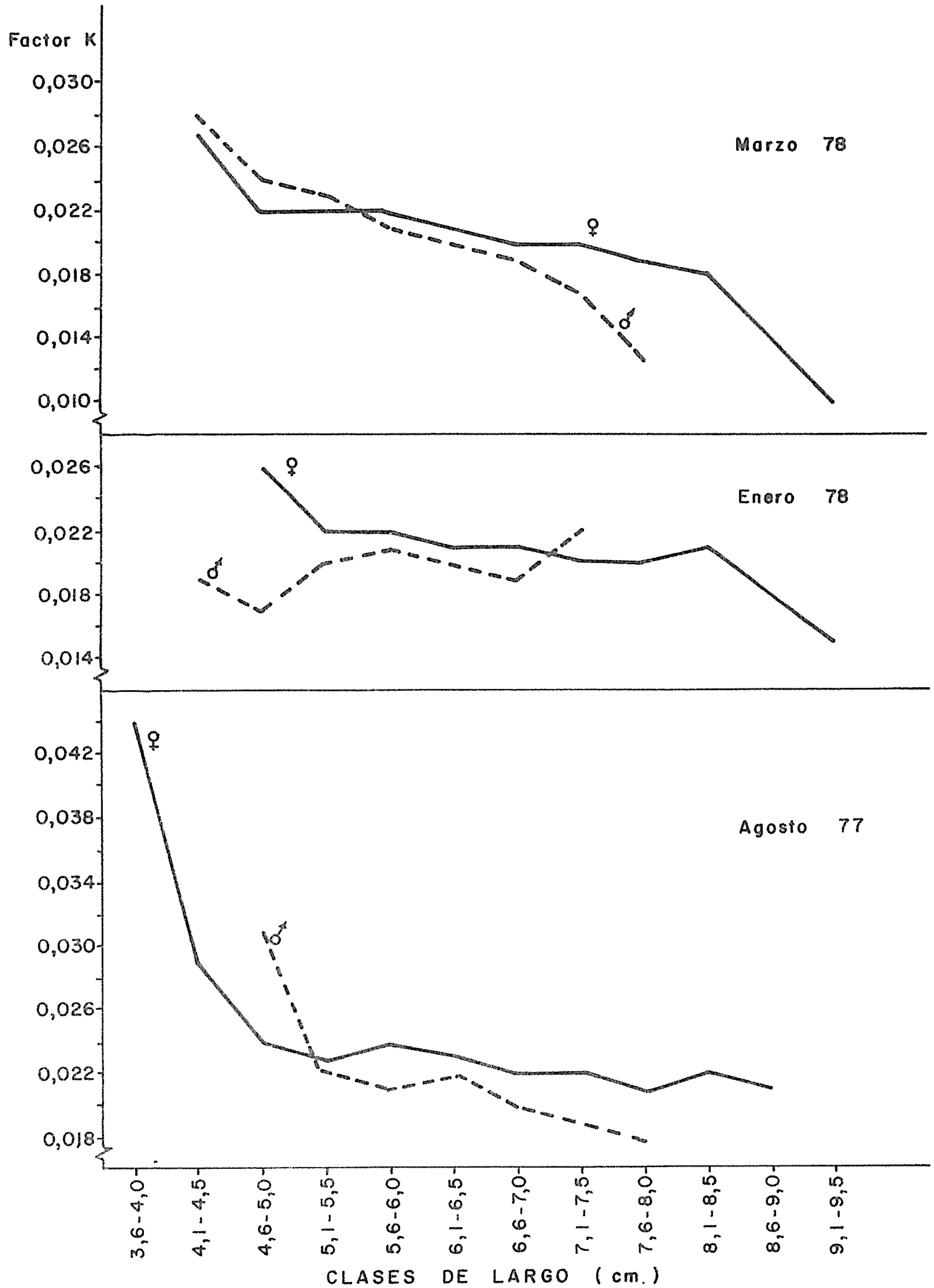

Figura 4.14.5.- Factor K por clases de largos de X. kroyeri. Guyana

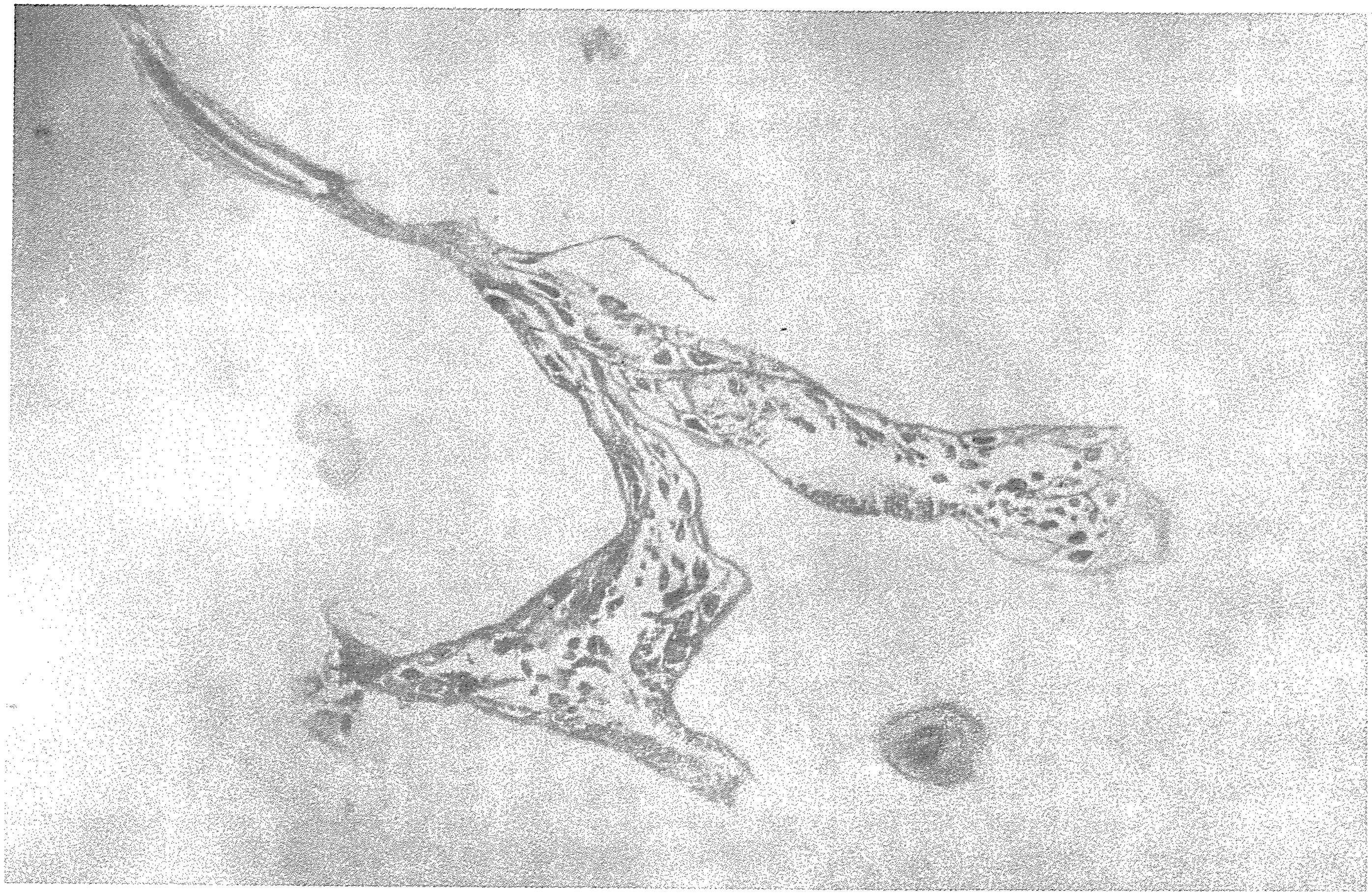

Figura 4.14.6 - Ovario en Estadio I de un ejemplar de X. kroyeri cuya talla fue de 5,5 cm y que pesó 4 g.

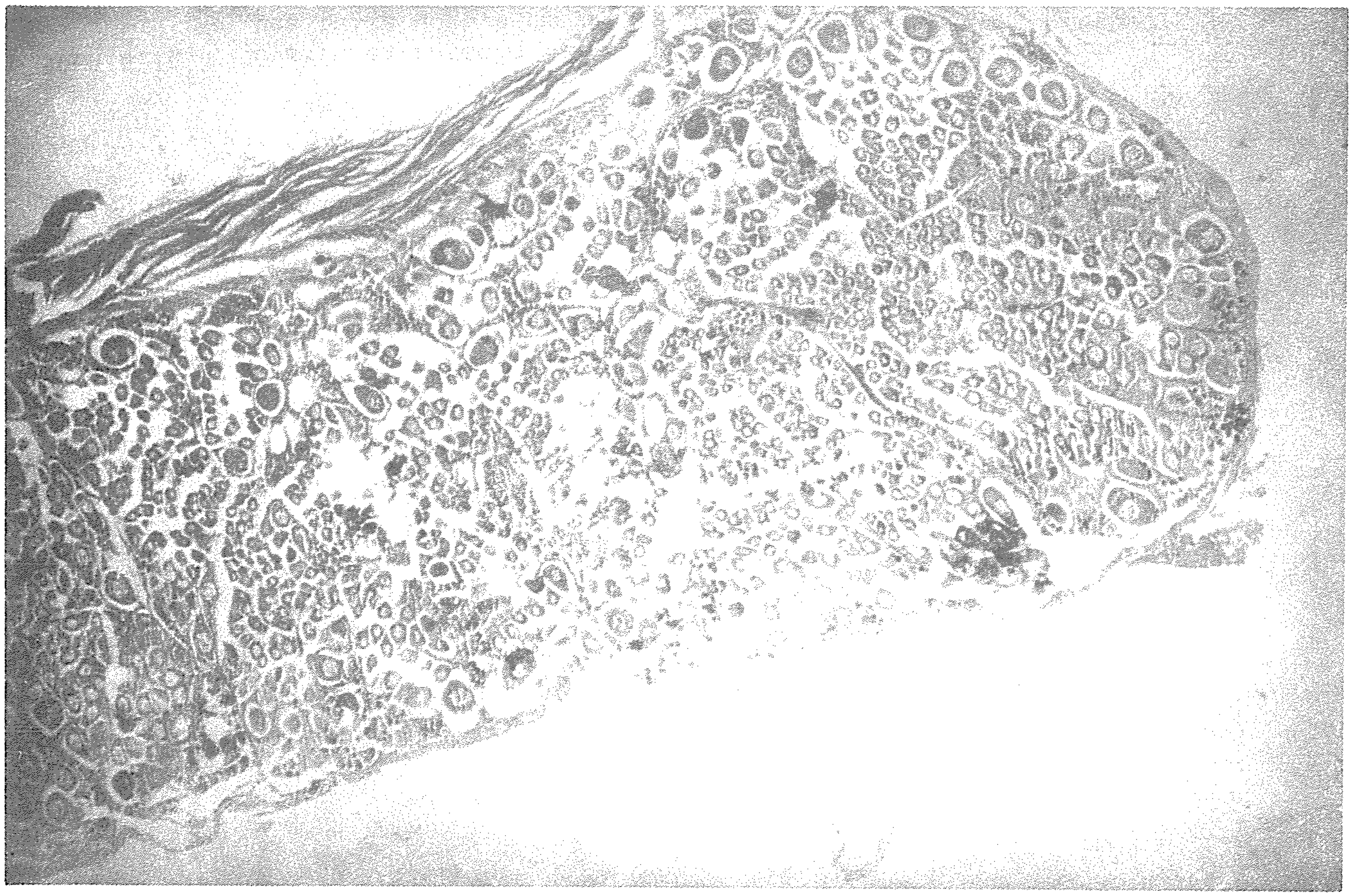

Figura 4.14.7 - Ovario en Estadio II de un ejemplar de X. kroyeri de 6 cm de largo y 4,5 g de peso.

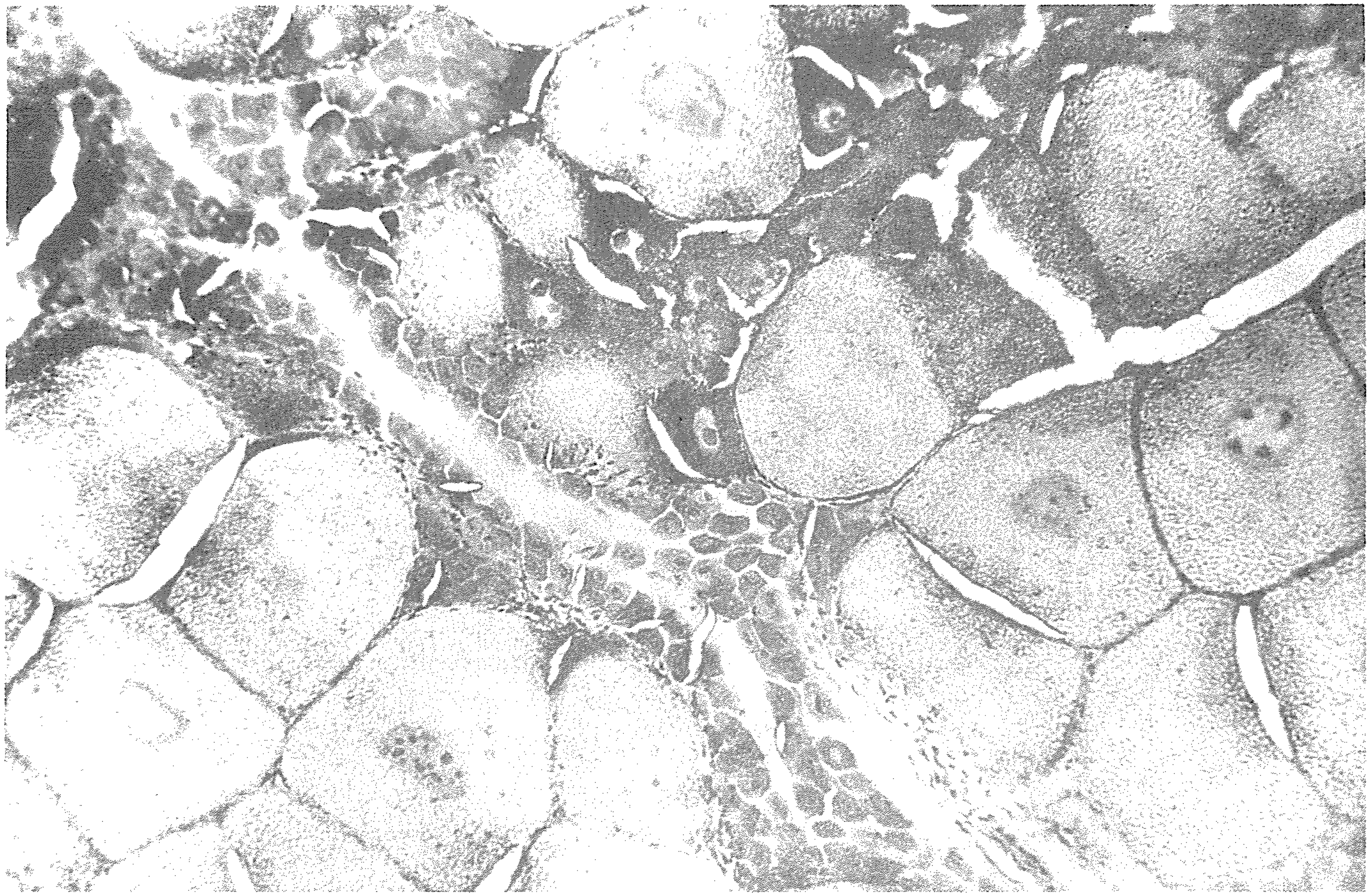

Figura 4.14.8 - Ovario en Estadio III de un ejemplar de X. kroyeri con una talla de 6,6 cm y un peso de 5,5 g.

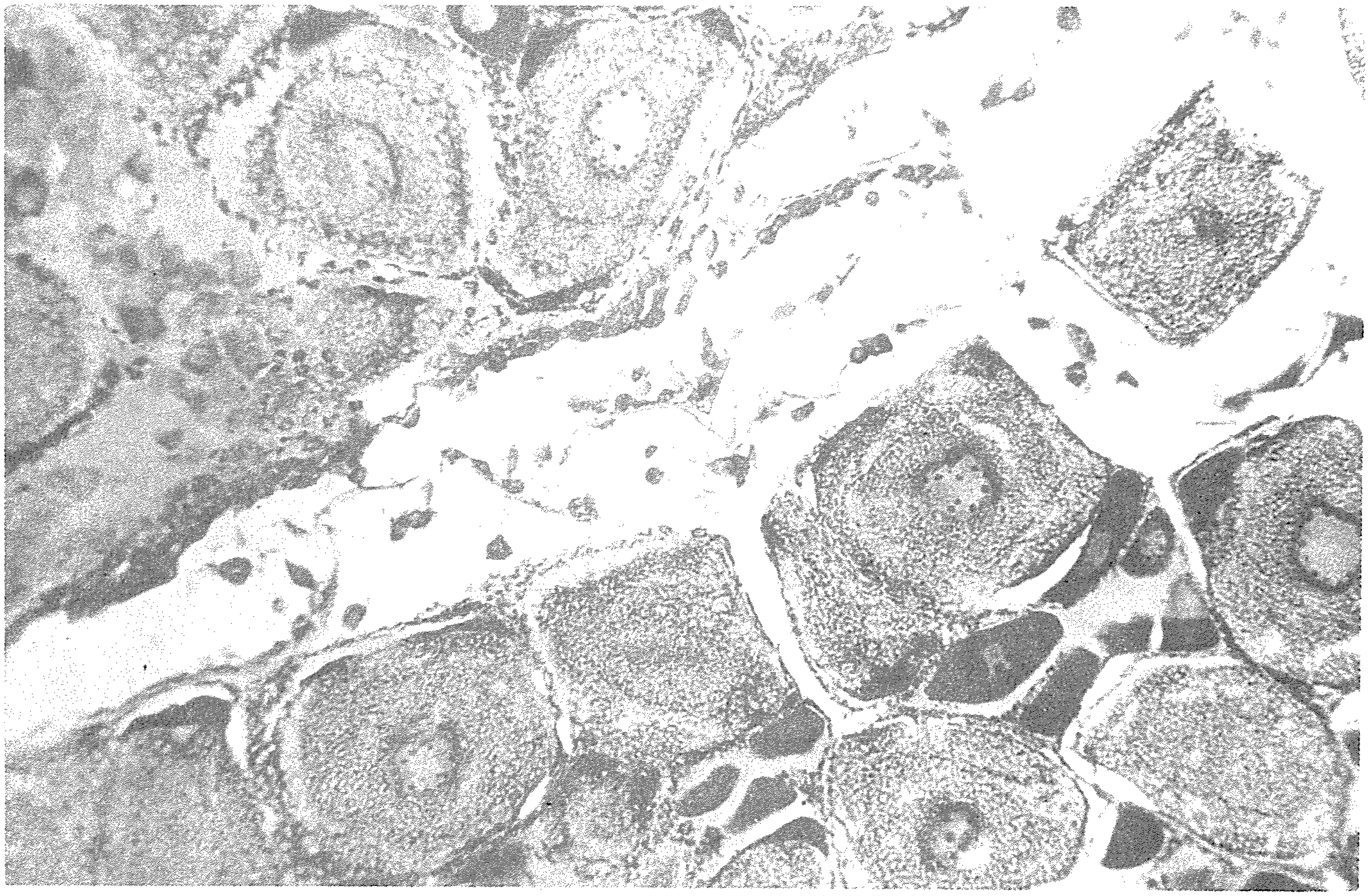

Figura 4.14.9 - Ovario en Estadio IV de un ejemplar de X. kroyeri que midió 7,5 cm y cuyo peso fue de 10,1 g.

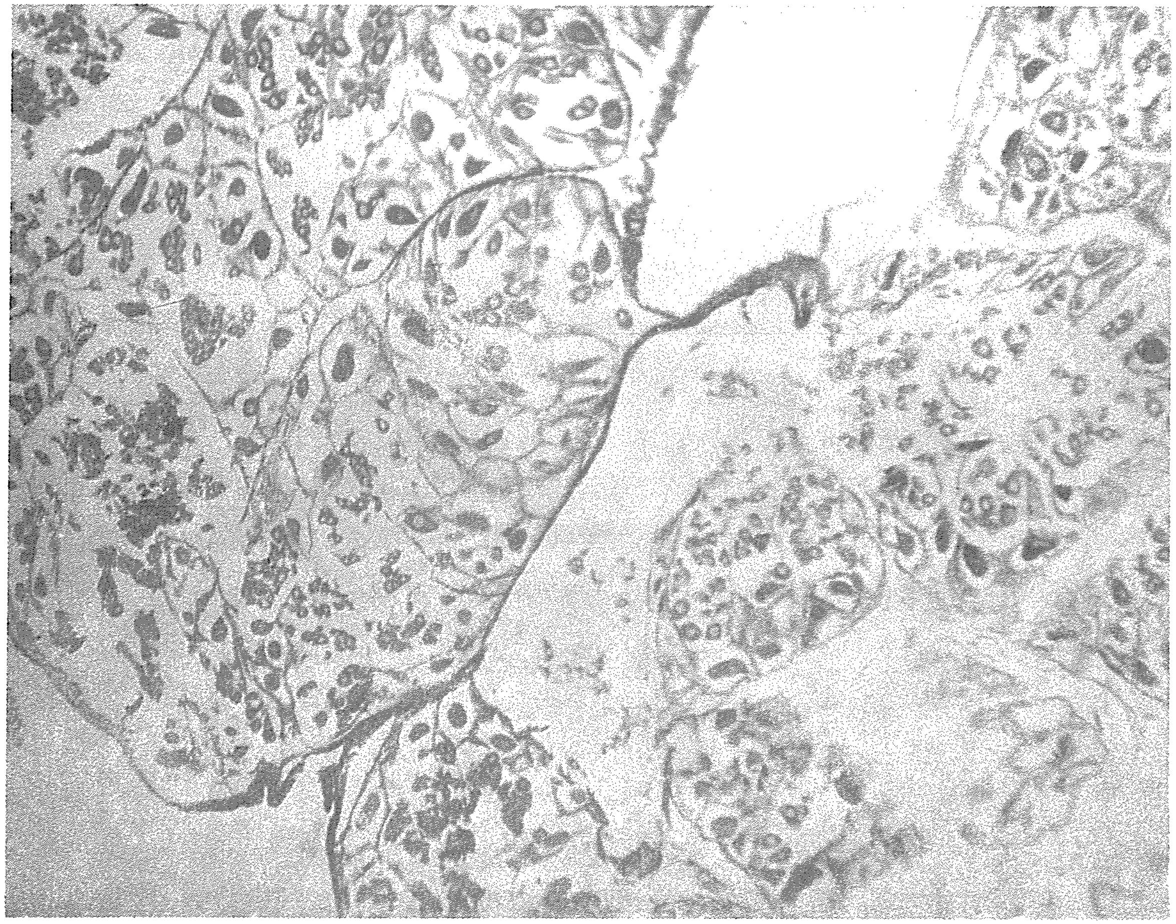

Figura 4.14.10 - Ovario en Estadio V de un ejemplar de X. kroyeri que midió 7,5 cm y cuyo peso fue de 8,3 g.

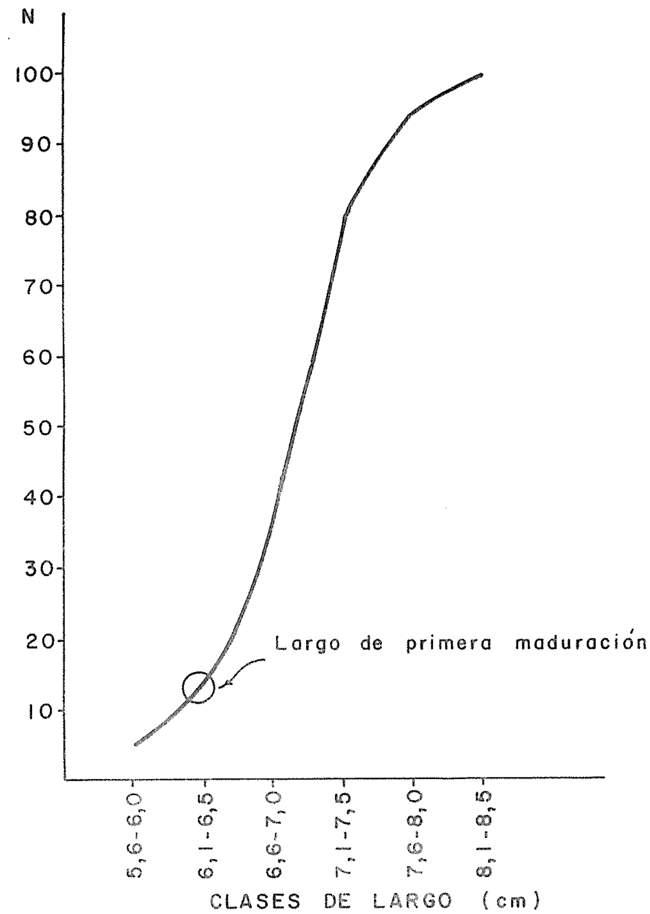

Figura 4.14.11 - Frecuencia acumulada de las hembras en las distintas clases de largo.

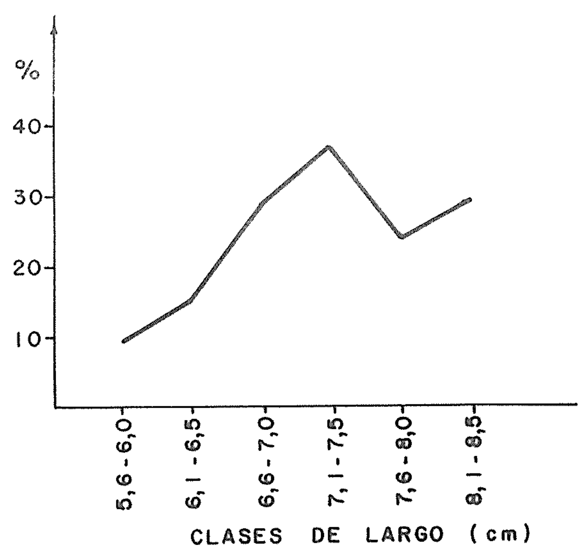

Figura 4.14.12 - Por ciento de hembras maduras por clases de largo.

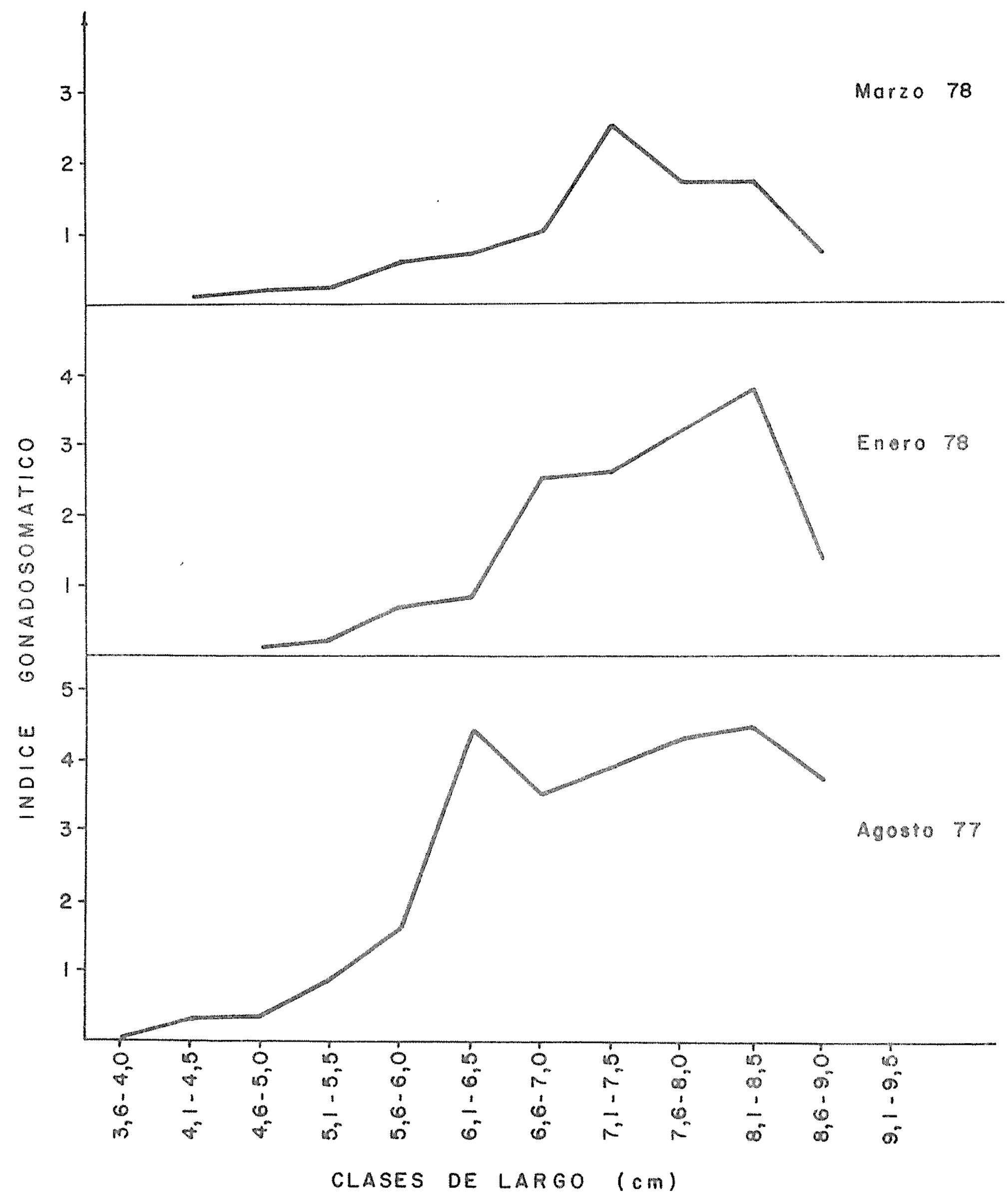

Figura 4.14.13 - Indice gonadosomático por clases de largo de X. kroyeri en los distintos viajes realizados.

Contribución 4.15

Relaciones Morfométricas de Algunos Peneidos de la Plataforma Guyanesa

(Morphometric Relationships for Some Penaeid Shrimps from the Guyanese Shelf)

por

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Indice

1. Introducción

El presente trabajo tiene como objetivo brindar algunas relaciones morfométricas de Penaeus schmitti, Penaeus subtilis y Xiphopenaeus kroyeri, que habitan en la plataforma de Guyana, con el fin de hacer posible la comparación de datos biológicos brindados por diferentes autores tales como Kunju (1956), Kubo (1951), Muhlia, et al. (1975) y Boschi (1970), aunque sus trabajos tratan de otras especies y zonas.

El recurso camarón es uno de los renglones más importantes de la industria pesquera cubana. Parte de las capturas son obtenidas en la plataforma Guyanesa, donde las principales especies son las pertenecientes al género Penaeus (Coyula y Carrillo 1976) y el X. kroyeri que por su abundancia constituye un recurso potencial (Jones y Dragovich, 1977), por lo que hemos hecho mayor énfasis en esta última especie.

2. Materiales y Métodos

Los datos fueron obtenidos de ejemplares capturados en agosto 1977, enero, marzo y diciembre 1978 por barcos camaroneros de la flota camaronera de Cuba.

El arte de pesca utilizado en todos los arrastres es el empleado por los barcos comerciales. Se trabajó con puertas de madera de 7 pies (2,13 m) de largo y cadena en la relinga inferior.

La velocidad de arrastre fue de 3-3,5 nudos y cada operación de pesca tuvo una hora de duración.

Las mediciones se realizaron a partir de muestras frescas, congeladas o preservadas en formol al 10 por ciento neutralizado con tetraborato de sodio para después ser procesados en tierra. El estado de preservación de las muestras se señala en los Cuadros 4.15.1 a 4.15.4.

Para la realización del trabajo se seleccionaron los ejemplares de cada clase de largo que presentaban las mejores condiciones, ya que, en el proceso de descongelación sufren con facilidad la separación del cefalotórax del abdomen.

Las mediciones de largo se realizaron con caricómetros especialmente diseñados al efecto con acproximación al milímetro y los pesos fueron determinados con aproximación a la décima de gramo.

Los datos fueron agrupados para la variable dependiente como la medida de todos los valores que correspondían a un valor fijo de la variable independiente en cada milímetro excepto en la relaciones obtenidas para hembras y machos de X. kroyeri.

Los resultados se expresan en gramos y centímetros.

Se tomaron las siguientes medidas:

Largo total (Lt) -Distancia desde el extremo distal del rostro hasta el extremo distal del telson.

Largo cubano (Lcub)-Distancia desde la base de la escotadura postorbital hasta el extremo distal superior del último segmento abdominal.

Largo cola (Lc) -Medido desde el extremo anterior y superior del primer segmento abdominal hasta la punta del telson.

Largo abdomen (La) -Se determinó por la diferencia entre el largo cubano y el largo del cefalotórax.

Se hicieron análisis de covarianza para determinar si existían diferencias significativas entre las ecuaciones de cada sexo calculadas para X. kroyeri.

La significación de los coeficientes de correlación se calculó por el método de los porcentiles de la distribución de r (Dixon y Massey, 1965).

3. Resultados y Discusión

Se utilizaron animales frescos en las relaciones morfométricas del género Penaeus donde se consideró el largo total y el largo cubano.

El coeficiente de correlación fue altamente significativo para todas las ecuaciones al nivel de 99 por ciento.

(a) Penaeus subtilis (Camarón café o "brown shrimp")

El Cuadro 4.15.1 muestra las ecuaciones obtenidas y las Figuras 4.15.1 a 4.15.4 las relaciones correspondientes.

(b) Penaeus schmitti (camarón blanco o "white shrimp")

Las ecuaciones obtenidas se muestran en el Cuadro 4.15.2 y las relaciones en las Figuras 4.15.5 a 4.15.8.
Se realizó un análisis de covarianza entre las relaciones largo cola - peso cola para hembras y machos combinados obtenidos a partir de muestreos en fresco y ejemplares conservados en formol durante 20 días, no observándose diferencia significativa entre ellos. Esto puede deberse a la poca deshidratación que provoca el formol al 10 por ciento en tejidos de la cola.

(c) Xiphophenaeus kroyeri (Camarón tití o "sea bob")

En el Cuadro 4.15.3 y Figuras 4.15.9 a 4.15.11 se expresan las ecuaciones y relaciones respectivamente, obtenidas para hembras y machos combinados. Los coeficientes de correlaciones fueron en todos los casos altamente significativos para el 99 por ciento.

En el Cuadro 4.15.4 se observan las relaciones obtenidas para hembras y machos en X. kroyeri con los resultados de los análisis de covarianza, los cuales fueron altamente significativos para un 99 por ciento del nivel de confiabilidad.

Las Figuras 4.15.15 a 4.15.20 muestran las relaciones morfométricas obtenidas.

Los datos analizados en este trabajo correspondedn a un período corto de tiempo, por lo que deben considerarse preliminares, ya que pueden existir algunas variaciones dependientes de la época del año. Además, por ser capturados los individuos con artes de pesca comerciales, no están representados los ejemplares de talla pequeña.

Por otra parte, en el proceso de congelación se produce la formación de cristales de hielo en los tejidos y su posterior fusión puede introducir algunas direfencias en las mediciones con respecto al animal fresco. Esta circunstancia junto con los errores de medición provocan la existencia de una traza en las ecuaciones donde se relacionan largos, ya que las rectas obtenidas deben pasar por el origen.

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Cuadro 4.15.1 Relaciones de P. subtilis para machos y hembras combinados [1]

Relación	Ecuación	Coeficiente correlación	No. ejemplares	Preservación
Largo cola-peso cola	$W_c = 0.00515\ L_c^{3.63}$	.9908	214	Congelados
Largo total-largo cola	$L_t = 0.0102 + 1.59\ L_c$	.9913	106	Fresco
Largo cubano-largo cola	$L_{cub} = 0.1363 + 1.131\ L_c$	.9919	106	Fresco
Largo cubano-largo total	$L_t = -(0.0807 - 1.403\ L_{cub})$	.996	106	Fresco

1/ Datos tomados en Diciembre 1978

Cuadro 4.15.2 Relaciones de P. schmitti para machos y hembras combinados[1/]

Relación	Ecuación	Coeficiente correlación	No. ejemplares	Preservación
Largo cola-peso cola	$W_c = 0.018\ L_c^{3.06}$	.9468	204	Congelados
Largo total-largo cola	$L_t = -(1.624 - 1.726\ L_c)$	.9856	80	Fresco
Largo cubano-largo cola	$L_{cub} = -(1.4452 - 1.28\ L_c)$	.9874	77	Fresco
Largo total-largo cubano	$L_t = -(0.751 - 1.359\ L_{cub})$	.985	50	Fresco

1/ Datos tomados Diciembre 1978

Cuadro 4.15.3 Relación de X. kroyeri para hembras y machos combinados 1/

Relación	Ecuación	Coeficiente correlación	No. ejemplares	Preservación
Largo cola-peso total	$W_t = .0319\ L_c^{3.075}$	0.9942	110	Congelación
Largo cola-largo total	$L_c = .4642 + 5071\ L_t$	.9873	110	Congelación
Largo total-peso total	$W_t = .00628\ L_t^{2.936}$	.9906	110	Congelación
Largo cubano-peso total	$W_t = .0310\ L_{cub}^{2.810}$	.9852	110	Congelación
Largo cola-largo cubano	$L_c = .350 + .788\ Lcub$	.9906	110	Congelación
Largo cubano-largo total	$L_t = .222 + 1.4837\ L_{cub}$	.9846	110	Congelación

1/ Datos tomados Diciembre 1978.

Cuadro 4.15.4 Relaciones de *X. kroyeri* para Hembras y Machos

Relación	Sexo	Ecuación	Coeficiente correlación	No. ejemp.	Análisis covarianza	Preservación
Largo cubano-largo total 1/	Hembras	$L_t = 1.1665 + 1.3615\ L_{cub}$	.9174	522	+	Formol
	Machos	$L_t = 1.2906 + 1.3151\ L_{cub}$	.8847	295		Formol
Largo cubano-largo abdomen 1/	Hembras	$L_a = .3988 + 0.5945\ L_{cub}$	.8728	396	+	Formol
	Machos	$L_a = -.1807 + .6976\ L_{cub}$	.8613	396		Formol
Peso total-peso cola 1/	Hembras	$W_c = .460 + 0.5649\ W_t$	.9637	375	+	Formol
	Machos	$W_c = .064 + 0.6512\ W_t$	.9542	396		Formol
Largo cubano-peso total 1/	Hembras	$W_t = 0.1109\ L_{cub}^{2.116364}$	.7749	871	+	Formol
	Machos	$W_t = .0782\ L_{cub}^{2.260712}$	.7845	528		Formol
Largo cola-peso cola 2/	Hembras	$W_c = .102272\ L_c^{2.164825}$	.9035	102	+	Congelado
	Machos	$W_c = .842094\ L_c^{2.250824}$	.8208	97		Congelado
Largo cola-peso total 2/	Hembras	$W_t = .133991\ L_c^{2.239166}$	.8723	182	+	Congelado
	Machos	$W_t = .10047\ L_c^{2.322113}$	.8330	97		Congelado

1/ Datos tomados agosto 1977, enero y marzo 1978

2/ Datos tomados diciembre 1978

W_c Peso cola

W_t Peso total

\+ Análisis de covarianza altamente significativo para un nivel de significancia de 1 por ciento

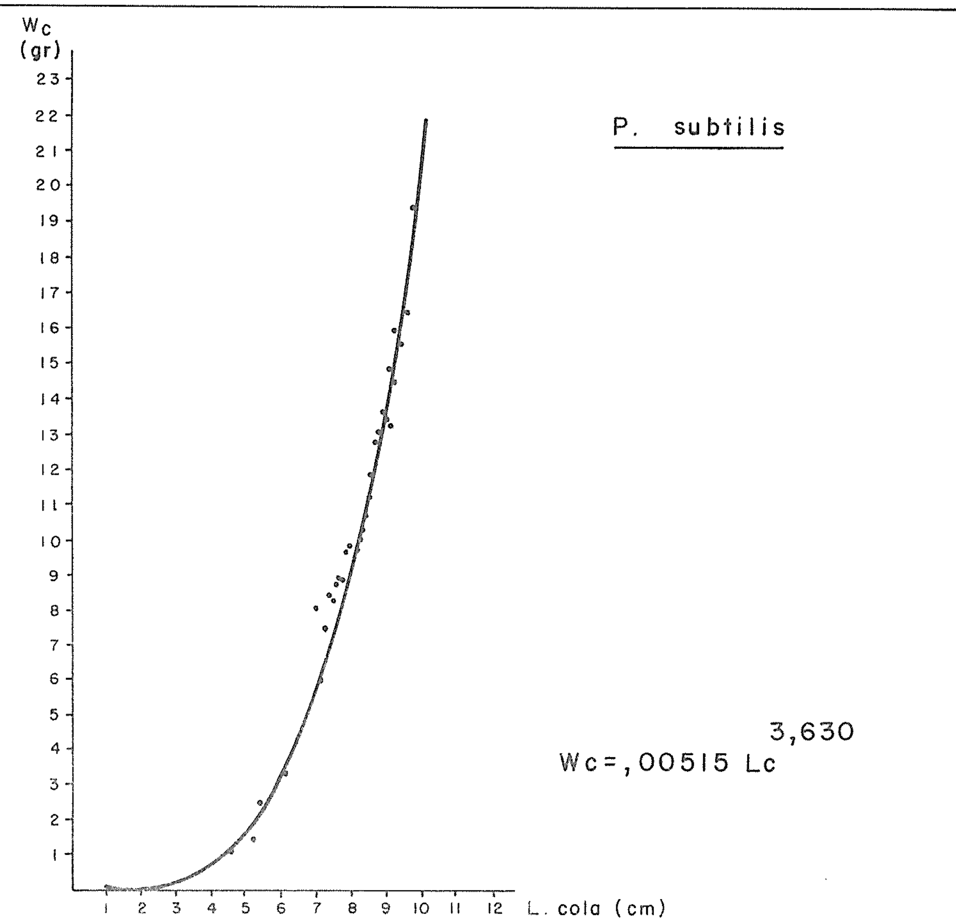

Figura 4.15.1 - Relación Largo cola - Peso cola

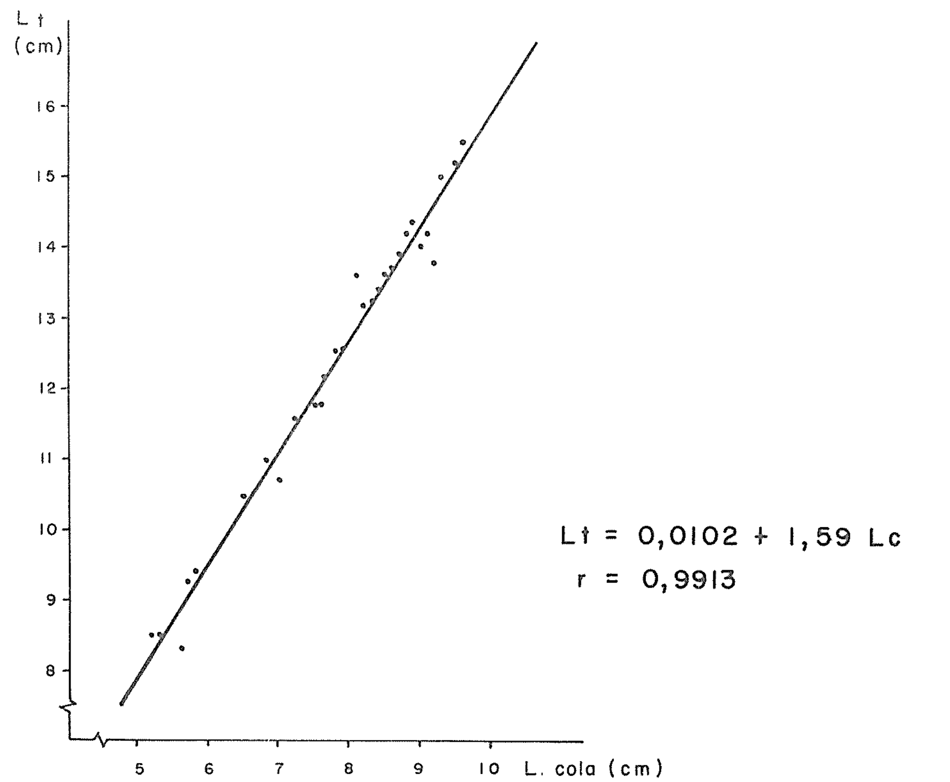

Figura 4.15.2.- Relación Largo total - Largo cola

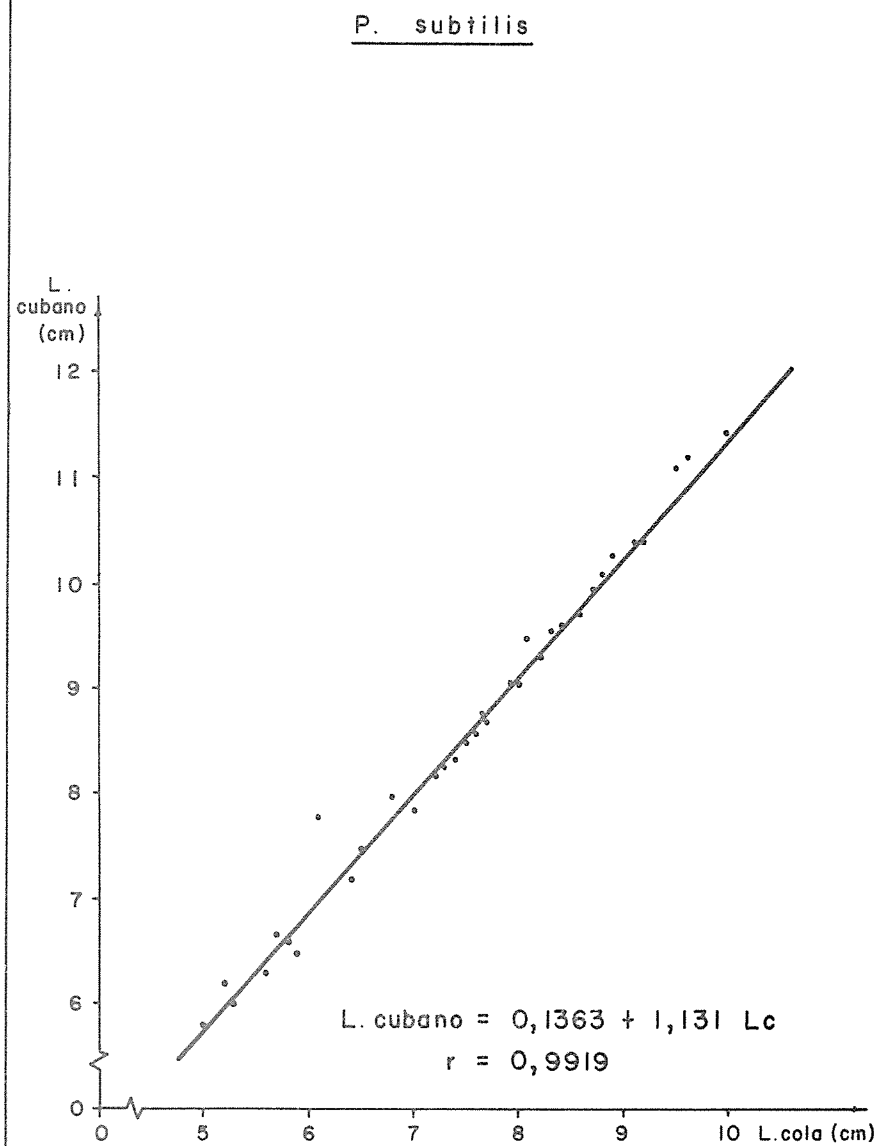

Fig. 4.15.3- Relación Largo cubano - Largo cola.

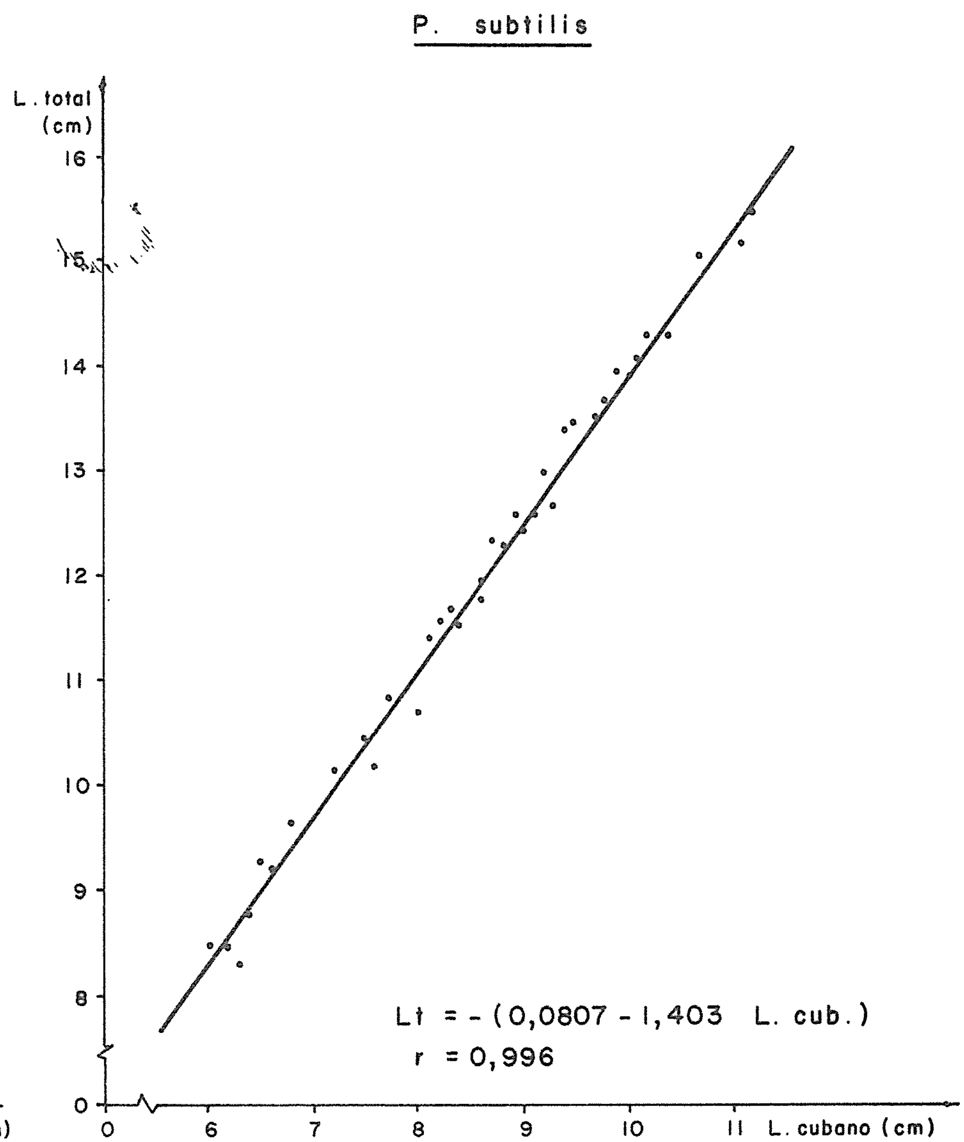

Fig. 4.15.4 – Relación Largo total - Largo cubano.

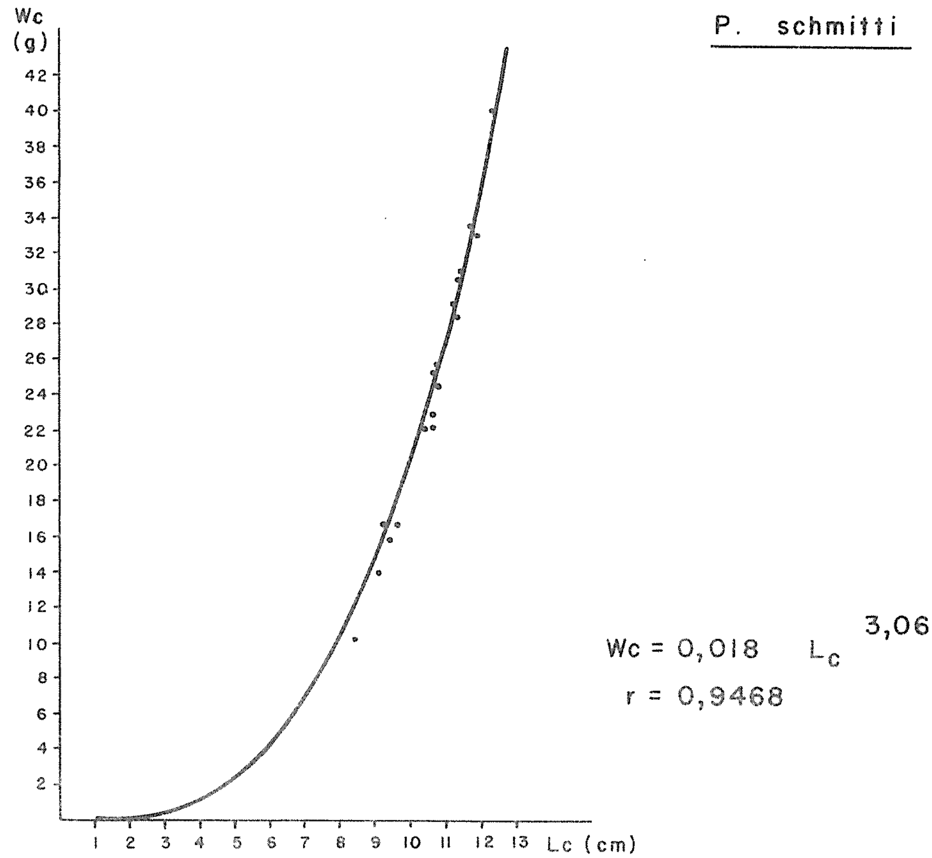

Figura 4.15.5.– Relación Largo cola - Peso cola.

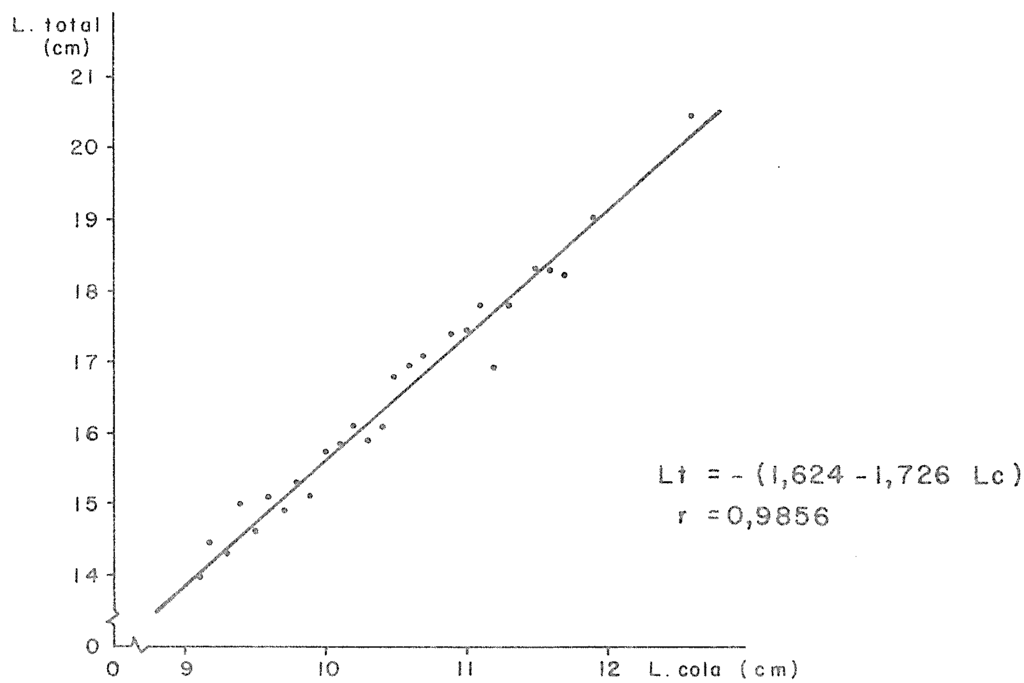

Figura 4.15.6.– Relación Largo total - Largo cola.

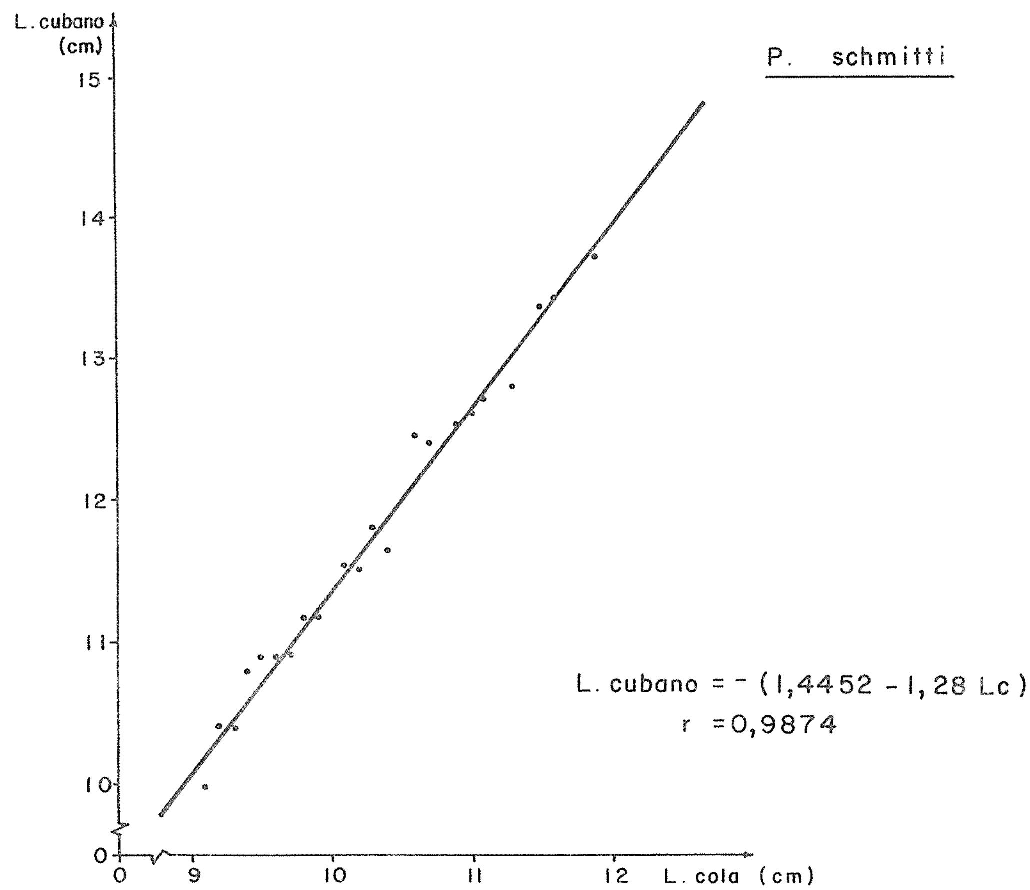

Figura 4.15.7.- Relación Largo cubano - Largo cola.

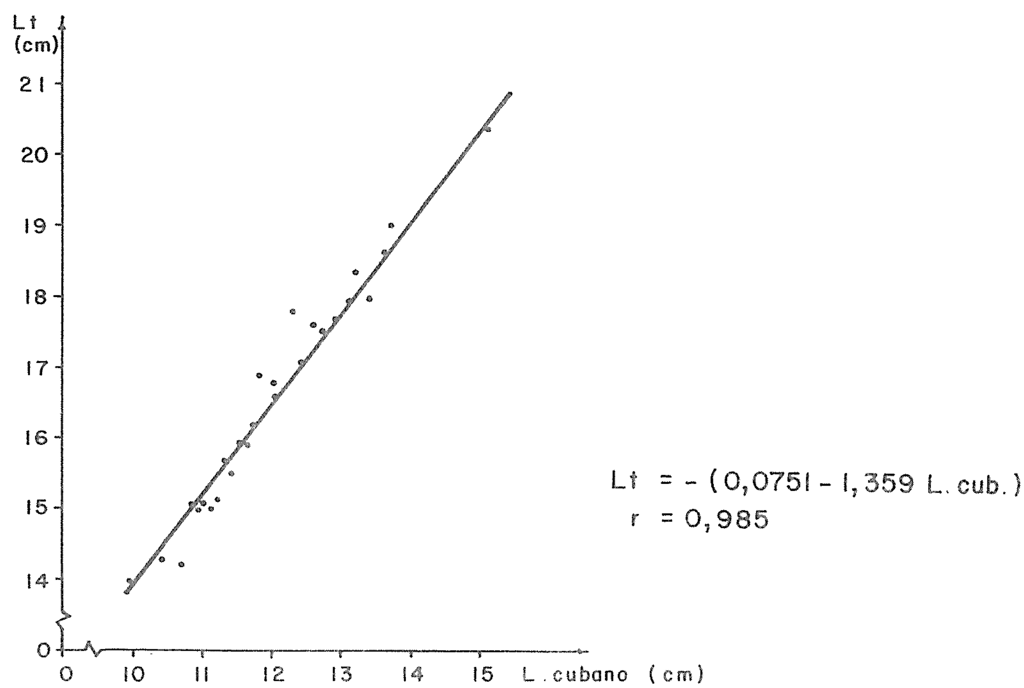

Figura 4.15.8 - Relación Largo total - Largo cubano.

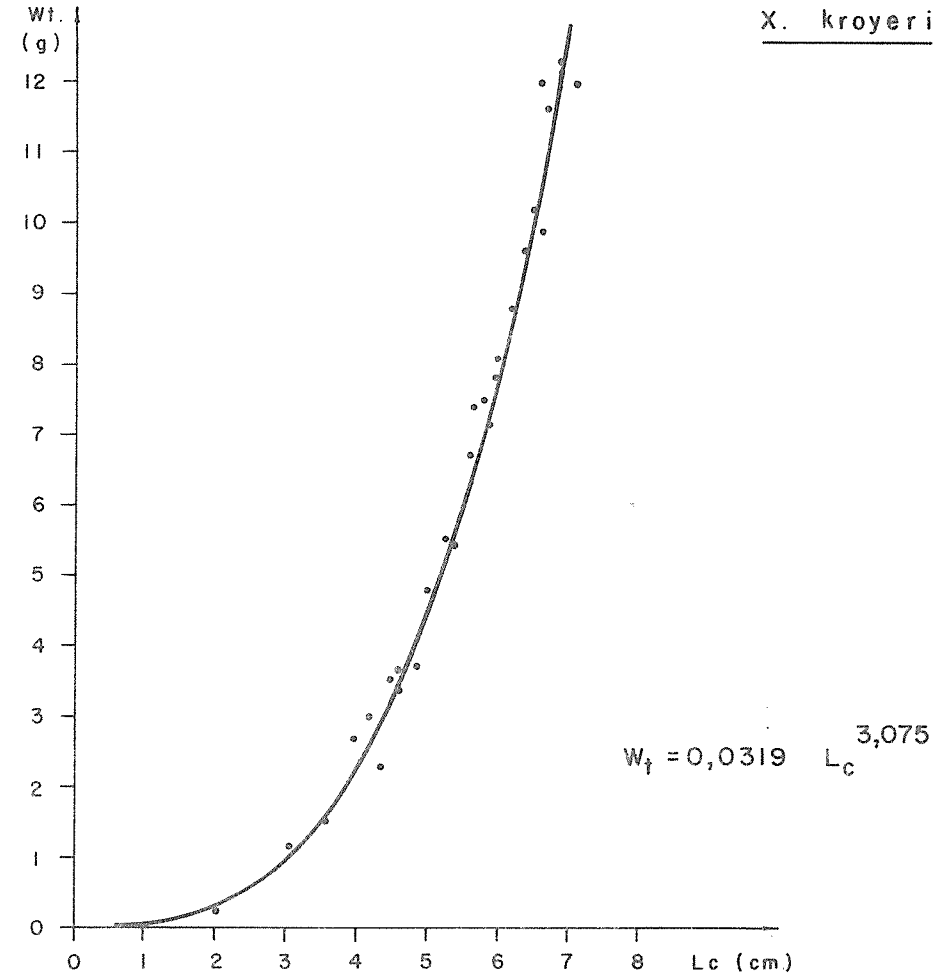

Fig. 4.15.9.- Relación Largo cola - Peso total.

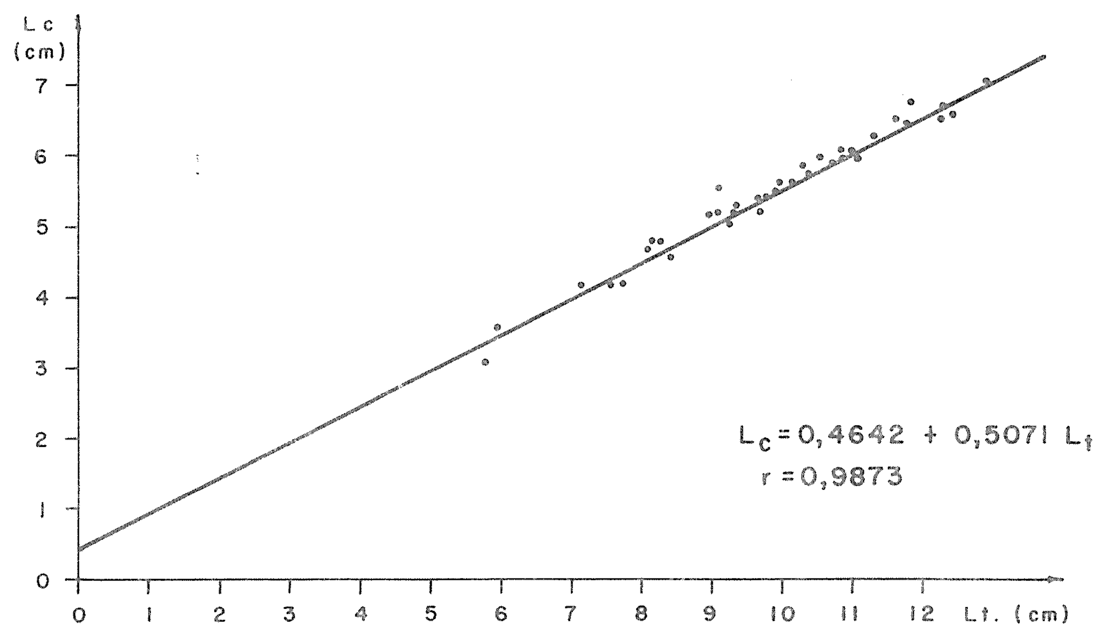

Fig. 4.15.10.- Relación Largo cola - Largo total.

X. kroyeri

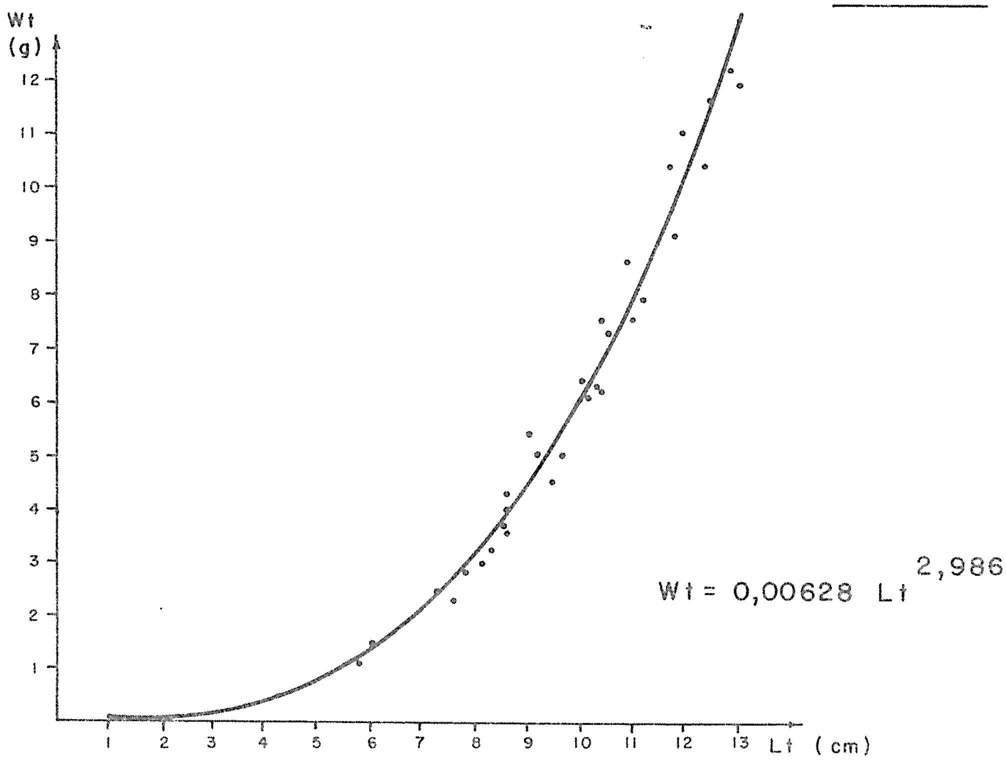

Figura 4.15.11 .- Relación Largo total - Peso total.

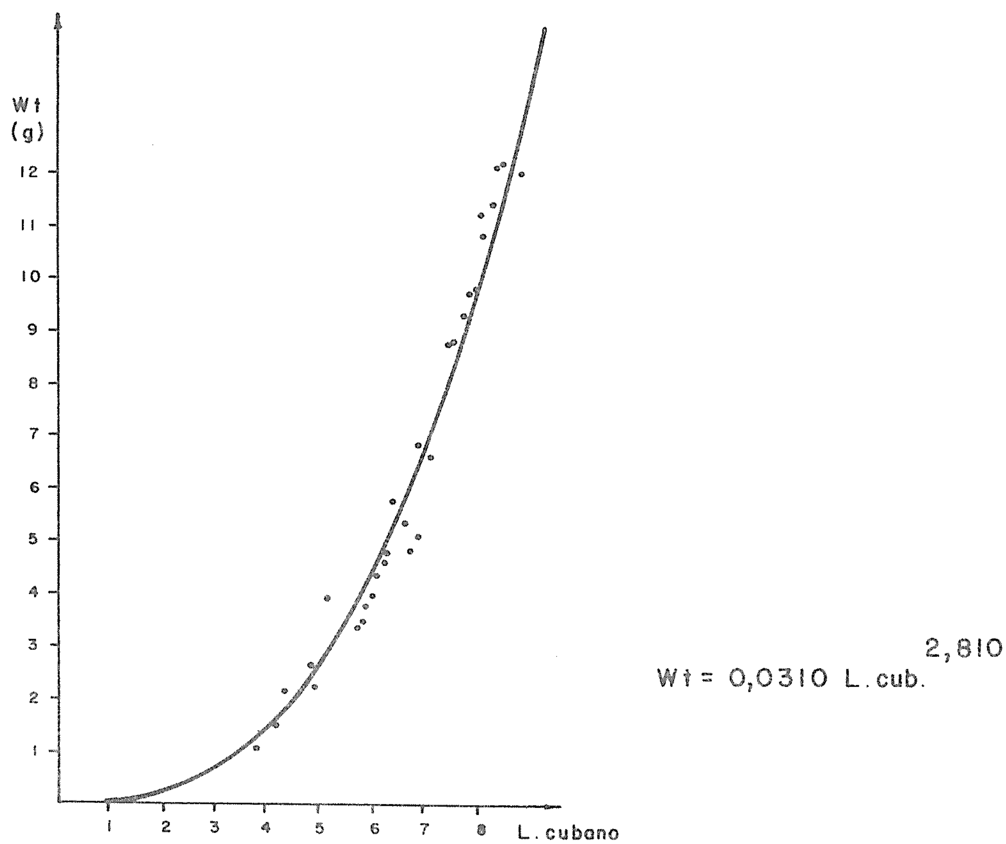

Figura 4.15.12 - Relación Largo cubano - Peso total.

X. kroyeri

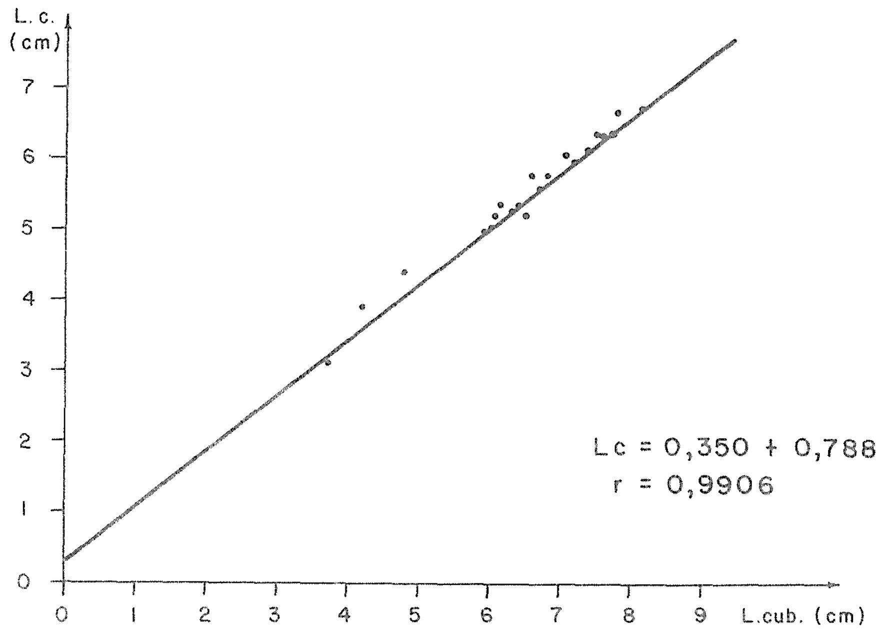

Fig. 4.15.13 - Relación Largo cola - Largo cubano.

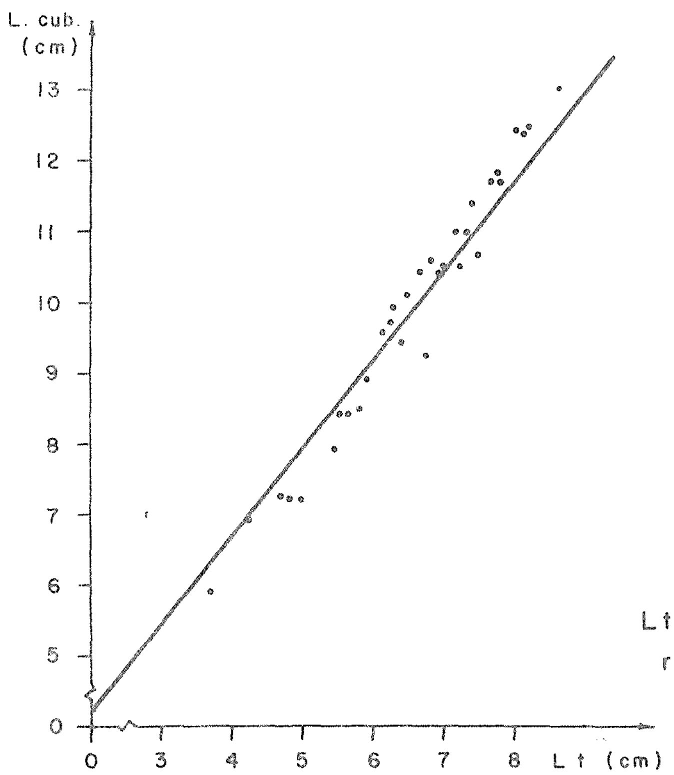

Fig. 4.15.14.- Relación Largo cubano - Largo total.

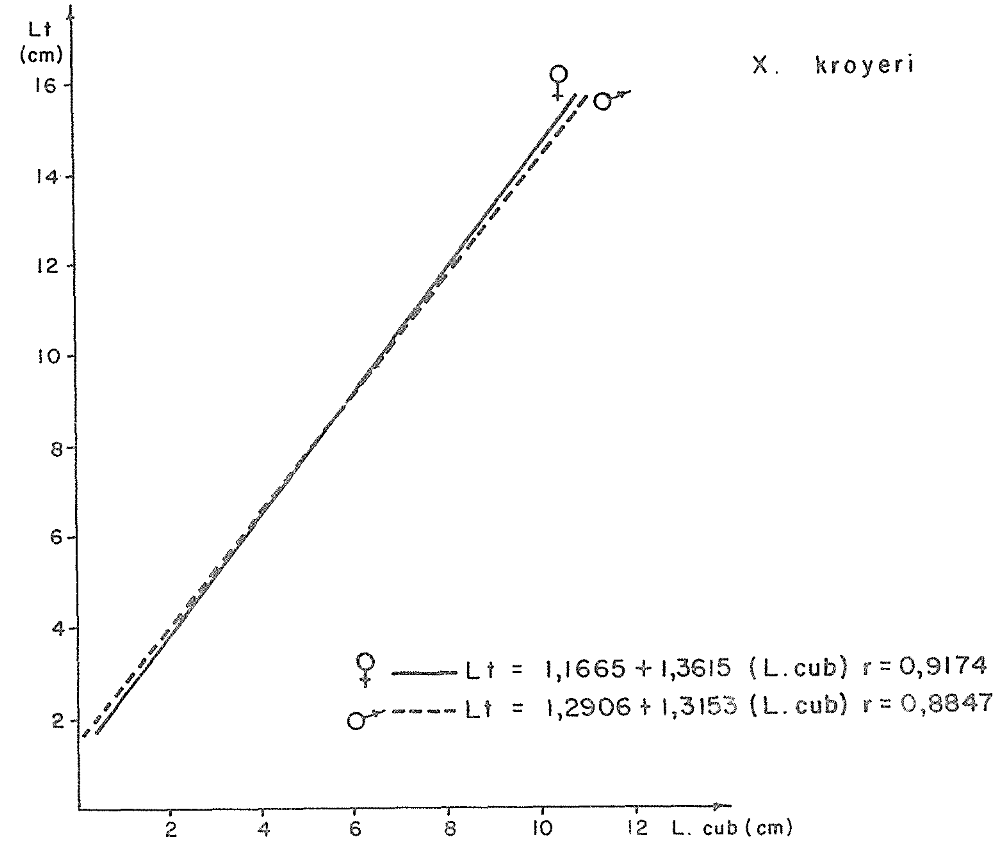

Figura 4.15.15 – Relación Largo cubano - Largo total.

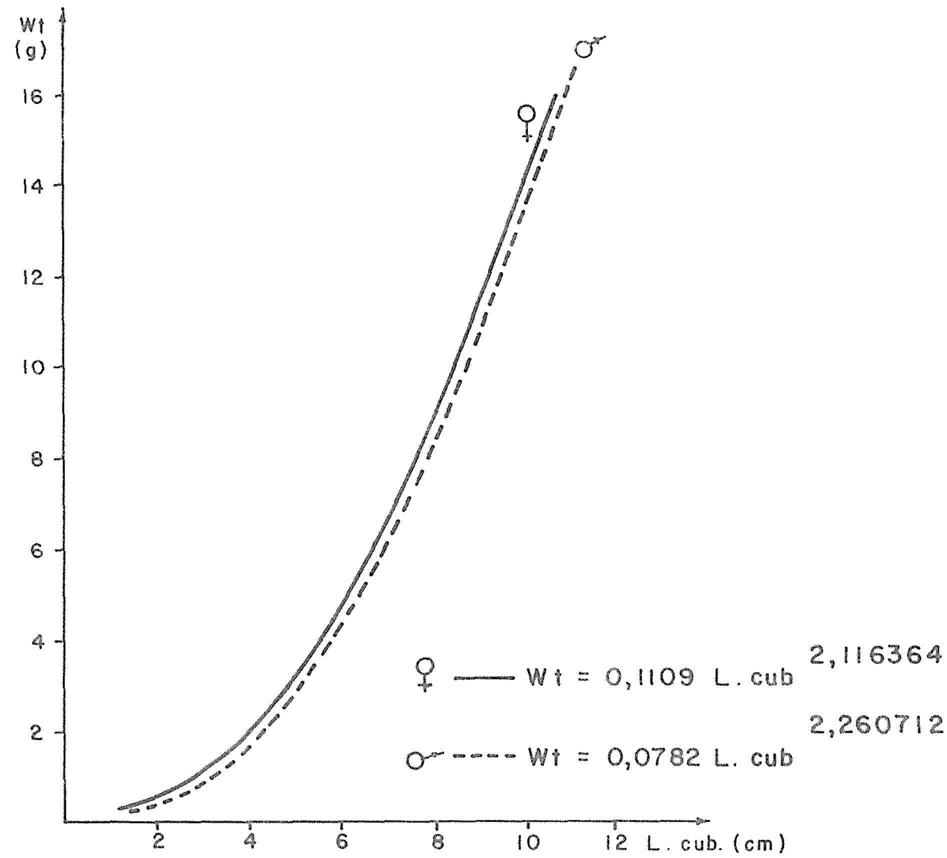

Figura 4.15.16 – Relación Largo cubano - Peso total

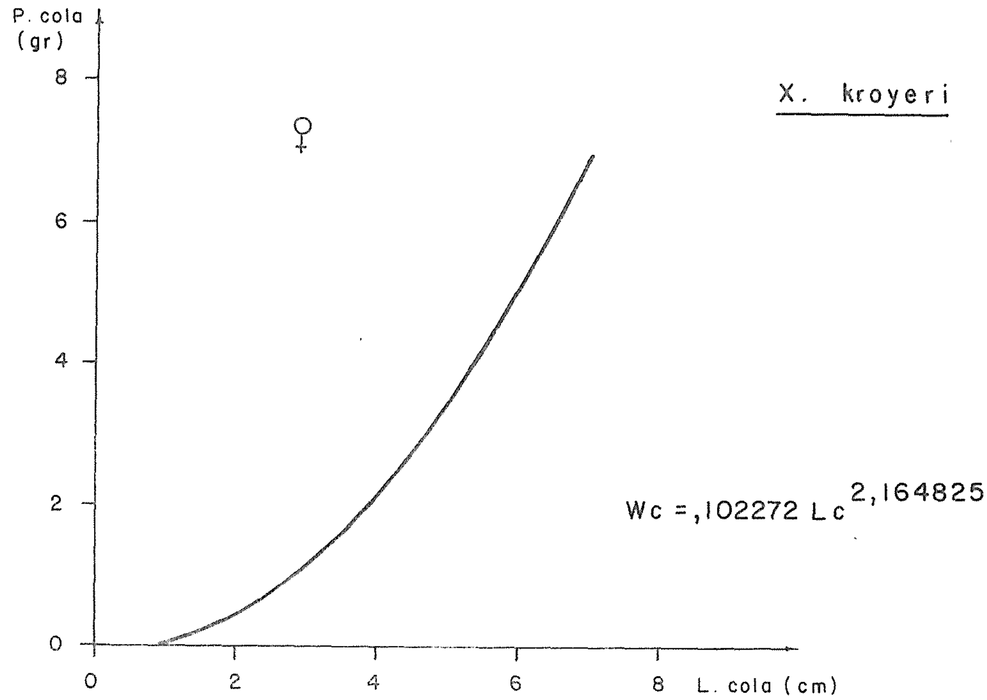

Fig. 4.15.17 – Relación Largo cola - Peso cola.

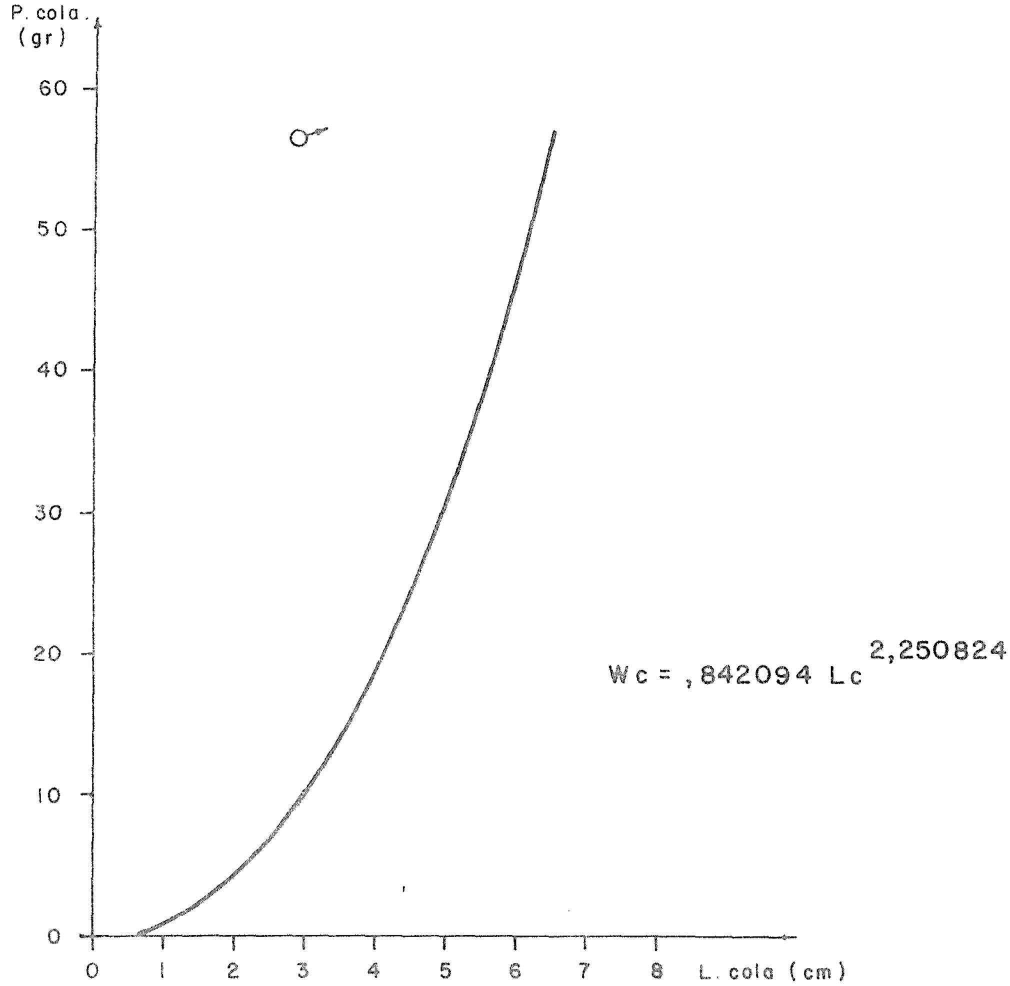

Fig. 4.15.18 – Relación Largo cola - Peso cola

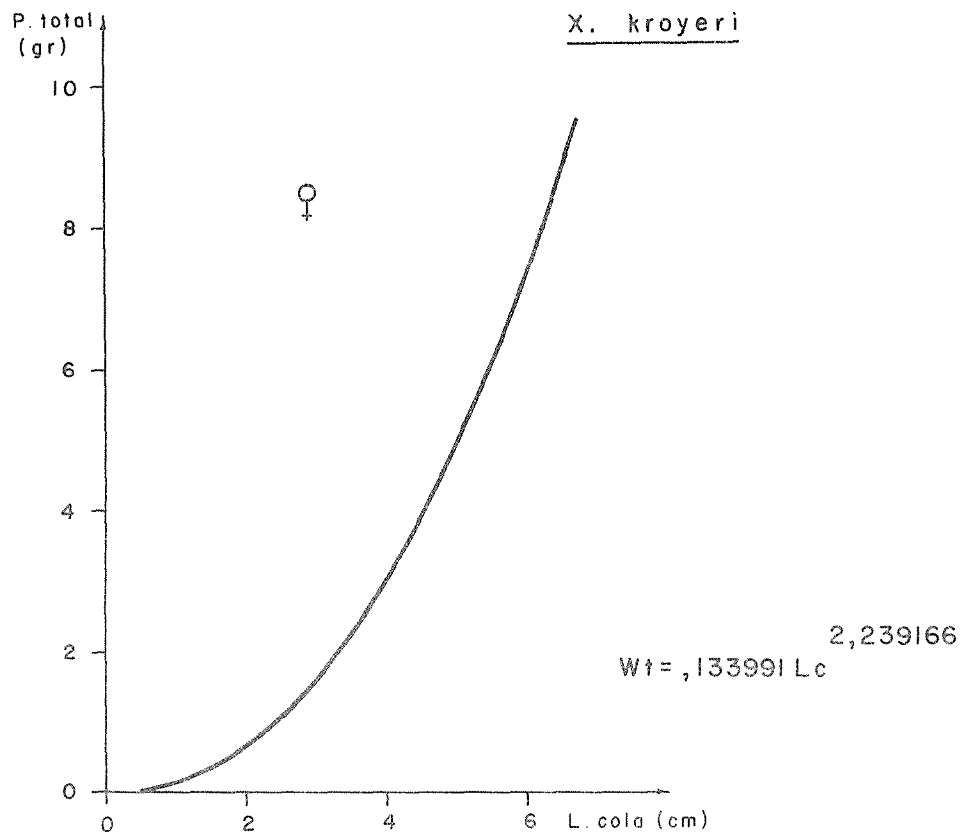

Figura 4.15.19.- Relación Largo cola - Peso total

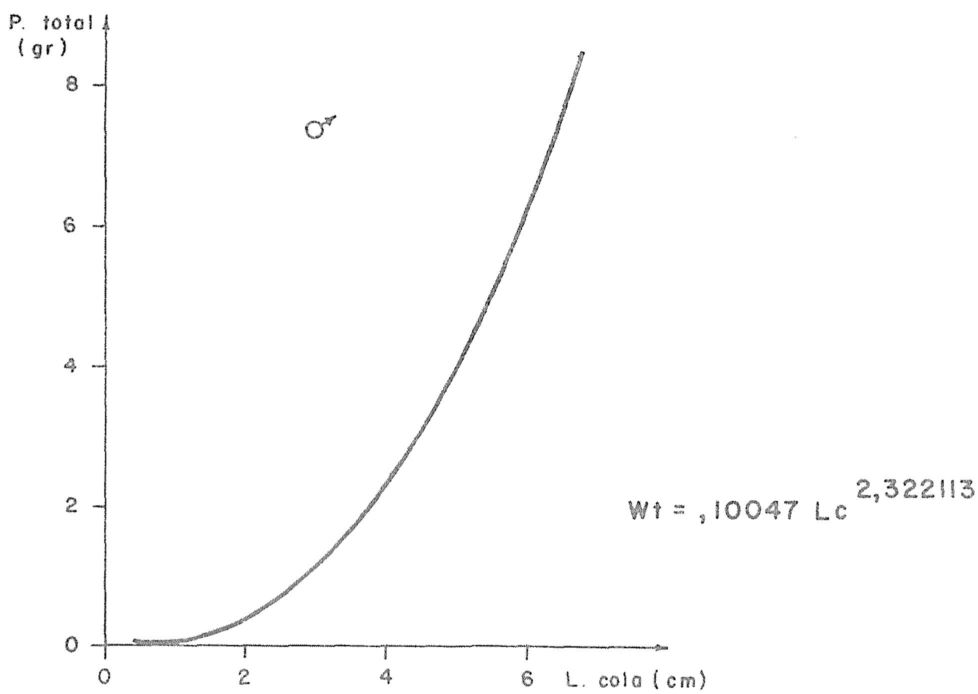

Figura 4.15.20 - Relación Largo cola - Peso total