AN ABSTRACT OF THE THESIS of Michael Julian Wilder for the Master of Science Degree in Biology presented September 23, 1977.

Title: Biological Aspects and Fisheries Potential of Two Deep Water Shrimps *Heterocarpus ensifer* and *Heterocarpus laevigatus* in Waters Surrounding Guam

Approved: ____________________
LUCIUS G. ELDREDGE, Chairman, Thesis Committee

Two species of pandalid shrimp, *Heterocarpus ensifer* and *Heterocarpus laevigatus*, were trapped along the leeward (west) coast of Guam over a two-year period, from May 1975 to May 1977. Seven depths between 244 and 732 m were sampled to define the depth distribution of each species. Primary environmental factors of depth, area, and season along with certain physical characteristics, particularly temperature, oxygen, salinity, and sediments were evaluated for their affect on catch rates. Catch rates were evaluated to determine the feasibility of a shrimp fishery on Guam.

Heterocarpus ensifer was collected between 213 and 732 m with the greatest abundance between 366 and 457 m. *H. laevigatus* was found at depths ranging from 457 to 732 m with the greatest abundance between 610 and 732 m. Depth was determined to be the most significant factor in

the variability of catches for both species. Area and season also effect the variability in catches of these shrimp, but these parameters account for considerably less variability than does depth.

Males outnumber females three or four to one for both species, and both species exhibit protandric hermaphroditism. The largest individuals of both species seem to congregate at the deep end of their depth distribution. The breeding and spawning season is well defined for H. laveigatus, occurring in winter and spring. The seasonal breeding and spawning pattern for H. ensifer is less defined but appears to occur from late winter to summer.

The results of this study indicate an annual yield of two to three metric tons for the total fishing grounds around Guam. It is possible that a small "cottage" fishery might support itself on these estimates.

BIOLOGICAL ASPECTS AND FISHERIES POTENTIAL OF TWO DEEP WATER SHRIMPS HETEROCARPUS ENSIFER AND HETEROCARPUS LAEVIGATUS IN WATERS SURROUNDING GUAM

by

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TO THE GRADUATE SCHOOL:

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INTRODUCTION

Two potentially commercial species of benthic pandalid shrimps--*Heterocarpus ensifer* A. Milne Edwards, 1881, and *Heterocarpus laevigatus* Bate, 1888--occur in the waters off Guam. Pandalid shrimp are deep water carideans considered to be of economic importance to the commercial fisheries of the United States (Barr 1970). Most pandalids of commercial value are found in temperate and boreal waters off Alaska, Maine, and Scandanavia. Both *H. ensifer* and *H. laevigatus* are found in temperate and tropical waters in the northern and southern hemispheres, exhibiting an extensive geographical range (Fig. 1). The global distribution of the genus *Heterocarpus* extends to approximately 40 degrees north and south latitude. The Azores are the northernmost limit of the range for the genus. *H. ensifer* is found as far north as Madeira, and *H. laevigatus* is found at the southernmost limit for the genus off South Africa. By far the greatest number of species for the genus occur in the Indo-West Pacific, and of these, the majority are found in the Malayan Archipelago.

Heterocarpus ensifer (Fig. 2A,B), for which this genus was established in 1881, was captured by the expedition of the "Blake" (1877-1880). Clarke (1972) and Struhsaker and Aasted (1974) trapped *H. ensifer* in the Hawaiian Islands

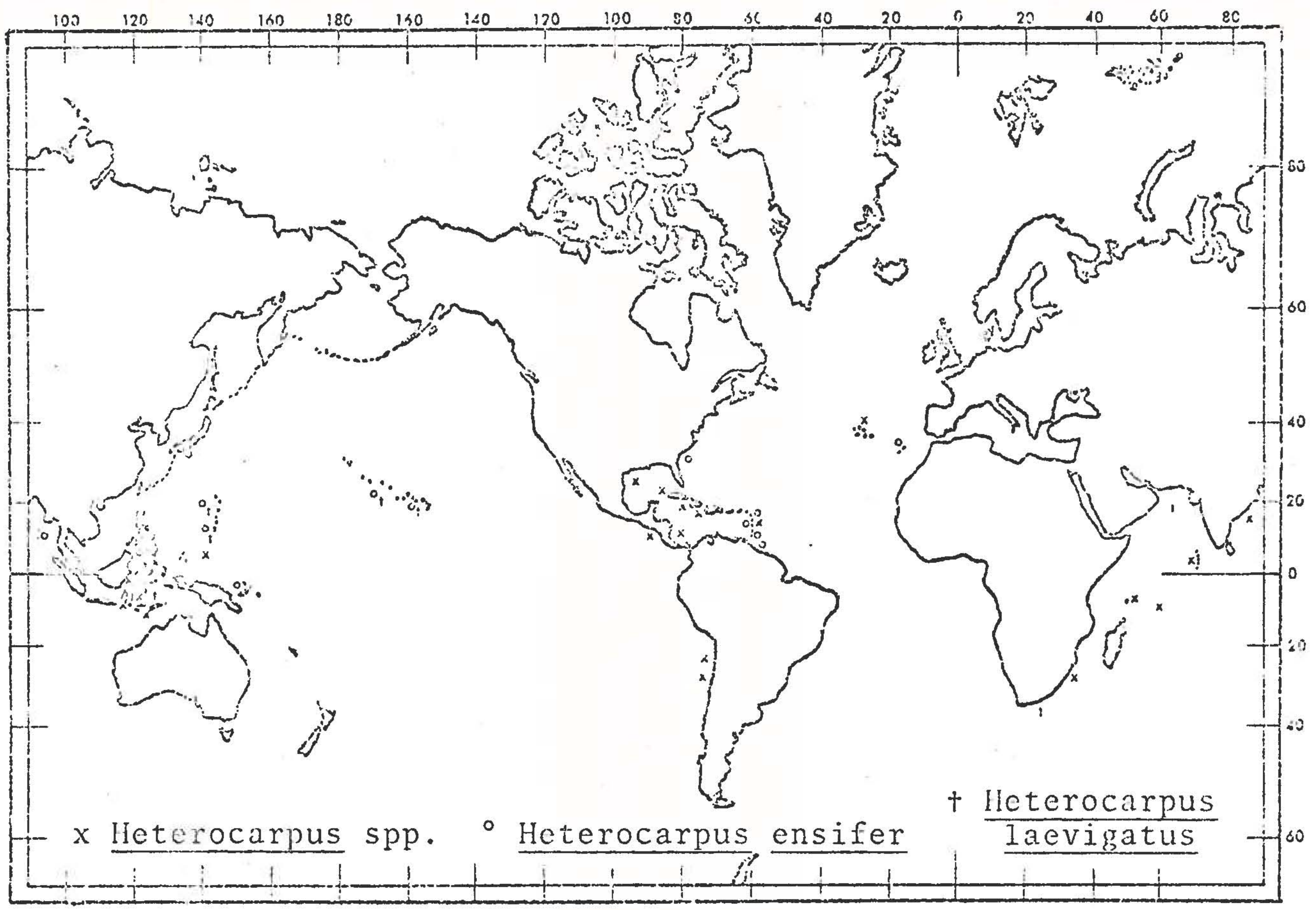

Figure 1. Global distribution of the genus *Heterocarpus* and of the species *H. ensifer* and *H. laevigatus*.

Figure 2. A. Heterocarpus ensifer ovigerous female. Approximately 12 cm total length.

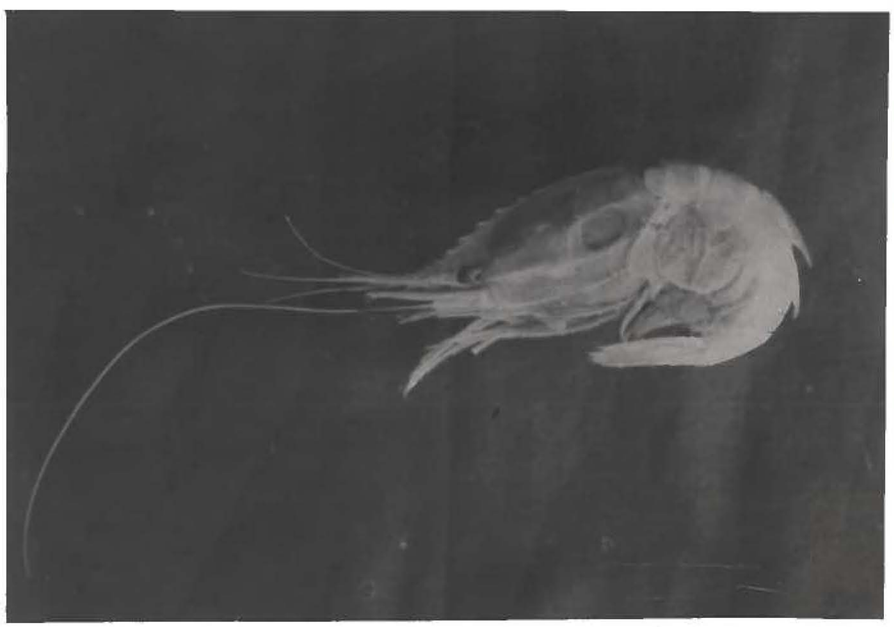

Figure 2. B. Heterocarpus ensifer ovigerous female. Approximately 11.5 cm total length.

and determined some basic depth and seasonal trends in abundance.

Clarke (1972) conducted trapping studies during 1969 and 1970 at several locations off Oahu, Hawaii, and obtained sufficient data on the abundance of *H. ensifer* to indicate that catches may support a commercial fishery. Struhsaker and Aasted (1974) conducted an extensive trapping survey and concluded that one to two metric tons/km^2 of *H. ensifer* could be harvested annually in Hawaiian waters. This study evaluated the coastal waters of the Hawaiian Archipelago in terms of a commercial shrimping industry. It was determined that traps were a more efficient means of harvesting *H. ensifer* than the trawl method.

Heterocarpus laevigatus (Fig. 3A,B) is a larger species and inhabits deeper waters than does *H. ensifer*. Clarke (1972) collected *H. laevigatus* in Hawaiian waters but had insufficient data to indicate whether sufficient quantities exist to support a fishery. However, he did mention that *H. laevigatus* would almost certainly bring a high price on the local fresh fish market.

Most species of the genus *Heterocarpus* occur at depths ranging from 183 to 732 m. DeMan (1920) reported *H. ensifer* in Hawaiian waters as shallow as 57 m. However, more extensive studies by Clarke (1972) and Struhsaker and Aasted (1974) showed the depth range for this species to be 146 to 732 m. Both authors agreed that around 366 m is the depth of greatest abundance for *H. ensifer*. *H. laevigatus*

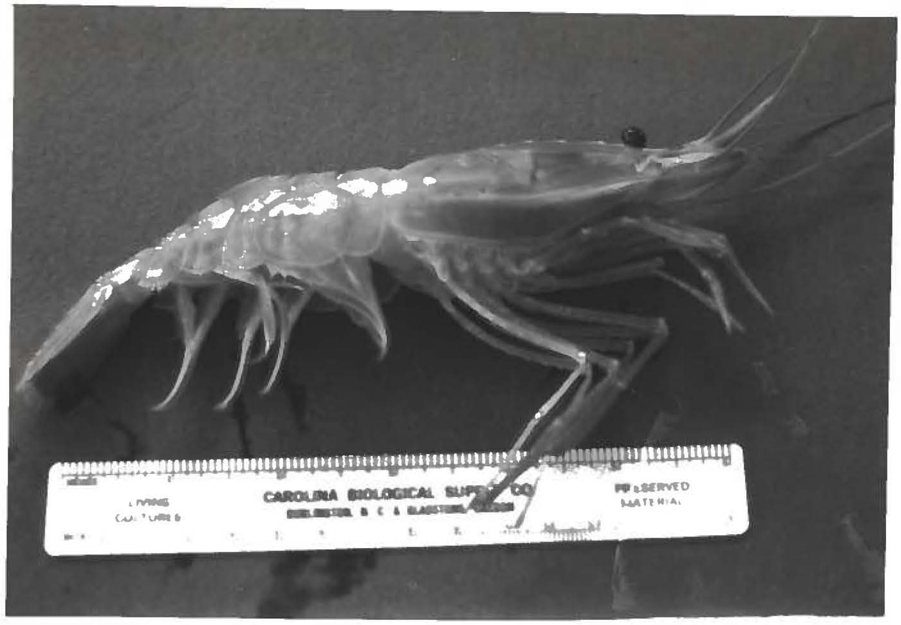

Figure 3. A. <u>Heterocarpus laevigatus</u> male. Approximately 18.5 cm total length.

Figure 3. B. <u>Heterocarpus laevigatus</u> non-ovigerous female. Approximately 19 cm total length.

has been collected as shallow as 302 m (DeMan 1920), however, Clarke (1972) and Struhsaker and Aasted (1974) concluded that the depth range for this species in Hawaiian waters is between 366 and 732 m. Clarke (1972) was unable to determine depth or seasonal trends in abundance for H. laevigatus. Struhsaker and Aasted (1974) conducted an extensive trapping survey for this species in the Hawaiian Islands and defined the depth distribution and outlined some basic biological parameters.

At present the only commercial fishery for the genus Heterocarpus (H. reedi Bahamonde) exists off Chile and, to a lesser extent, Peru. Hancock and Henriquez (1968) estimate that the trawl fishery produces 10,000 metric tons annually. Gulland (1971) indicated that in this highly productive region of upwelling, production could reach 20,000 metric tons annually if the total fishing grounds were exploited.

Preliminary trapping investigations by the University of Guam Marine Laboratory from 1972 to 1973 indicated that the deep water shrimps H. ensifer and H. laevigatus might exist in quantities sufficient to support a commercial fishery on the island.

The basic goals of this study are to investigate the biology of these shrimp, to study the relationship of abundance to various environmental and physical parameters, particularly depth, area, season, temperature, salinity, oxygen, and sediments, and to determine the feasibility of a shrimp fishery on Guam. This information will be useful in expanding the knowledge of the genus and should prove valuable in extending the range of the fishery to previously unexploited areas.

MATERIALS AND METHODS

Location of Trapping Sites

Heterocarpus ensifer and *Heterocarpus laevigatus* were trapped along the leeward (west) coast of Guam from Ritidian Point (north) to Facpi Point (south). Three study areas--Double Reef, Agana Bay, and Agat Bay--were chosen to allow sampling along the entire coast, and to provide reasonable accessibility from launch sites (Fig. 4).

Study transects were determined by aligning permanent land structures as a center coordinate. A compass course was then steered seaward of these points keeping them aligned until the desired depth was reached. Depth was determined with the aid of a Ross Fine-line printout fathometer. Accuracy at 732 m was within two percent of the recorded depth as stated in the operation manual. Trapping sites at seven depths along each transect were established as follows: 244 m (800 ft), 305 m (1000 ft), 366 m (1200 ft), 457 m (1500 ft), 549 m (1800 ft), 610 m (2000 ft), and 732 m (2400 ft). Trapping was carried out at each depth on each of three transects during summer (June 21 to September 21), fall (September 22 to December 20), winter (December 21 to March 19), and spring (March 20 to June 20).

Distribution of Sampling Effort

During the period of April 1975 to May 1977, 112 shrimp trap sets were effected off the leeward coast of Guam. Sets

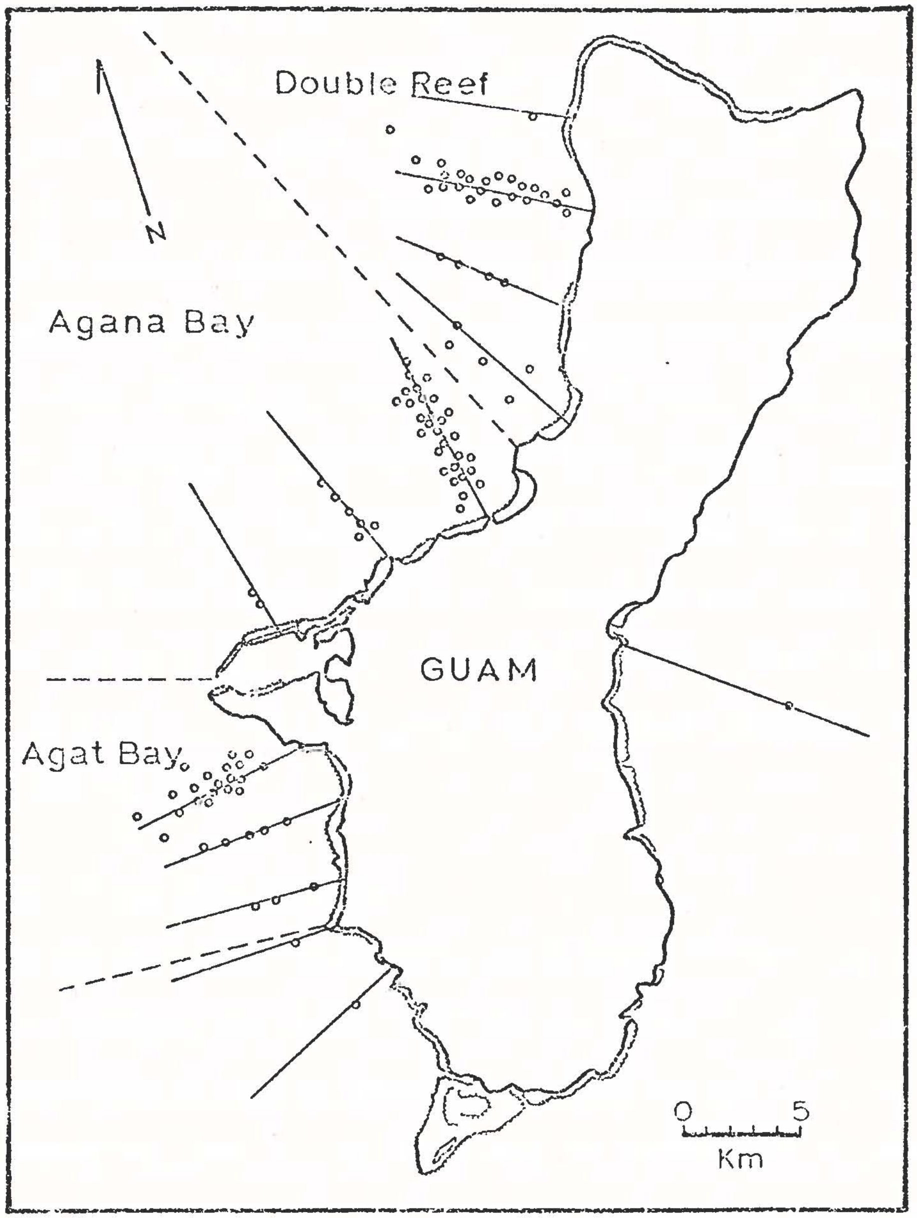

Figure 4. Study areas, transects, and trapping locations. Circles show position of sets.

were distributed among the three areas as follows: Double Reef, 34 sets; Agana Bay, 46 sets; Agat Bay, 32 sets. The distribution of sampling effort by depth for H. ensifer was as follows: 244 m, 15 sets; 305 m, 16 sets; 366 m, 16 sets; 457 m, 21 sets; 549 m, 15 sets; 610 m, 14 sets; 732 m, 15 sets. Sets shallower than 244 m were discontinued because of insignificant catches. The range of the fathometer prohibited sets deeper than 732 m. The distribution of sampling effort by depth for H. laevigatus was as follows: 457 m, 21 sets; 549 m, 15 sets; 610 m, 14 sets; 732 m, 15 sets. Sets shallower than 457 m did not catch H. laevigatus and are therefore not included in the distribution of sampling effort for this species. Although the range of the fathometer did not permit sampling deeper than 732 m, the distribution of H. laevigatus may extend somewhat beyond this depth.

Schedule of Trapping Program

Trapping sites in each area were sampled monthly from April 1975 through May 1977. Traps were set for a 24-hour period beginning in early morning and hauled on a three day basis. Three or four traps were set at different depths on day one and hauled on day two. These traps were then rebaited and set again in the same manner until the following day when they were hauled. This process was effected in a different area each week. One week of lab work each month was necessary to organize the following week's trapping and analyze the previous week's data. Data were not obtained for some months because of loss of traps. Four 6-hour sets were effected in Agana Bay at 457 m on January 15, 1976, to test the hypothesis of inshore migration. These sets began at noon. During the same period a single set was effected for a 24-hour period only 30 m away.

Design of Traps

Trap design was modified from the "square" trap of Struhsaker and Aasted (1974). Overall design remained the same, but the size was reduced to 46 X 46 X 92 cm. This was necessary because of greater ease in handling and efficiency in storing while aboard the work boat. There was no significant difference in catch rate between the two trap sizes. Traps were constructed of 3/8 inch reinforcing bar, welded in the shape of a large rectangular box (Fig. 5). These frames were then covered with a heavy industrial plastic mesh with a 0.65 cm opening, then covered with burlap. Lighter covering materials such as chicken wire should be avoided since the wire tends to tear away from the frame after minimal use. Tunnel ends tapering to a 7.5 cm opening were fabricated of the same plastic material, but these were left uncovered. Butler (1963) suggested that possibly the covered traps are more effective because the bait scent is concentrated at the trap entrances, rather than diffused through the sides and the entrances. Struhsaker and Aasted (1974) confirmed the hypothesis that

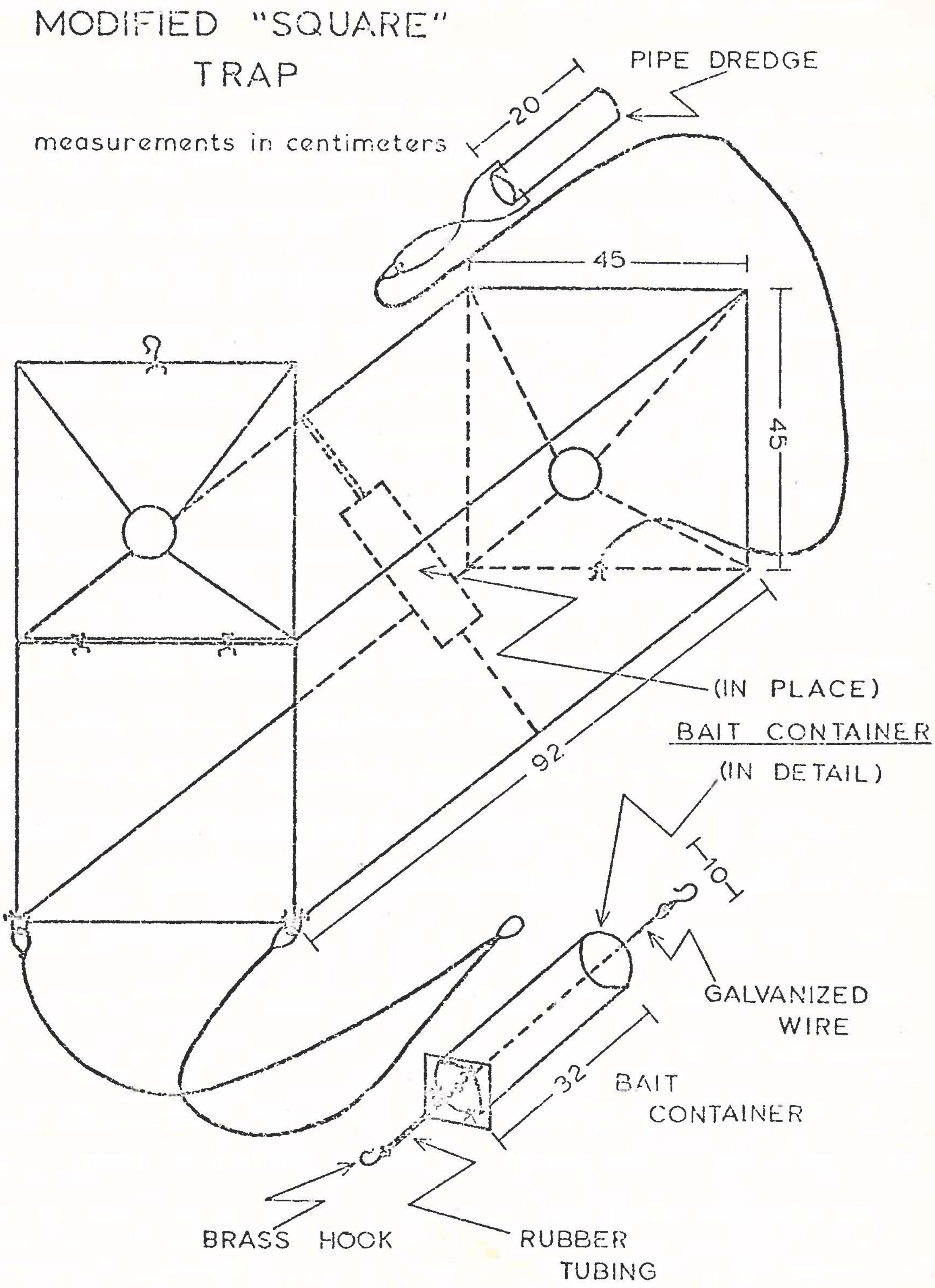

Figure 5. Modified "square" trap with bait container and pipe dredge.

covered traps offer better catch results than uncovered traps. One of the tunnel ends was hinged as a door and a 2 m bridle was attached at this end. A small rot-out panel was cut into this end and tied together with light cotton string. The string will rot away after a short period allowing shrimp to escape if the trap is lost. It was thought that a bridle secured lengthwise to the trap would keep shrimp from filtering out the ends while being hauled, but considerable lag time was experienced during setting and hauling. When the bridle was attached to one end, water moved through the trap with less drag and the traps could be set and retrieved more rapidly. Individuals as small as one cm carapace length (Cl) were caught in traps with both bridle arrangements suggesting that this is the smallest size trappable. Popypropylene line (3/8 inch twist) was utilized for buoy lines.

Bait containers were modified into a cylindrical tube approximately 32 X 10 cm (Fig. 5), and constructed from the same plastic mesh as the trap. These were suspended across the trap near the middle. Several bait containers were built and kept full, ready for use, in the freezer. Approximately 0.5 to 1 kg of bait was sufficient for sets of 24-hours duration. Three types of bait were tested: coarsely chopped fish, shrimp (*H. ensifer*), and conger eel meat. Bloody and oily fishes such as skipjack tuna

(Katsuwonus pelamis) or big eyed scad (Trachurops crumenopthalmus) were found to be highly effective and were used in 94 percent of the sets.

A short section of 2-inch galvanized pipe fashioned in the form of the "Emery" pipe dredge was tethered on a 2 m cable from the end opposite the bridle (Fig. 5). The pipe dredge scooped a small portion of the sediments when the trap was hauled.

Flag poles (Fig. 6) were constructed from a 2 m length of 1-inch PVC pipe (ID) inserted in a 1 m section of 1 1/2-inch PVC pipe (ID) and secured together by two bolts. Plastic buoys approximately 30 cm in diameter were tied to the pole approximately one-third the distance from the bottom. A section of lead or galvanized pipe was bolted beneath the buoys for ballast. The flag poles could be telescoped out to 3 m and locked in place or shortened for storage. Flag poles could be sighted as far away as 1 km in fair weather.

Procedure for Setting and Retrieval

Upon location of a study depth the necessary equipment was readied for use. Traps were baited prior to setting, pipe dredges attached, and buoy lines secured to the bridle. The buoy line was passed over a bow roller and the trap released. Constant pressure was maintained on the buoy line to insure setting the trap properly. The boat operator maintained the boat directly above the trap at all times.

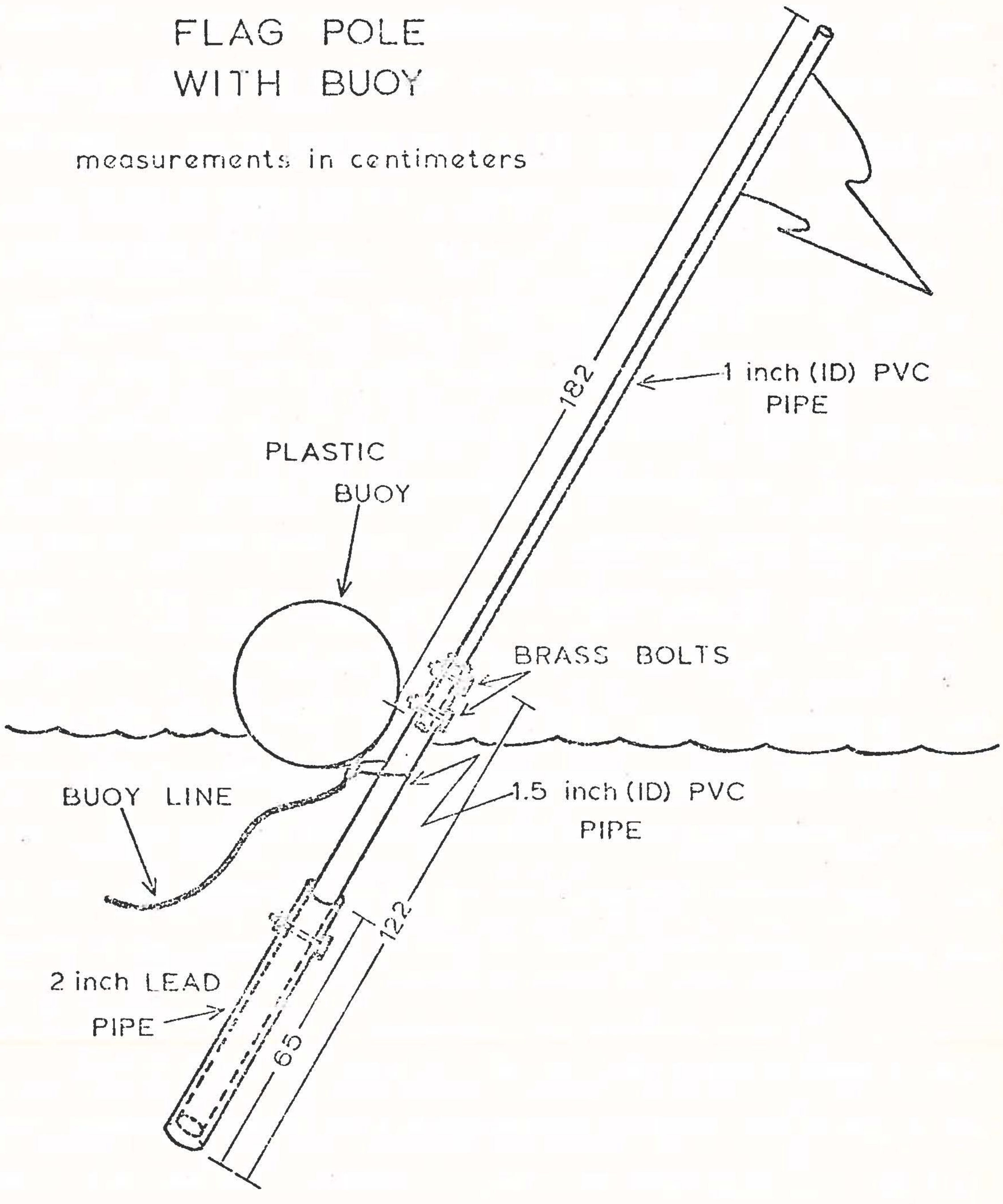

Figure 6. Flag pole and buoy assembly.

Once the trap was below 100 m it acted as a sea anchor keeping the boat on station. Line was paid out and sections were tied together until the trap touched bottom. An excess of line (scope) equivalent to 25-50 percent of the depth of the trap was paid out to allow for the influence of wind or water motion on the floating buoy. A flag pole supported by buoys was attached to the buoy line to aid in finding the trap later. A 6-m pickup line with a small float was attached to the flag pole. Line left floating on the surface was weighted and sunk below the buoys. An efficient set at 457 m could be effected in approximately 30 minutes. Hand bearing compass readings were then taken on established land positions in order to plot the position of the set on hydrographic charts and for relocation purposes. Unusual weather conditions such as current or wind were also noted to aid in relocation. During periods when adverse weather conditions might affect the set, a short observation period on station was necessary in order to make adjustments in scope and insure a proper set. Too hasty a set sometimes ended in loss of the trap, line, and flag pole.

Traps were hauled with the aid of a gypsy-head winch pot hauler powered by a 3-hp engine. Line was brought in over the bow roller and wrapped over the capstan. As the line was retrieved by the pot hauler it was piled into plastic buckets. Approximately 15 minutes were necessary to haul one trap from 457 m.

Upon retrieval of the traps, catches were placed in separate bags and put on ice for the trip to the laboratory. Sediment samples were placed in jars and fixed with 70 percent alcohol.

Measurements on Catch

Each catch was evaluated for total weight and number, total weight and number of each species, weight and number of all males, ovigerous individuals, and nonovigerous females. Weights were taken by a Salter Suspended Weighter scale to the nearest 10 g.

Males were determined by the presence of a pair of setae located distally between the first and second abdominal segments. Shrimps carrying eggs were obviously females and nonovigerous females were distinguished from males by the lack of the pair of setae. The external opening of the sex organ (gonopore) was examined as necessary to verify the determination of sex.

Carapace length, measured from the base of the eye socket to the posterior mid-dorsal edge of the carapace, was determined for all shrimps with vernier calipers, accurate to 0.01 cm. Selected individual shrimps, spanning the size range for each species, were weighed with an Ohaus Dial-O-Gram balance accurate to 0.01 g.

Environmental Data

Temperature, salinity, oxygen, and sediments were examined in the three study areas along the transects. Water samples and temperatures were taken with the aid of a Nansen Sampler fitted with reversing thermometers in December 1976 and June 1977 along the three transects. Temperature was measured with thermometers accurate to 0.2°C and were recorded within 20 m of the depth of the trapping locations.

Salinity was measured to the nearest 0.1 ppt. Both temperature and salinity were calculated by using correction formulas described by LaFond (1951).

Water samples for oxygen determination were taken from the Nansen Sampler, siphoned into BOD bottles, and fixed in the field with Winkler reagents. Titrations were performed in the laboratory following the alkaline-azide modification of the basic Winkler technique (A.P.H.A. 1975).

Sediment samples from 92 stations were categorized into fine sand or clay according to Shepard (1973). Particles larger than 4.76 mm (small pebbles) were discarded, since they occurred only sporadically and were not representative of the sediment as a whole. Separation of these particles was done by shaking the sample through a No. 4 (4.76 mm mesh) sieve on a Ro-Tap automatic shaking machine. The remaining sample was then placed in a container and weighed on a Torbal balance to the nearest 0.01 g. Samples were then washed for five minutes through a No. 200 (0.074 mm mesh) sieve and returned to the same container. These were then allowed to dry in an oven at 60°C for four days. Each container was final weighed to determine percent greater and less than 0.074 mm, the distinction between sand and clay. These data were then used to relate catch rate to sediment size.

RESULTS

Environmental Parameters

Bottom profiles were constructed from actual fathometer printouts along the transects in each area (Figs. 7, 8, and 9). In general, study depths on the Double Reef transect are located approximately 0.5 to 1 km further offshore than those in Agana Bay or Agat Bay. Temperatures taken at each depth did not show any significant change with area and time of year (Table 1). Salinity showed little variation with depth, varying from 34.0 ppt at 244 m to 34.4 ppt at 732 m at all three areas. Oxygen values of 5.6 to 6.6 ppm were measured at depths of 244 to 457 m. Below 457 m oxygen measured 2.7 to 6.6 ppm. Oxygen values increased from 5.6 ppm to 6.6 ppm between 305 and 457 m suggesting an oxygen inversion layer. Below 457 m oxygen values decrease steadily to 2.7 ppm at 732 m. Sediments were collected in 94 of the 112 sets. Fine sand and silt, < 0.2 mm, was found at depths of 366 to 732 m. Coarse sand, granules, tiny pebbles, and occasional rocks smaller than 5 mm in diameter, were collected from 244 to 366 m. Small gorgonians frequently were caught on the trap or collected in the pipe dredge at shallow depths (244 m). Finer sediments are more predominant at greater depths offshore than on the inshore slopes.

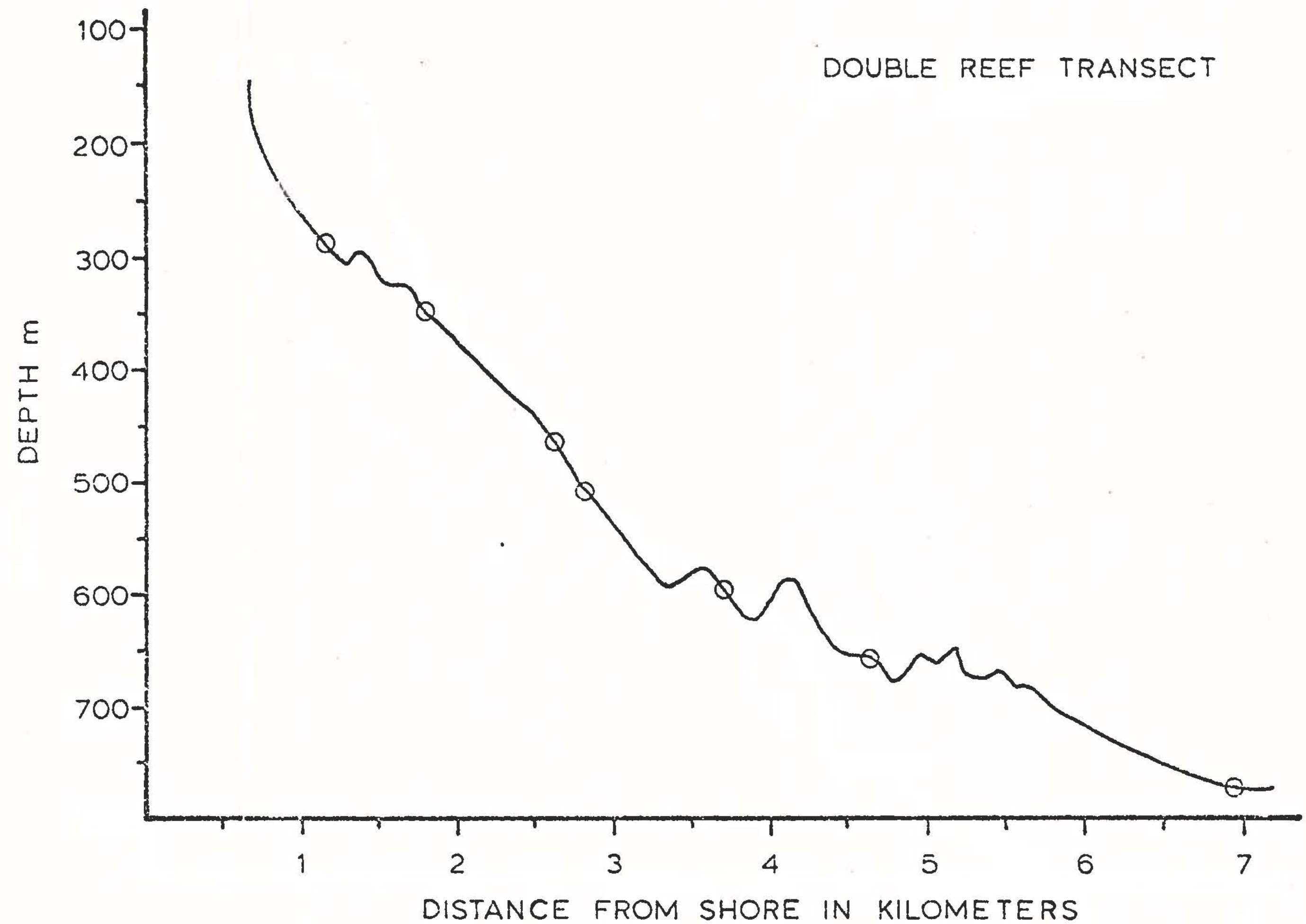

Figure 7. Profile of transect at Double Reef derived from actual fathometer printout. Sampling stations are indicated by circles.

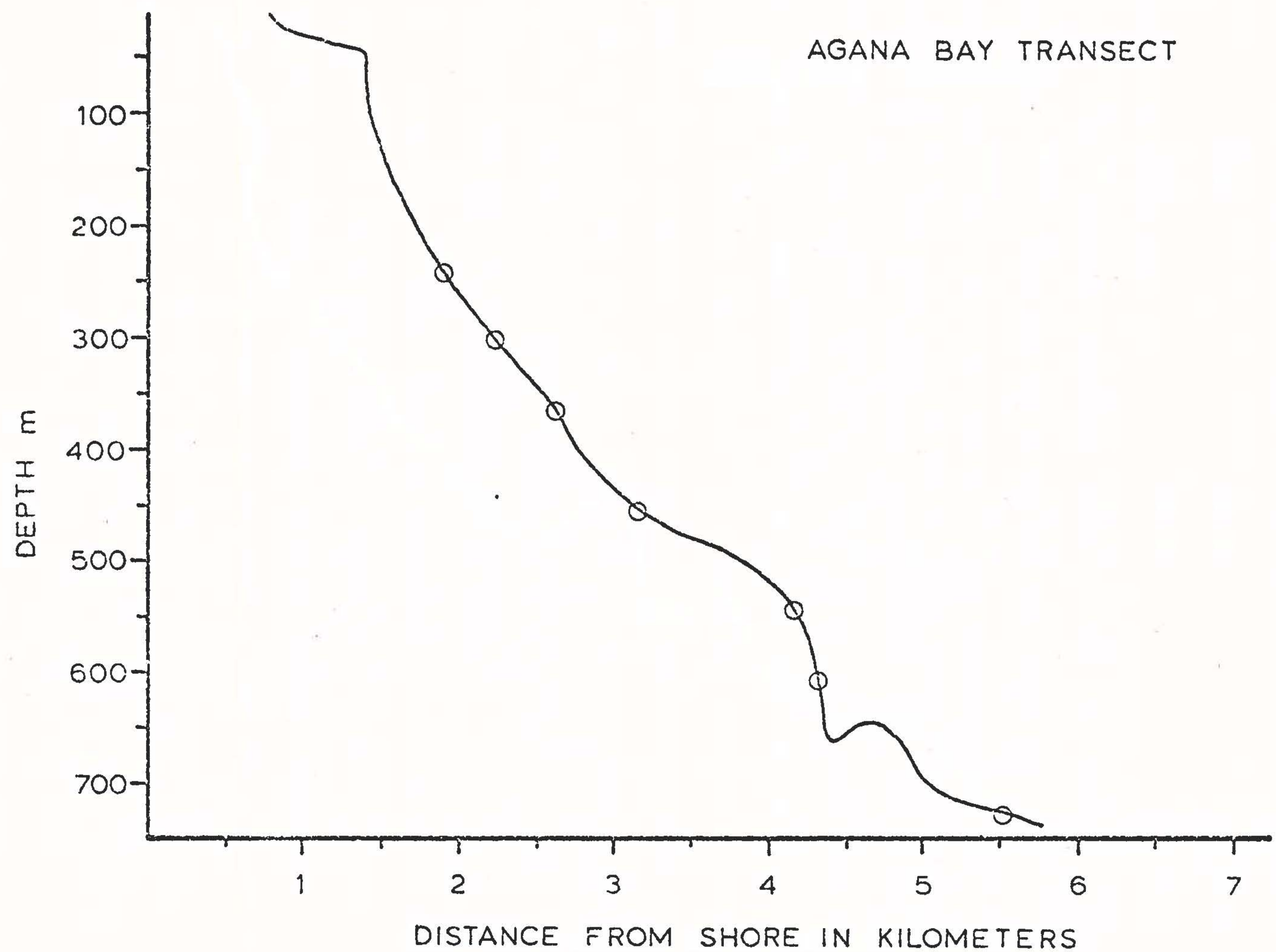

Figure 8. Profile of transect at Agana Bay derived from actual fathometer printout. Sampling stations are indicated by circles.

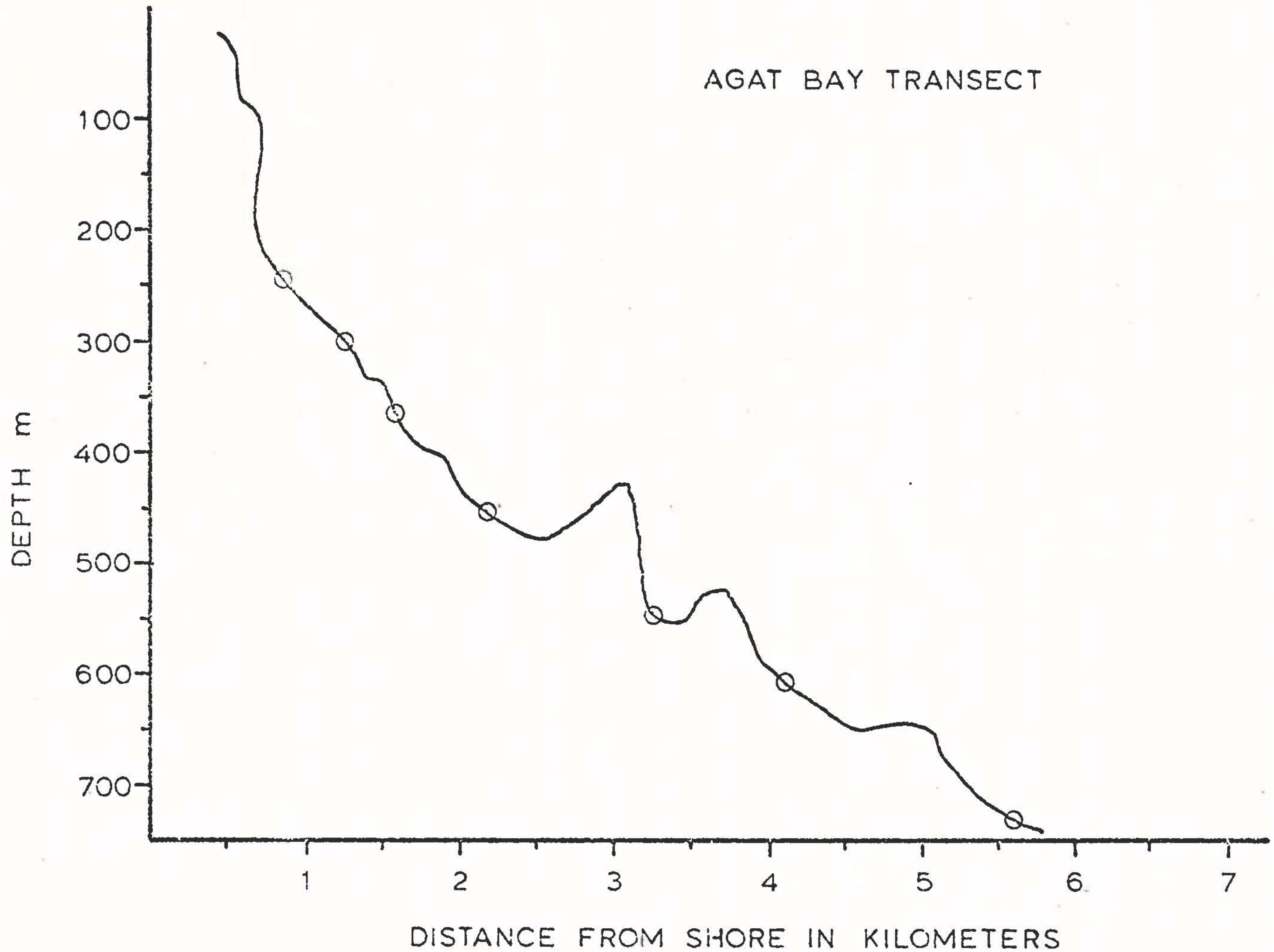

Figure 9. Profile of transect at Agat Bay derived from actual fathometer printout. Sampling stations are indicated by circles.

Table 1. Profile of temperatures (°C) by depth. Temperatures were recorded within 20 m depth of the trapping depths.

Depth (m)	December 1976	June 1977
244	16.6	16.8
305	14.6	14.8
366	11.2	10.8
457	8.6	8.6
549	6.2	6.4
610	5.6	5.8
732	5.0	5.2

There was no significant correlation of sediment size to catch rate ($p >>> .05$, product-moment correlation). The range of the physical and chemical parameters of the waters which are measured within the depth ranges of the two species are shown in Table 2.

Heterocarpus ensifer

Heterocarpus ensifer (Fig. 2A,B) is found at depths ranging from 213 to 732 m with the depth of greatest abundance between 366 and 457 m (Figs. 10 and 11). The general trend of depth distribution for this species is a gradual increase to the depth of greatest abundance (366 to 457 m) and a sharp drop in abundance down to 732 m, the point of least abundance. H. ensifer was collected at depths as shallow as 212 m and has been reported by fishermen as shallow as 152 m. Although no trapping was done below 732 m, it seems likely that H. ensifer does not occupy depths much greater than this.

Figures 12 and 13 show variations in abundance with respect to depth and area. Variation in abundance with respect to depth and season indicate that summer catches were significantly less over most depths than all other seasons (Figs. 14 and 15). Figures 16 and 17 show variations in abundance with respect to area and season.

The largest single catch of H. ensifer was 7.7 kg at 244 m in Agana Bay. Of the 112 total sets, all but 24 caught H. ensifer and 22 of these were situated in the

Table 2. The range of physical and chemical parameters in Guam waters within the depth ranges for *H. ensifer* and *H. laevigatus*.

Species	*H. ensifer*	*H. laevigatus*
Depth	244-732+m	457-732+m
Depth of greatest abundance	366-457 m	610-732+m
Temperature	16.7°-5.1°C	8.6°-5.1°C
Temperature in depth of greatest abundance	11.0°-8.6°C	5.7°-5.1°C
Salinity	34.0-34.4 ppt	34.0-34.4 ppt
Salinity in depth of greatest abundance	34.0-34.4 ppt	34.0-34.4 ppt
Oxygen	6.6-2.7 ppm	6.6-2.7 ppm
Oxygen in depth of greatest abundance	5.6-6.6 ppm	3.0-3.7 ppm

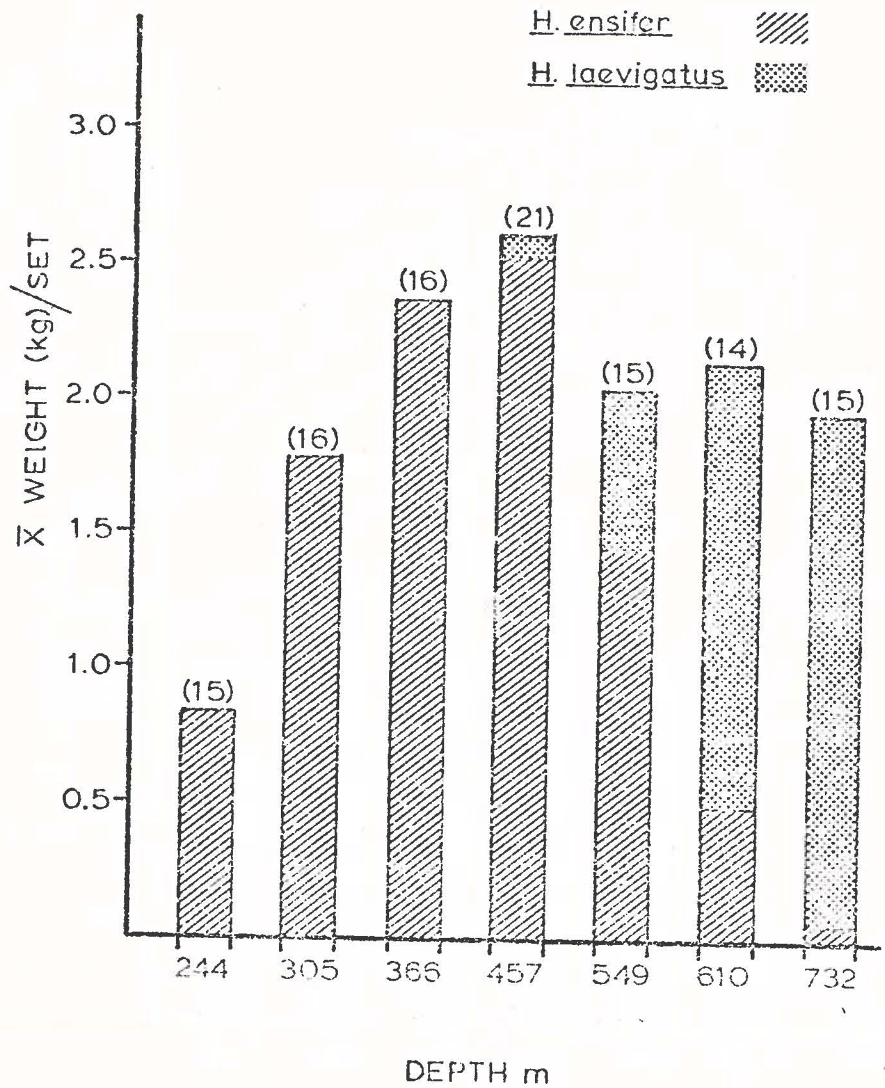

Figure 10. Depth distribution by weight (kg) for both species, H. ensifer and H. laevigatus. Number of sets at each depth is in parentheses.

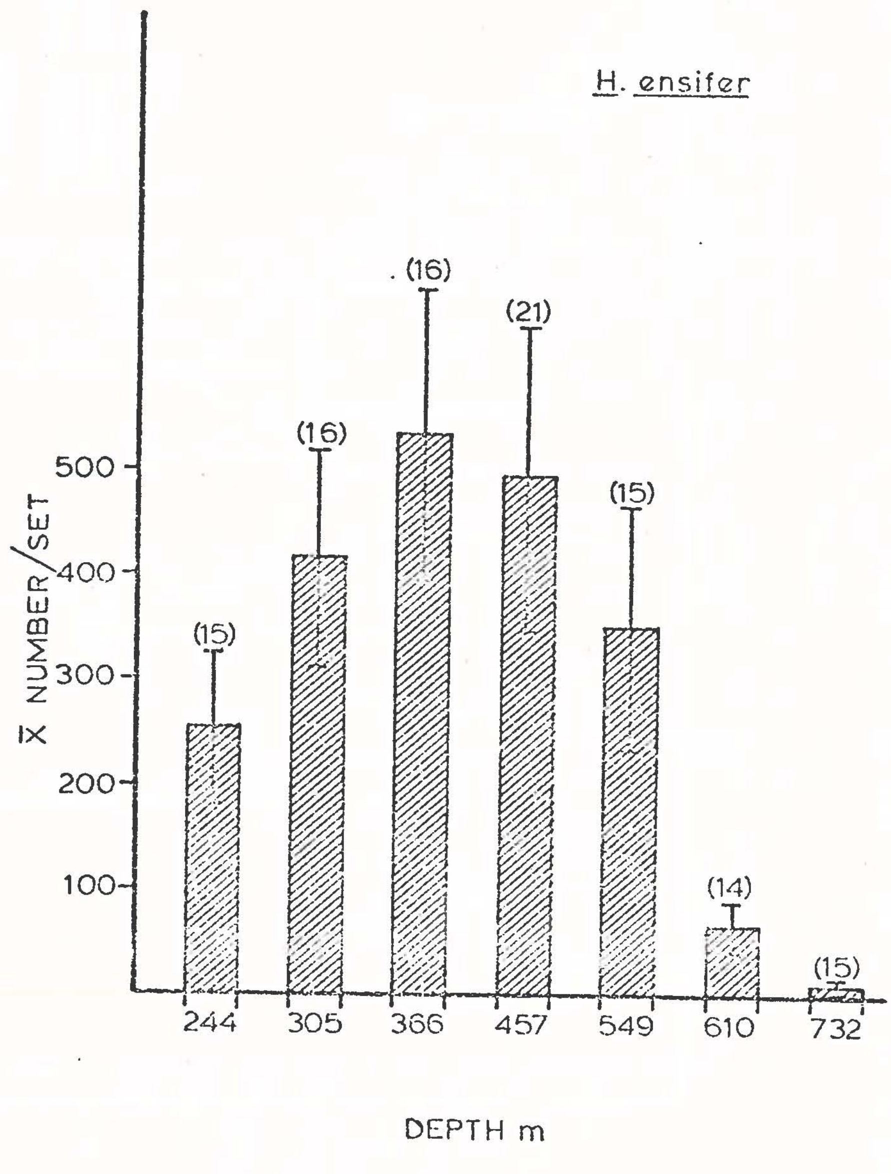

Figure 11. Depth distribution by numbers of *H. ensifer* caught per set, all areas and seasons inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

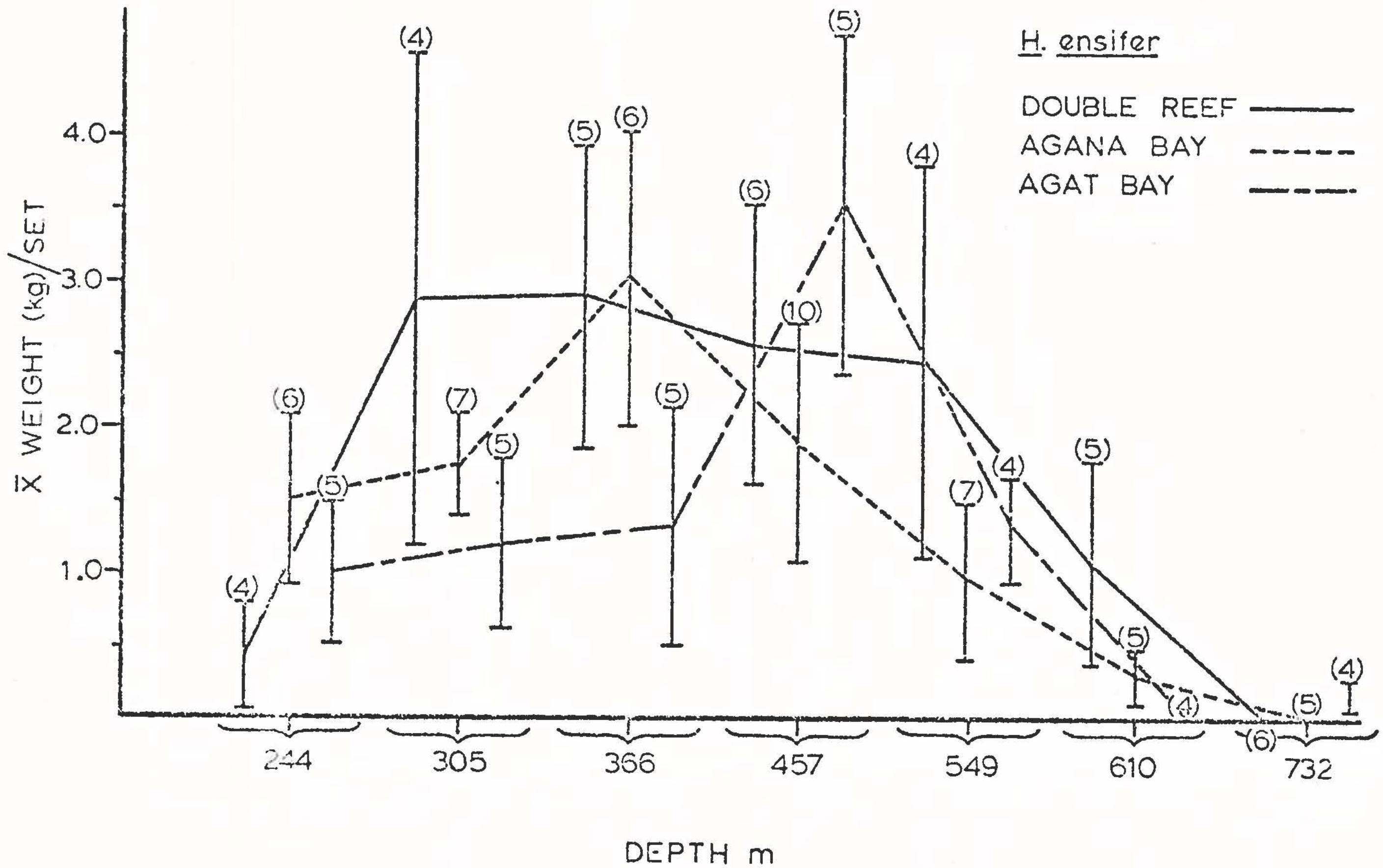

Figure 12. Mean catch weight (kg) of H. ensifer per set by depth for each area, all seasons inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

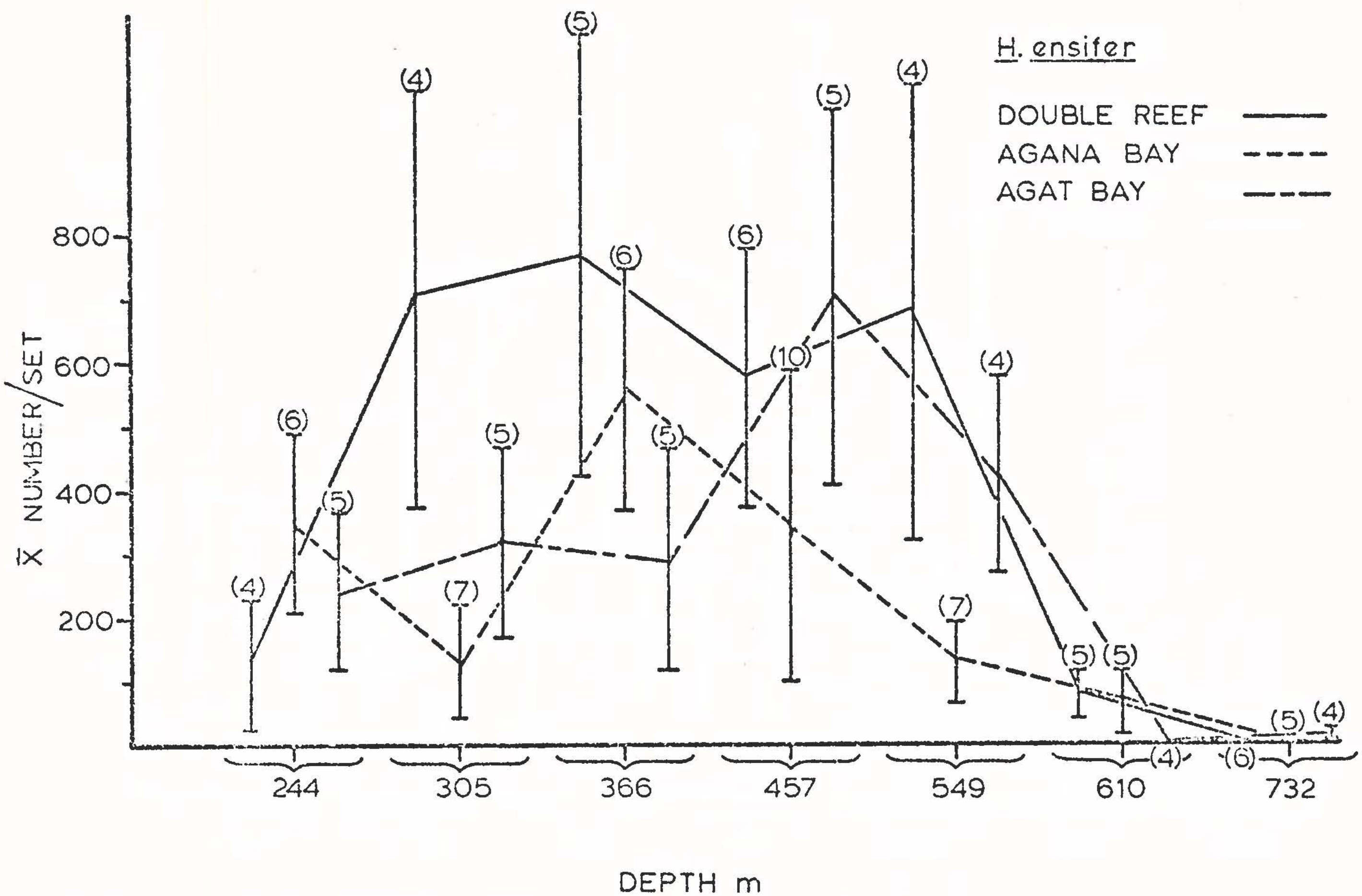

Figure 13. Mean number of H. ensifer per set by depth for each area, all seasons inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

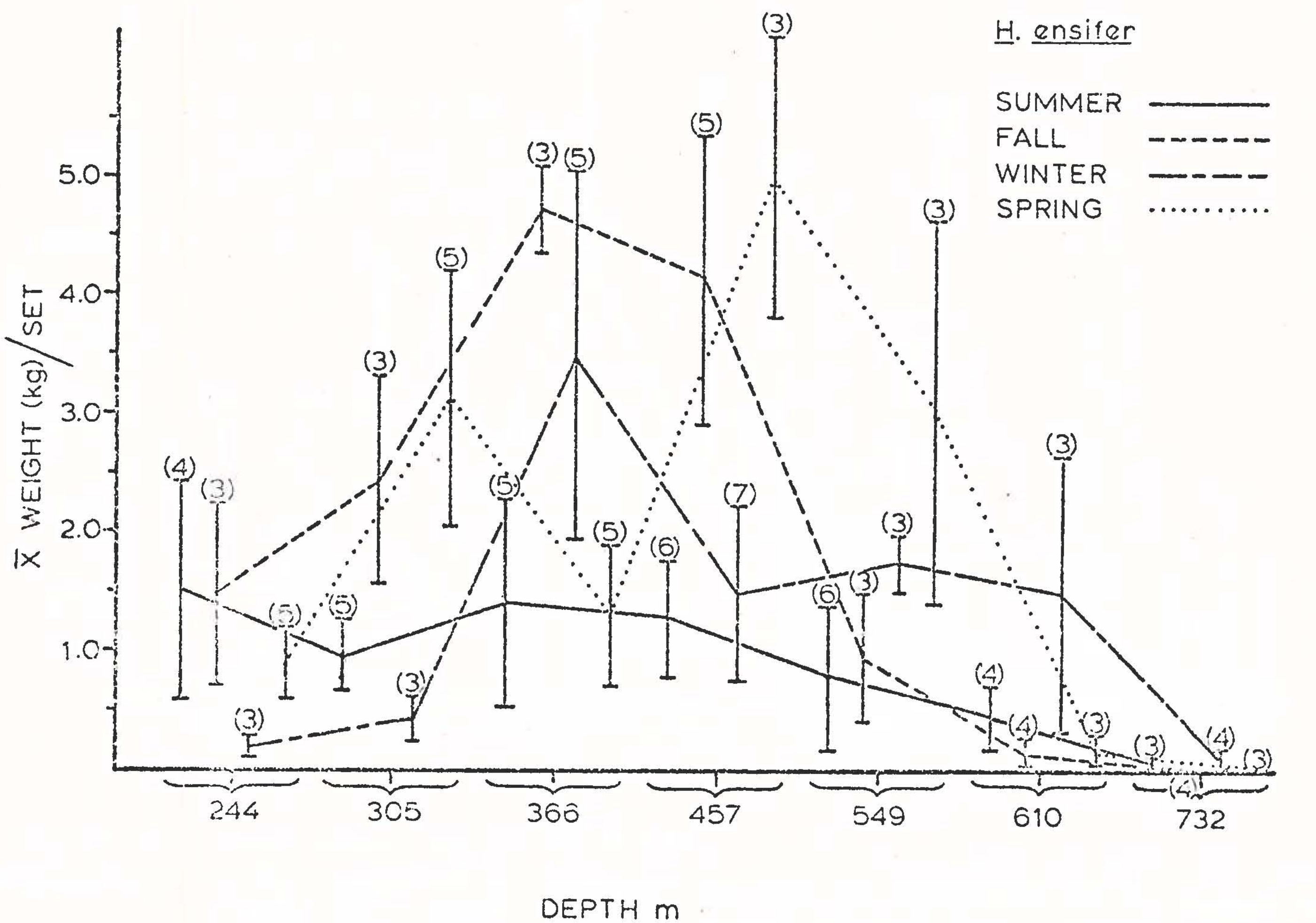

Figure 14. Mean catch weight (kg) of H. ensifer per set by depth for each season, all areas inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

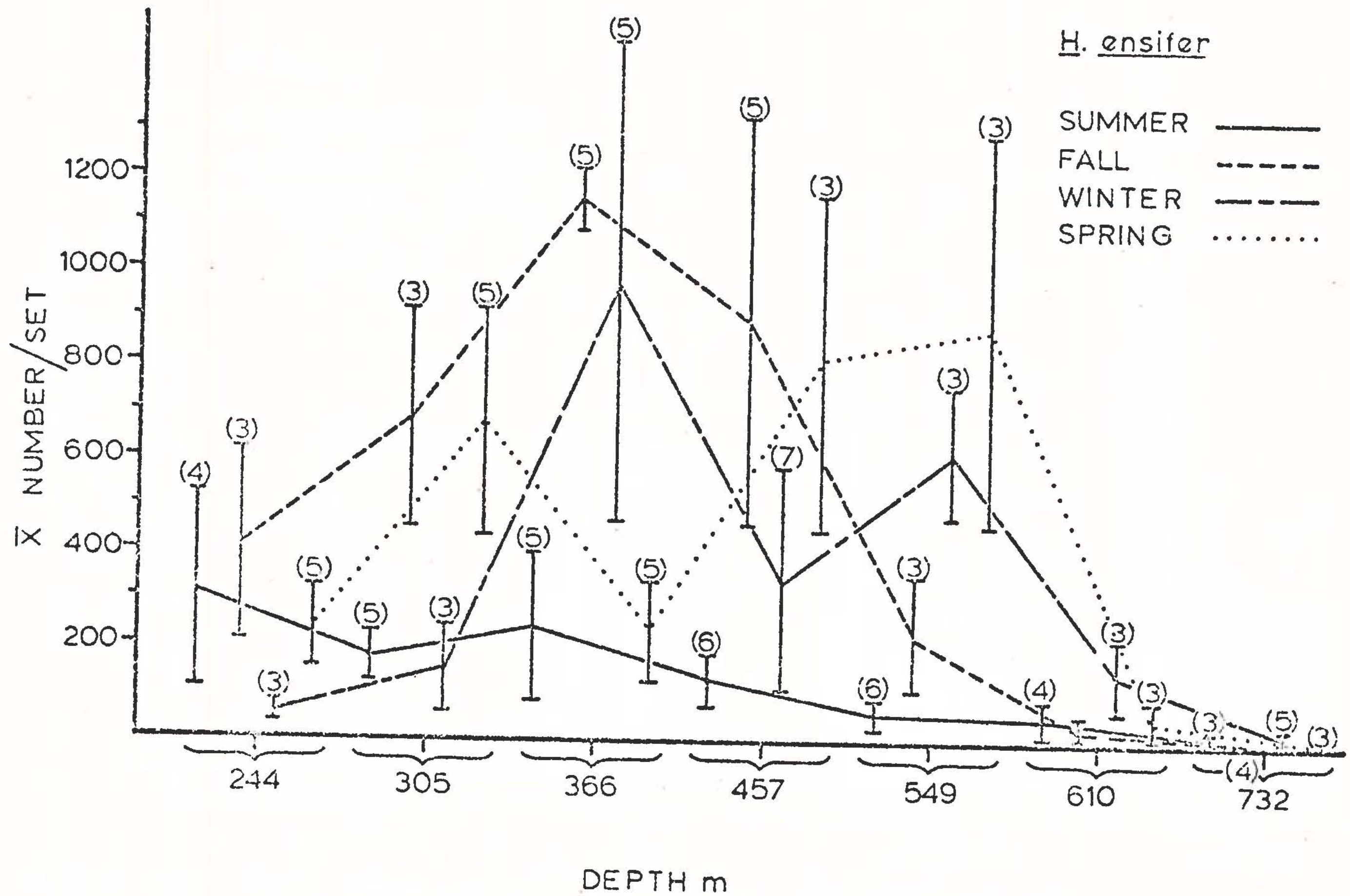

Figure 15. Mean number of H. ensifer per set by depth for each season, all areas inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

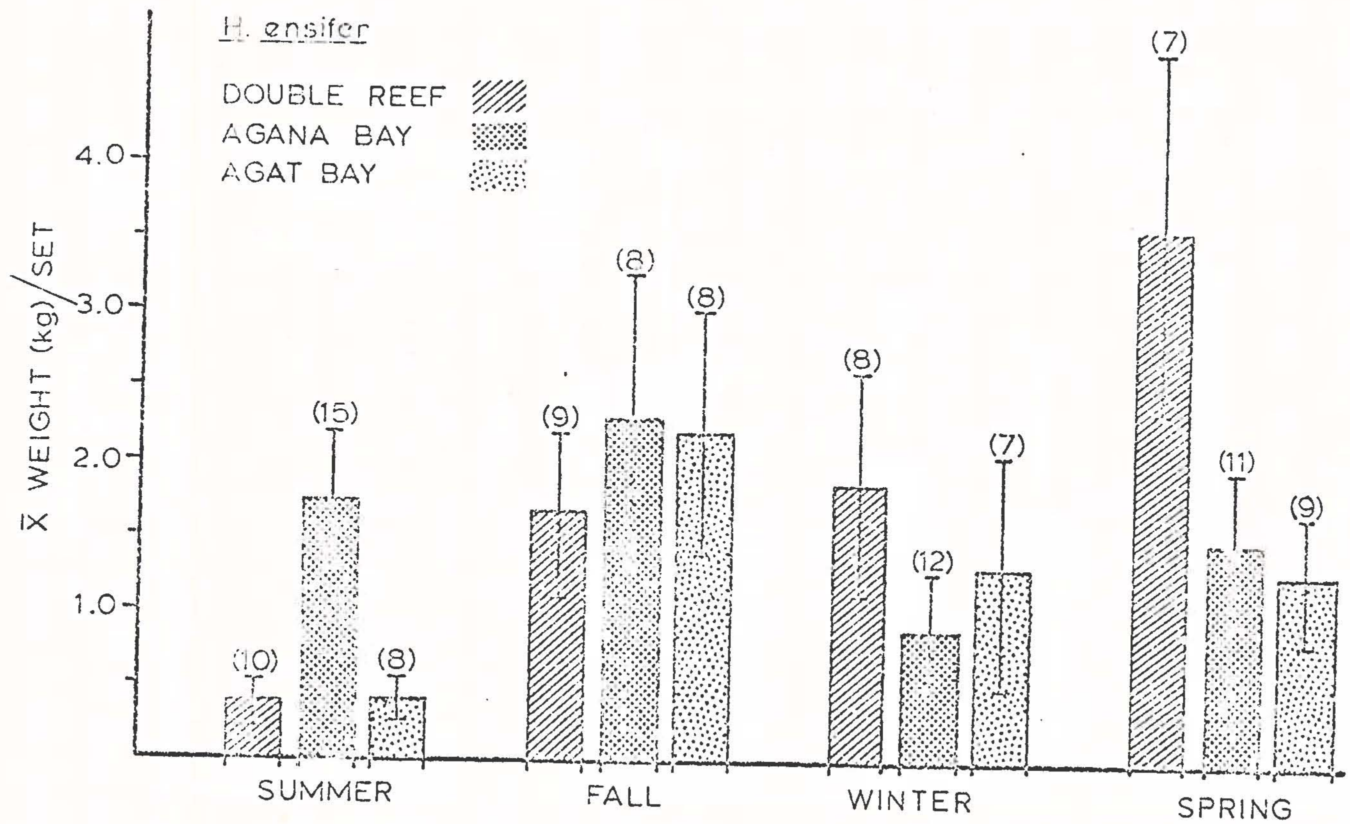

Figure 16. Mean catch weight (kg) of *H. ensifer* per set by area for each season, all depths inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

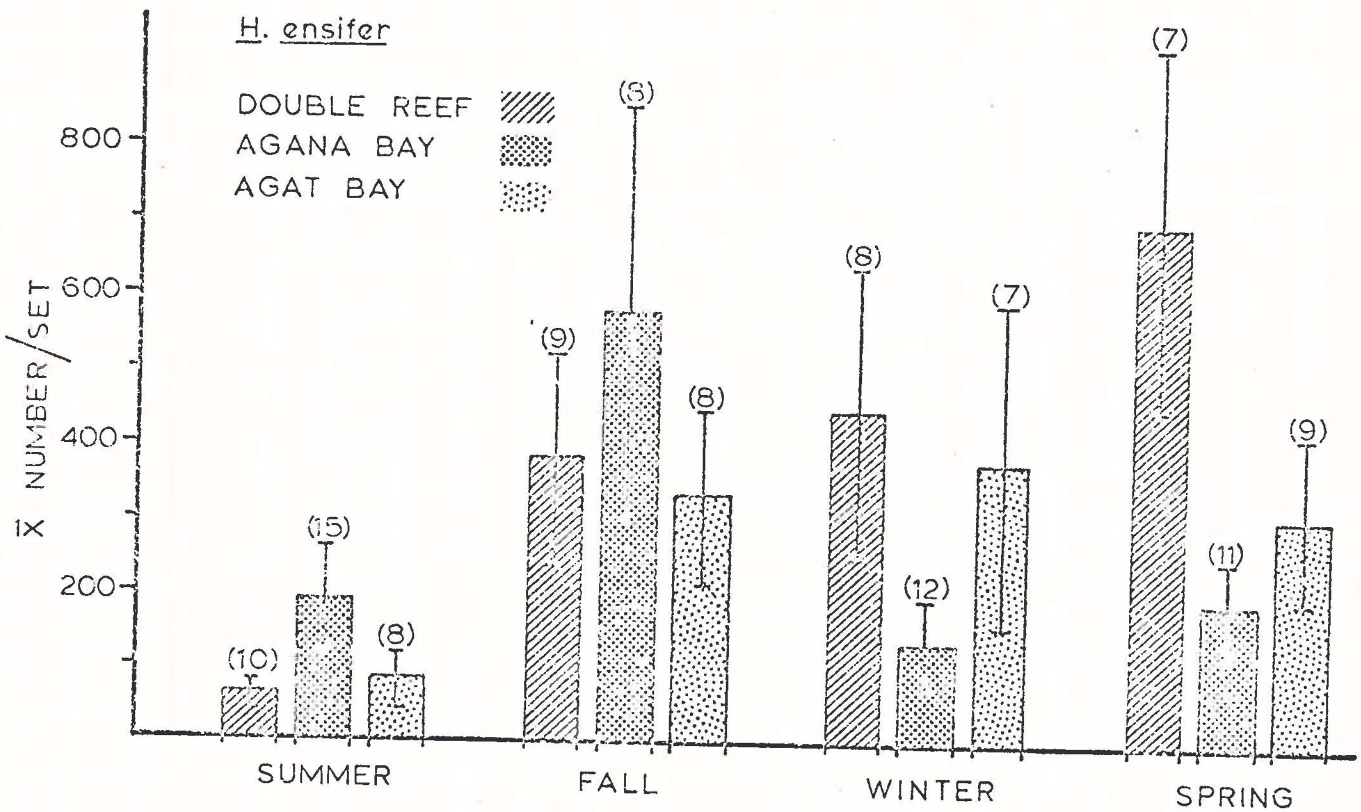

Figure 17. Mean number of *H. ensifer* per set by area for each season, all depths inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

549 to 732 m depth range or the depths of least abundance for this species.

A comprehensive seasonality study was conducted for a one year period beginning in May 1976. Results of this study indicate that the three primary factors of depth, area, and season are all significant in accounting for variations in weight and number among catches ($p < .001$, 3-way ANOVA), although depth seemed to have the greatest effect. Statistics also show that variations in abundance related to the combination of factors, depth and area, depth and season, and area and season are all significant by weight and numbers as well ($p < .001$, 3-way ANOVA), with depth and season having the greatest effect.

There is a definite trend for larger individuals of H. ensifer to be collected from greater depths (Table 3). There is a significant difference in the mean weight per individual between 366 and 457 m ($p < .05$, Student's t-test). When the data for depths 457 to 610 m are lumped and tested against the data at 732 m a highly significant difference is also found to exist ($p < .001$, Student's t-test).

In the majority of sets, males outnumbered females by three or four to one (Tables 4 and 5). The largest percentage of ovigerous individuals was 2.13 percent by number at 244 m. A maximum of 2.08 percent nonovigerous females by number were found at 305 m. There is a well defined sex

Table 3. Mean number per kilo and mean weight (g) per individual as a function of depth for *H. ensifer* and *H. laevigatus*. Sample size (N) represents the number of sets where shrimp were caught. SE refers to standard error of the mean.

Depth (m)	*Heterocarpus ensifer* Mean No. per kilo	Mean wt. (g) per indiv.	N	SE	*Heterocarpus laevigatus* Mean No. per kilo	Mean wt. (g) per indiv.	N	SE
244	297.39	4.30	15	2.15	--	--	--	--
305	224.42	4.74	15	1.88	--	--	--	--
366	217.04	5.45	15	1.51	--	--	--	--
457	188.70	8.48	21	8.69	21.34	50.85	7	19.53
549	241.34	5.51	13	5.01	86.99	20.82	12	18.74
610	123.60	7.68	7	6.78	67.39	21.58	14	17.82
732	98.41	13.74	2	6.03	49.21	23.93	14	11.79

Table 4. Percent of males, ovigerous females, and nonovigerous females for both *H. ensifer* and *H. laevigatus* in terms of weight.

WEIGHT						
H. ensifer			Depth (m)	*H. laevigatus*		
Male ♂	Ovig. ♀	Nonovig. ♀		Male ♂	Ovig. ♀	Nonovig. ♀
61.63	38.37	--	244	--	--	--
70.02	25.89	4.09	305	--	--	--
59.29	37.17	3.54	366	--	--	--
64.24	32.98	2.78	457	67.18	32.82	--
79.68	16.64	3.68	549	63.92	18.89	17.17
81.39	18.61	--	610	71.51	8.37	20.12
82.31	17.69	--	732	60.77	17.93	21.30

Table 5. Percent of males, ovigerous females, and nonovigerous females for both *H. ensifer* and *H. laevigatus* in terms of numbers.

NUMBERS						
H. ensifer			Depth (m)	*H. laevigatus*		
Male ♂	Ovig. ♀	Nonovig. ♀		Male ♂	Ovig. ♀	Nonovig. ♀
75.70	24.30	--	244	--	--	--
81.61	16.31	2.08	305	--	--	--
81.26	17.29	1.44	366	--	--	--
82.17	16.46	1.37	457	73.91	26.09	--
93.42	5.25	1.33	549	86.88	5.59	7.53
87.23	12.77	--	610	91.56	2.22	6.22
94.74	5.26	--	732	83.21	7.50	9.29

ratio trend in the depth distribution of this species, males increasing and females decreasing with depth.

Modal carapace length data for H. ensifer indicate that ovigerous females are largest in the winter months and males smallest as summer approaches (Fig. 18). These data also indicate the minimum reproductive size for H. ensifer to be 1.4 cm with a mean reproductive size of 1.9 cm (CL). The increase in modal carapace length over time suggests that H. ensifer grows at a rate of one cm per year, indicating maturation (smallest recruit size to mean reproductive size of females) in approximately three to four years. The growth rates suggested here are approximate since size increases with the change in sex from male to female.

Computerized length-weight regression analysis was conducted on H. ensifer using 258 males (Fig. 19), 240 ovigerous females (Fig. 20), and 78 nonovigerous females (Fig. 21). The fitted exponential length-weight curves for each group is as follows:

Males: $\log W = 1.9565 \log CL - 0.0079$

$$W = 0.982\ CL^{1.9565}$$

$$r^2 = 0.738$$

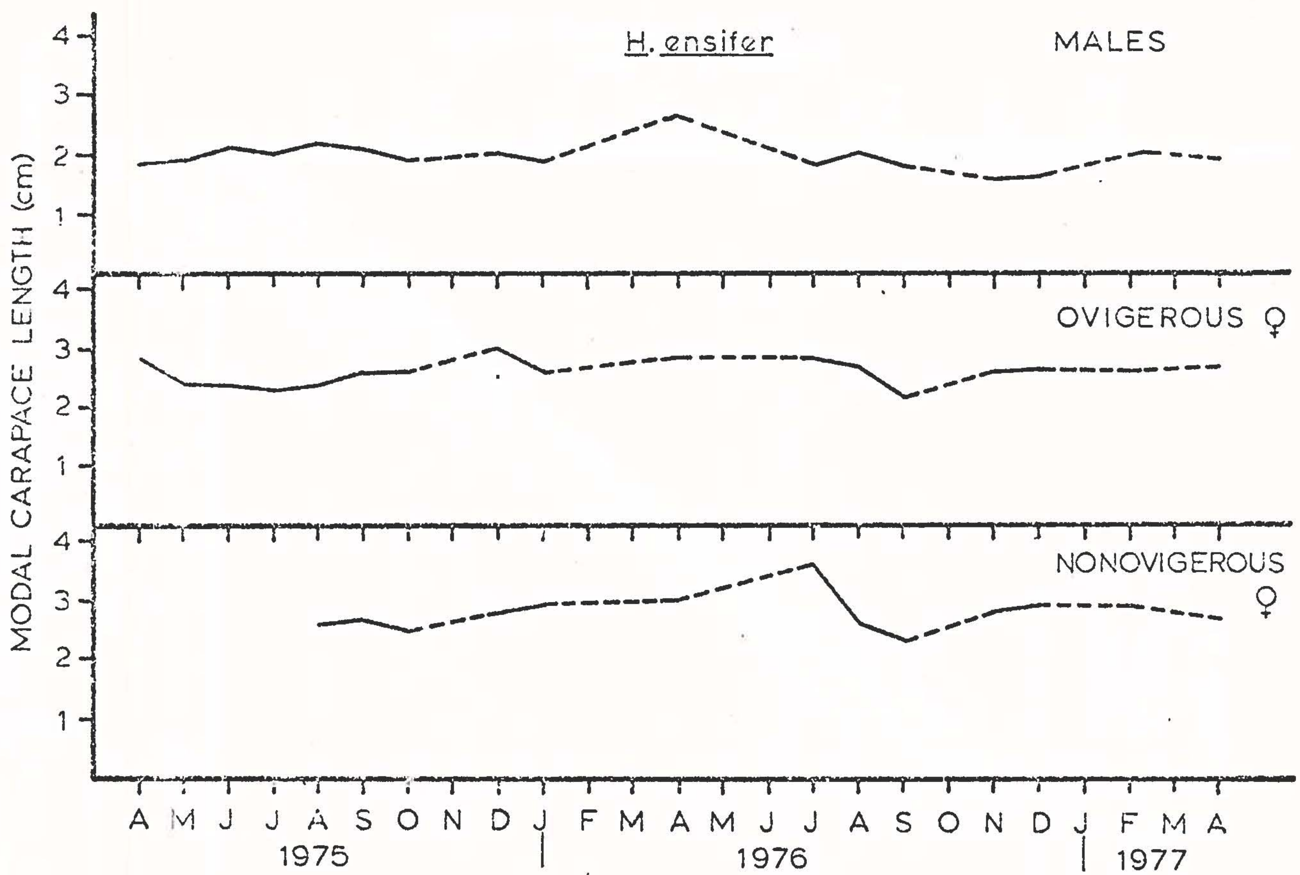

Figure 18. Variations in modal carapace length (cm) during the months April 1975 to April 1977. Dotted lines represent periods when no data were collected.

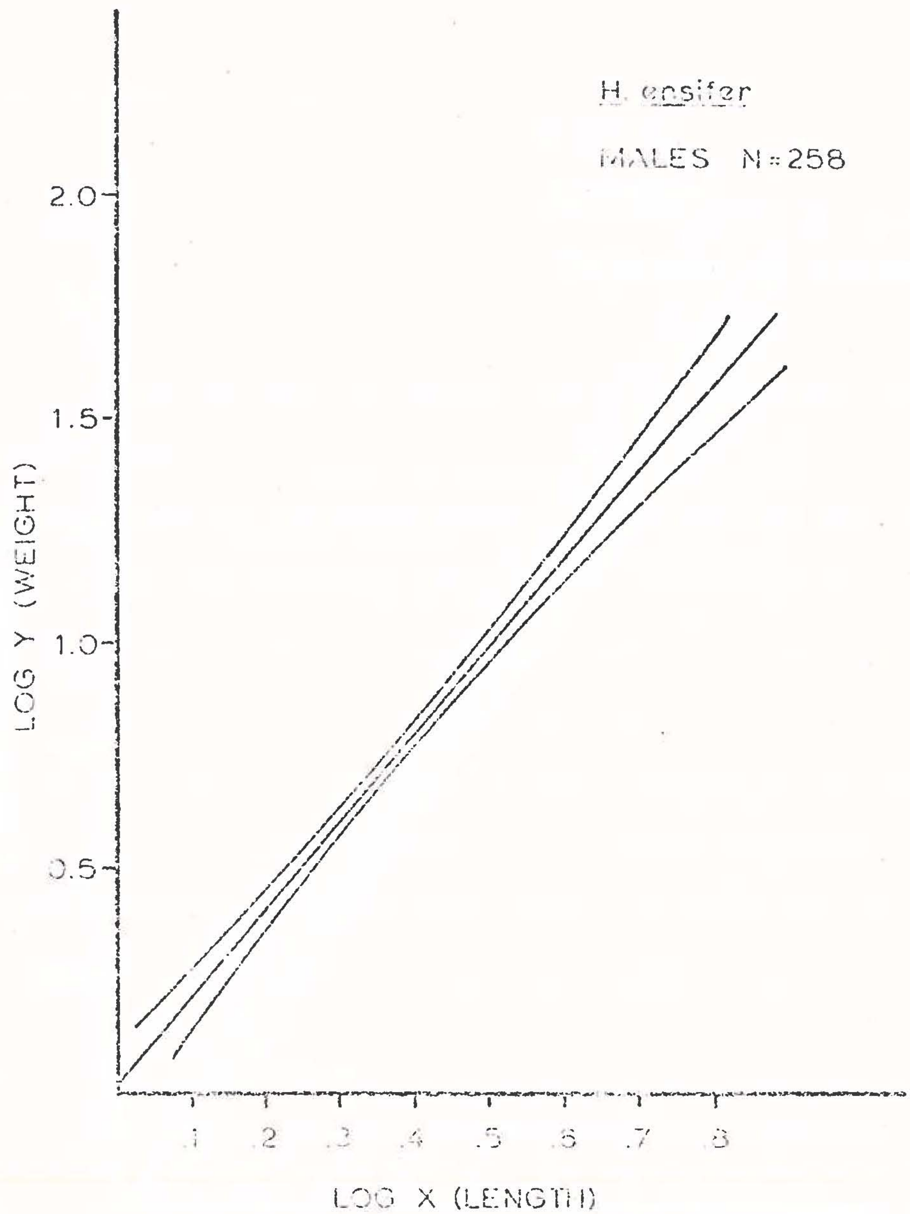

Figure 19. Length-weight regression line for 258 H. ensifer males, with 95 percent confidence limits.

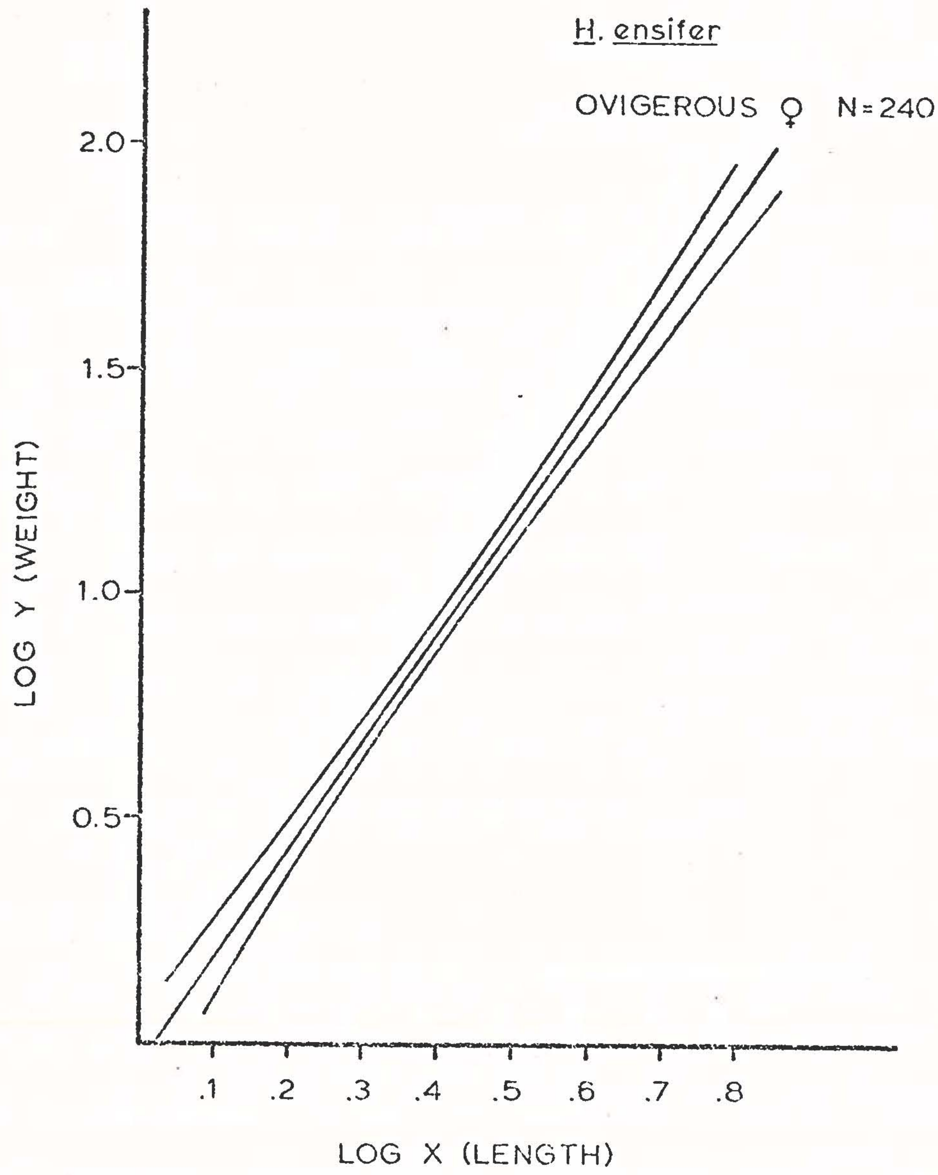

Figure 20. Length-weight regression line for 240 H. ensifer ovigerous females, with 95 percent confidence limits.

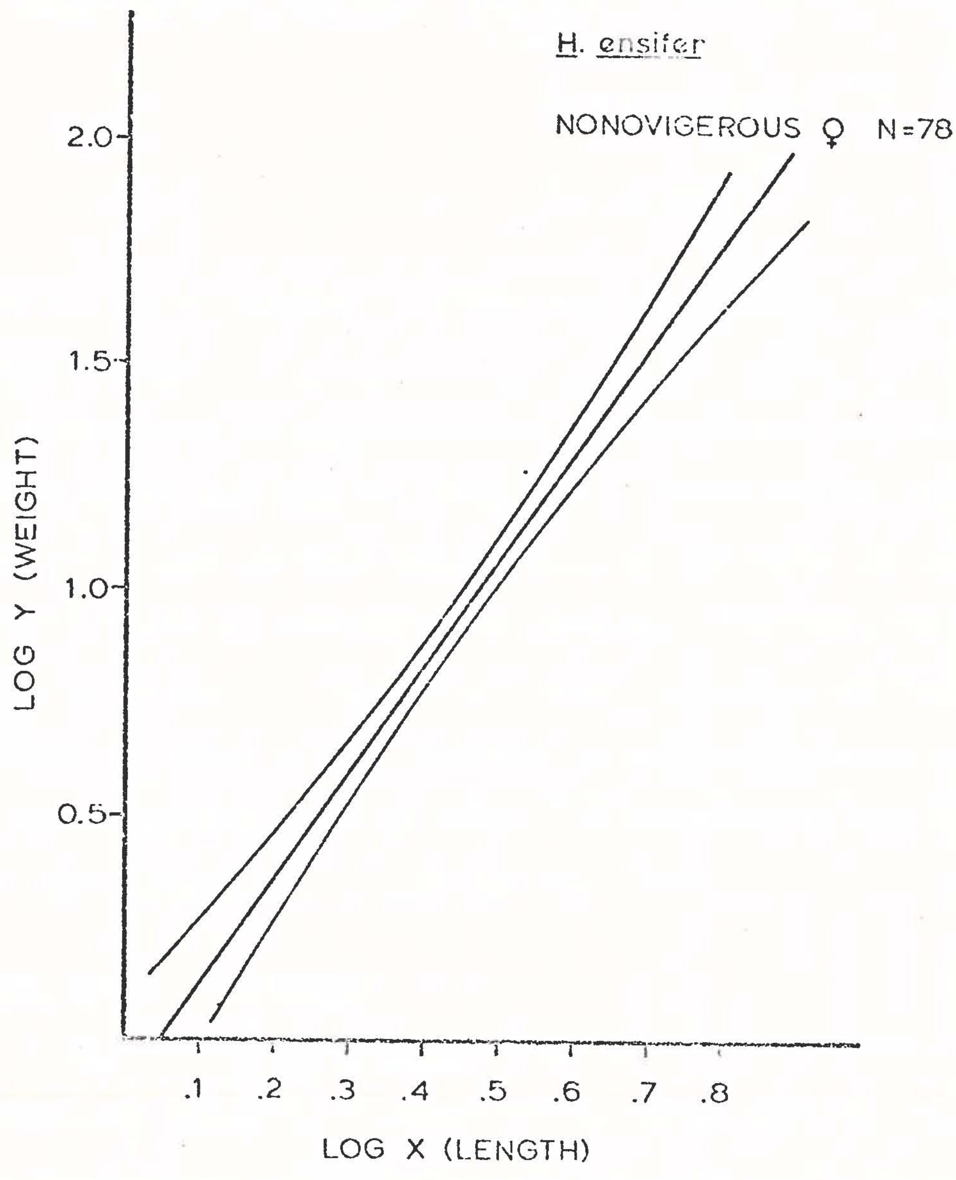

Figure 21. Length-weight regression line for 78 H. ensifer nonovigerous females, with 95 percent confidence limits.

Ovigerous females: $\log W = 2.4380 \log CL - 0.0594$

$$W = 0.872\ CL^{2.4380}$$

$$r^2 = 0.801$$

Nonovigerous females: $\log W = 2.3906 \log CL - 0.1222$

$$W = 0.7548\ CL^{2.3906}$$

$$r^2 = 0.724$$

where W = total weight in grams and CL = carapace length in centimeters.

Tails make up approximately 45 percent of the weight of both males and females (Fig. 22). There is no significant variation in tail weight with an increase in total size for males or nonovigerous females. However, tail weight of ovigerous individuals does change as an inverse function of total size. Regression analysis showed a significant decrease in tail size with increase in total size ($p < .001$, Student's t-test on the slopes).

Heterocarpus laevigatus

Heterocarpus laevigatus (Fig. 3A,B) is a larger species and inhabits a deeper depth range than *H. ensifer*. This species was collected between 457 and 732 m with the depths of greatest abundance between 610 and 732 m (Figs. 10 and 23). Although trapping below 732 m was not performed because of the range of the fathometer, it appears that *H. laevigatus* probably occurs at depths beyond this.

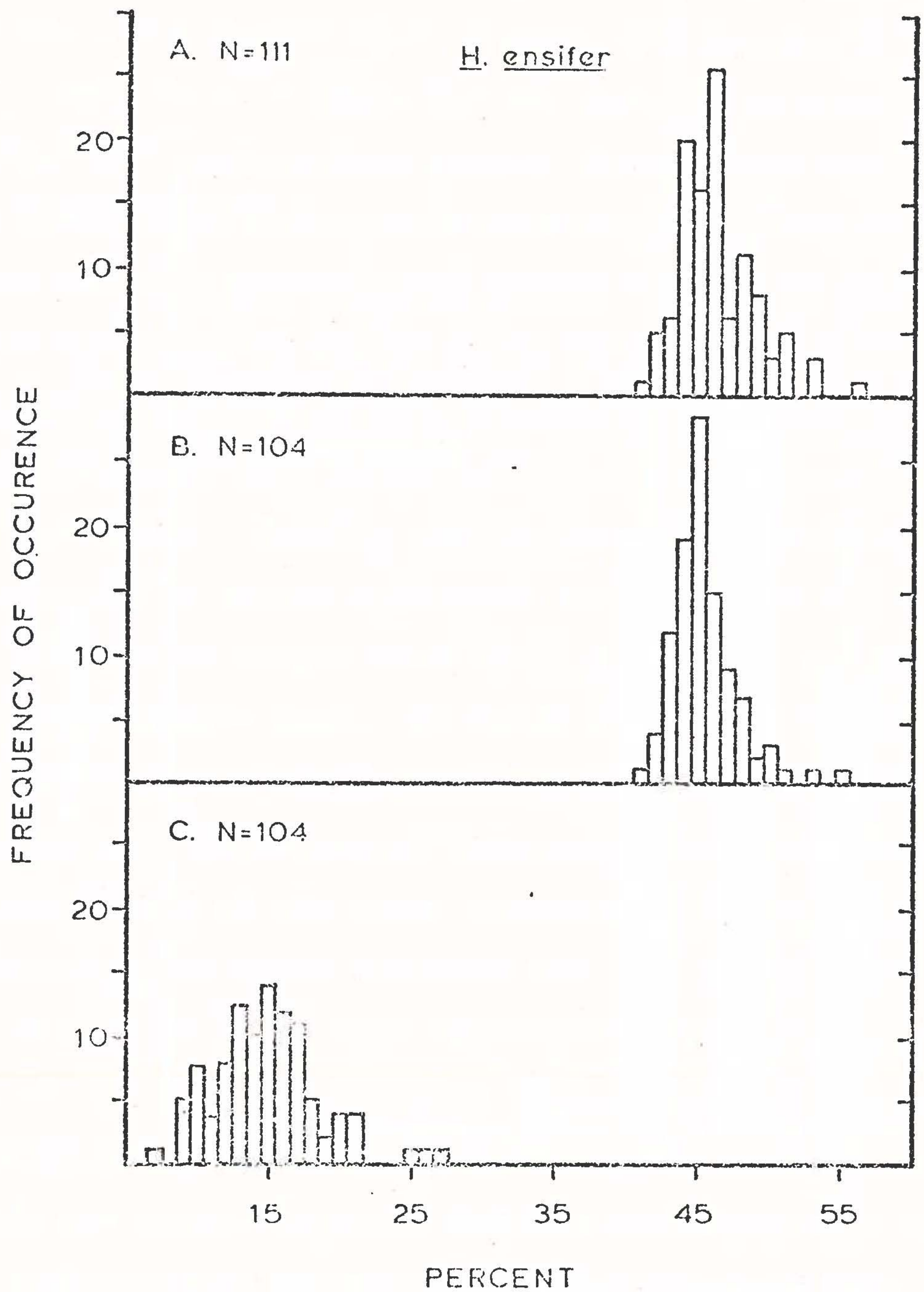

Figure 22. Weight of tail with shell as a percent of the total weight for H. ensifer. A. Males and nonovigerous females. B. Ovigerous females. C. Weight of eggs as a percent of total weight for ovigerous females.

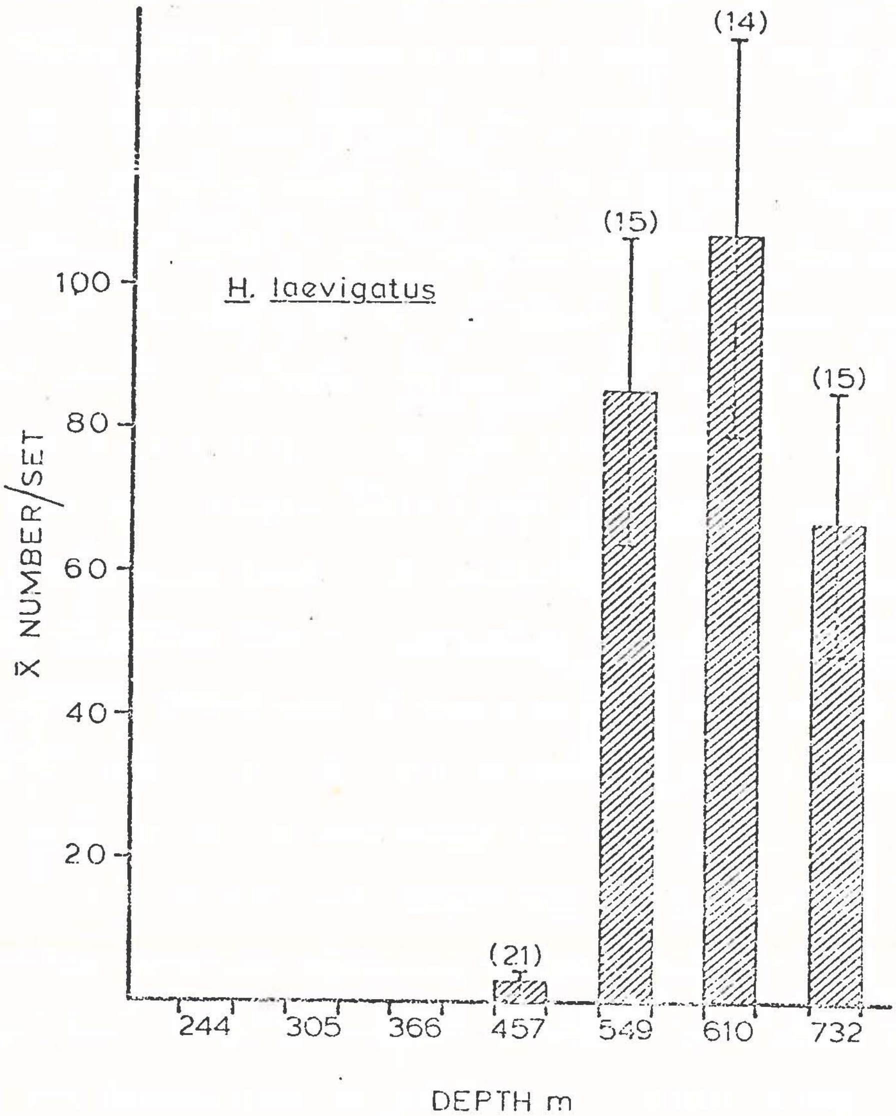

Figure 23. Depth distribution by numbers of H. laevigatus caught per set, all areas and seasons inclusive. Standard error of the mean is indicated, and the number of sets in parentheses.

Variation in abundance with respect to depth and area indicate the greatest catches occurred in Agana Bay by weight and number between 610 and 732 m (Figs. 24 and 25). Catch rates at Double Reef and in Agana Bay by weight were consistent and significantly greater than catches in Agat Bay. Catch rates in Agana Bay and Agat Bay by number were constant and significantly greater than catches at Double Reef. Variation in abundance with respect to depth and season indicate significantly greater catches in summer by weight and spring by number (Figs. 26 and 27). Variations in abundance related to area and season were evaluated and results indicate that catches decrease from summer through fall and winter. Catches are consistent in fall and winter and increase as spring approaches (Figs. 28 and 29).

The largest single catch of *H. laevigatus* was 3.7 kg at 732 m at Double Reef. Of the 65 total sets within the depth distribution for *H. laevigatus*, all but 18 caught this species. Seventeen of these sets were situated at the shallow end of its depth distribution, 457 and 549 m, or the depths of least abundance for this species.

Results of a one year comprehensive seasonality study indicate the greatest variation in abundance of *H. laevigatus* by weight and number is related to depth ($p < .001$, 3-way ANOVA), and ($p < .05$, 3-way ANOVA). Statistics also show that variations in abundance related to area are significant for weight ($p < .05$, 3-way ANOVA) but are not significant for numbers. There are significant variations in abundance

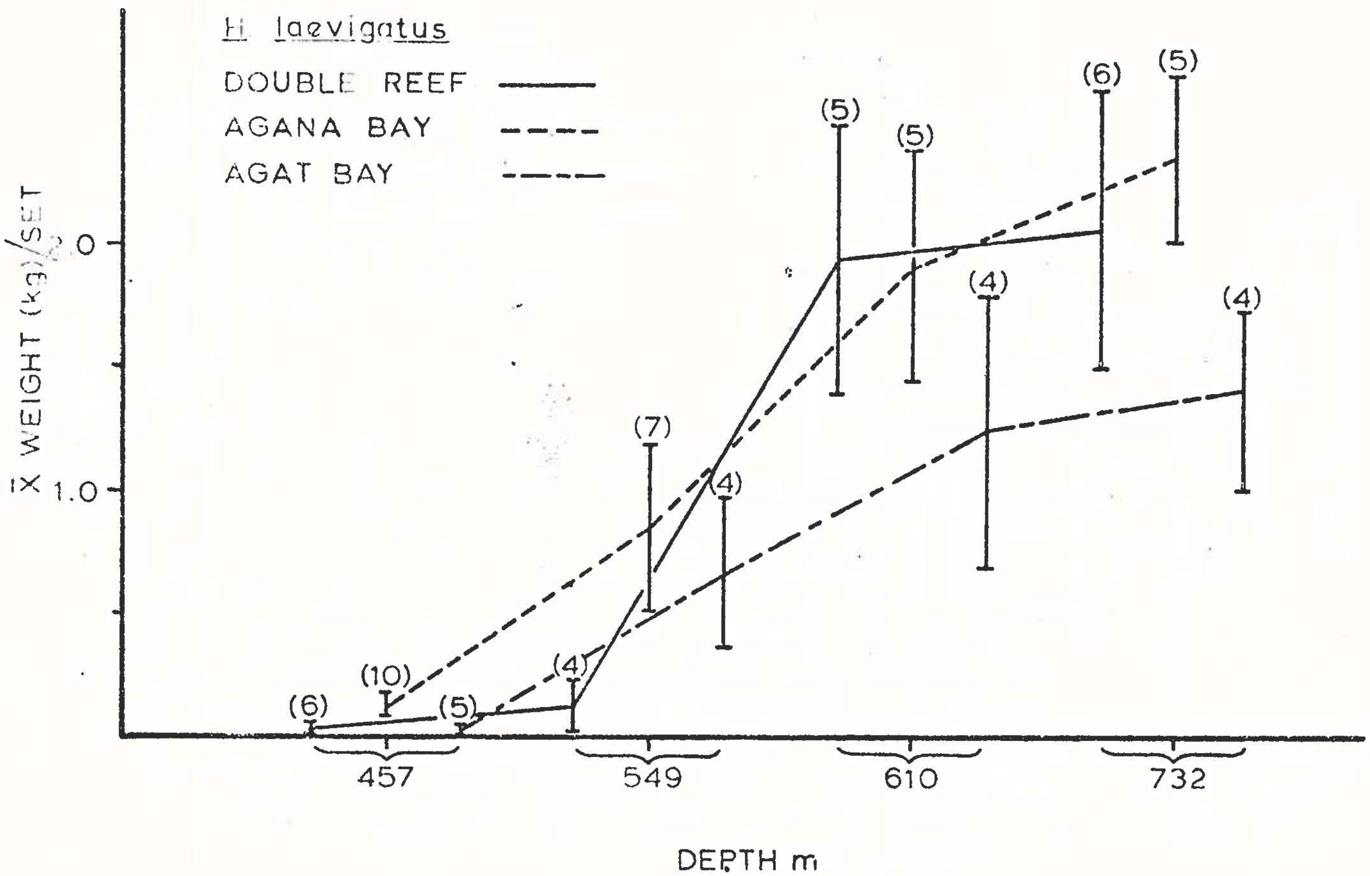

Figure 24. Mean catch weight (kg) of H. laevigatus per set by depth for each area, all seasons inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

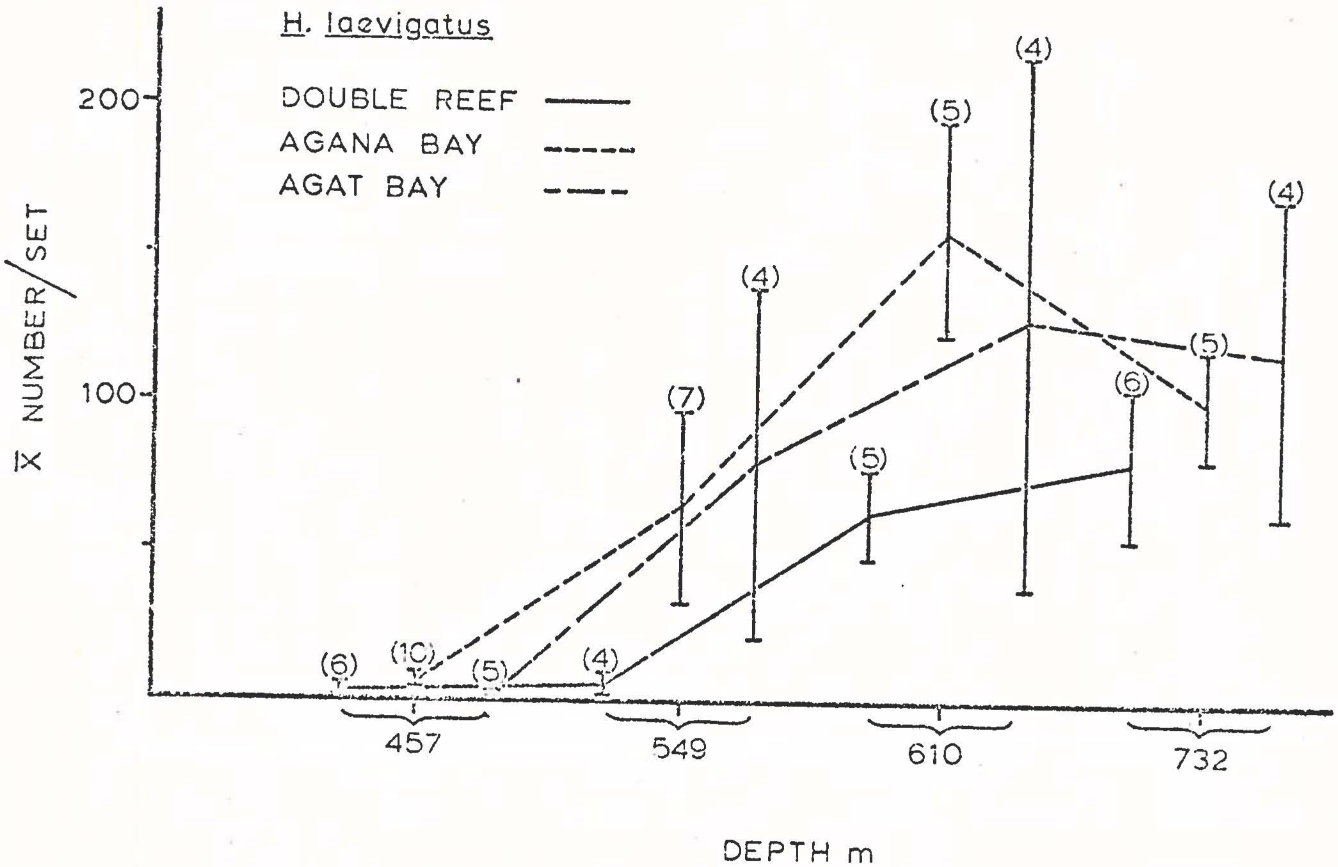

Figure 25. Mean number of H. laevigatus per set by depth for each area, all seasons inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

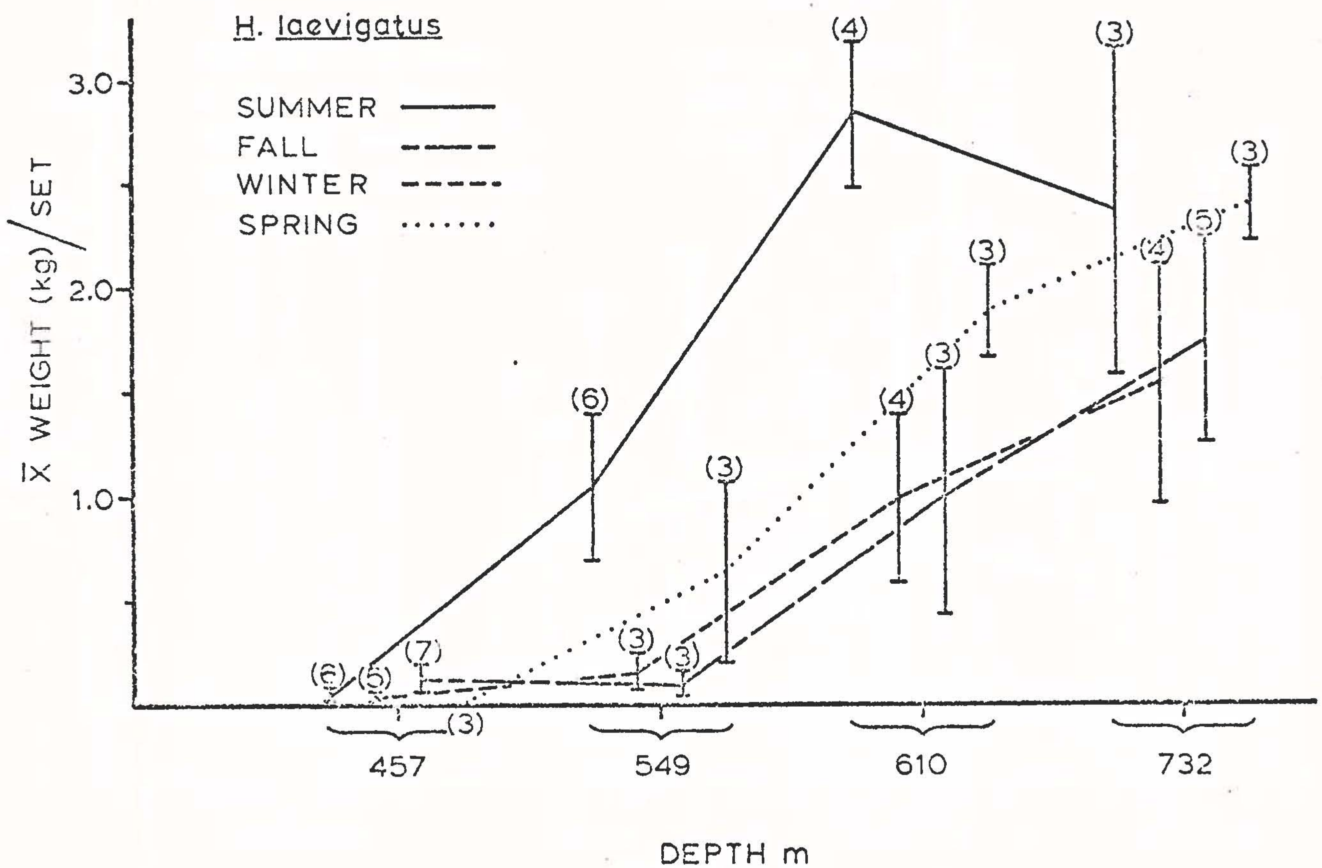

Figure 26. Mean catch weight (kg) of H. laevigatus per set by depth for each season, all areas inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

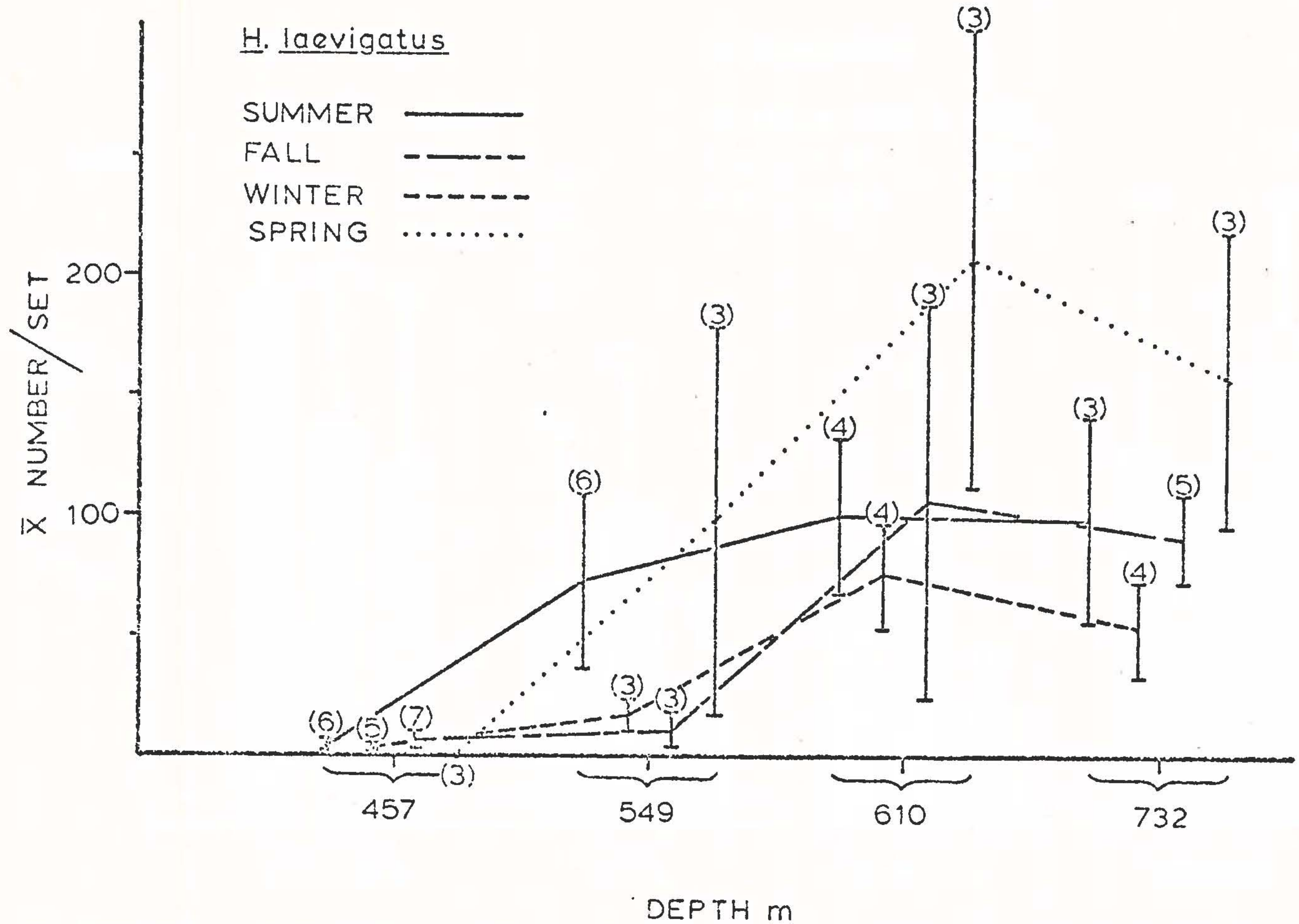

Figure 27. Mean number of H. laevigatus per set by depth for each season, all areas inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

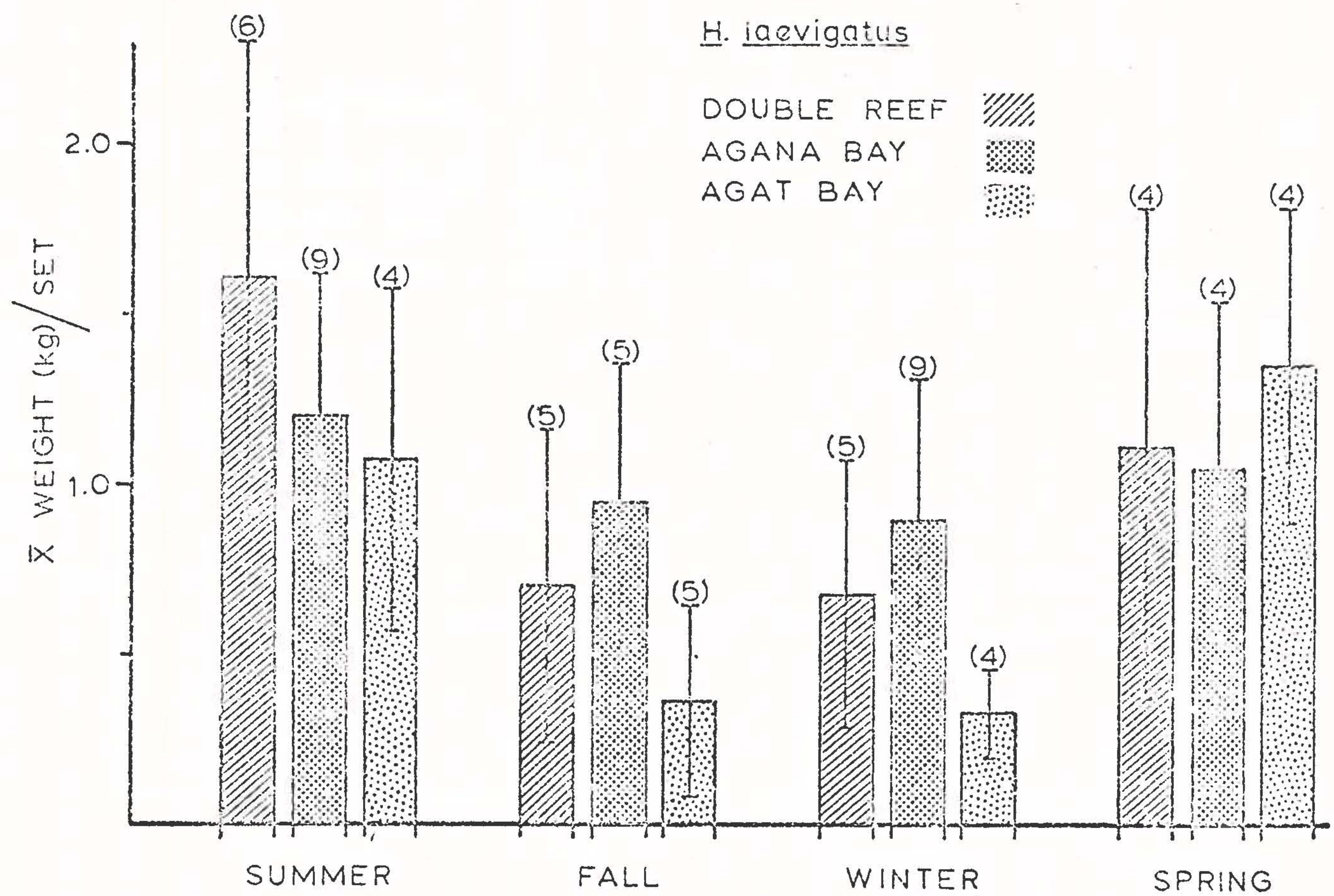

Figure 28. Mean catch weight (kg) of *H. laevigatus* per set by area for each season, all depths inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

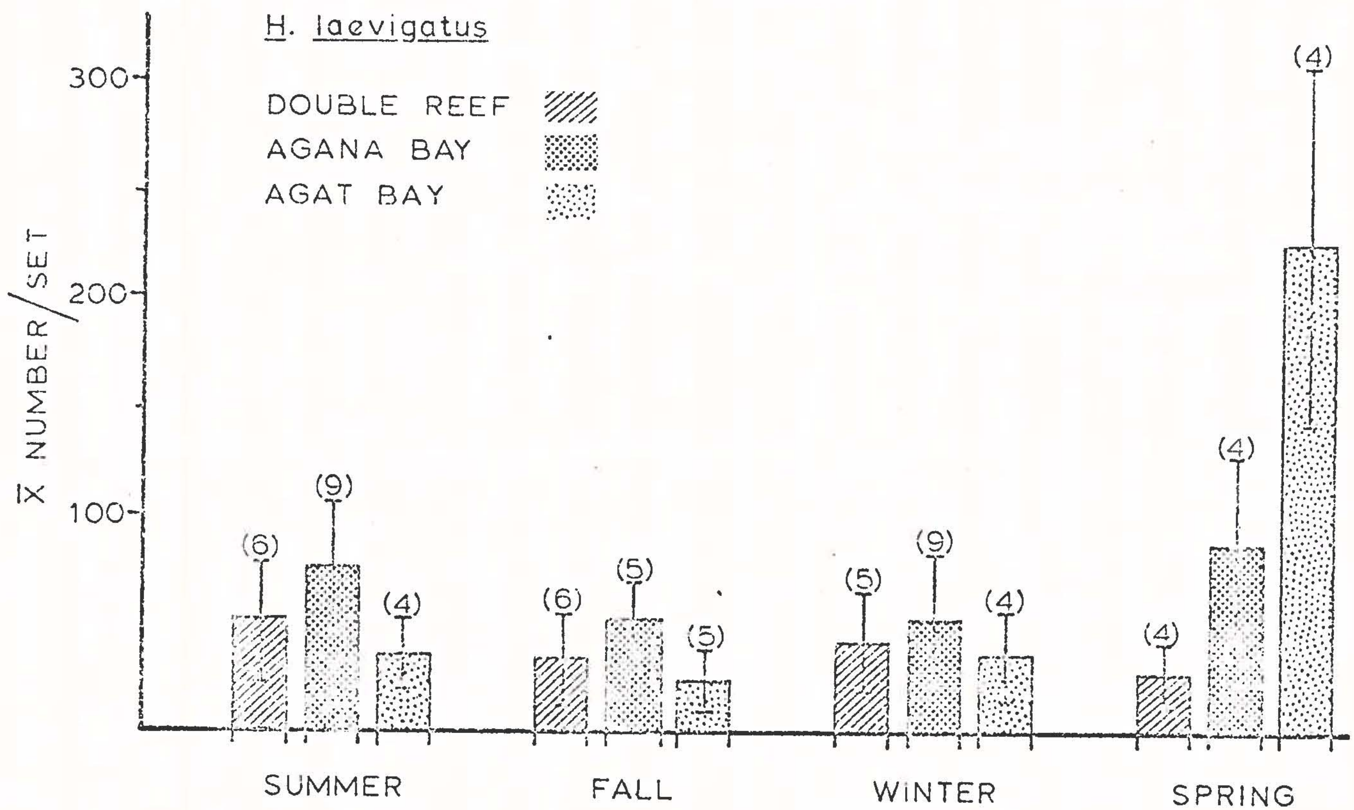

Figure 29. Mean number of *H. laevigatus* per set by area for each season, all depths inclusive. Standard error of the mean is indicated, and the number of sets is in parentheses.

by weight for the combination of factors, depth and area, and depth and season ($p < .01$, 3-way ANOVA). Variations in abundance related to area and season are also significant for numbers ($p < .05$, 3-way ANOVA).

There is a significant difference in the mean weight per individual of H. laevigatus between 457 and 549 m (Table 3) ($p < .001$, Student's t-test). When the data for depths 549 and 732 m are lumped and tested against the data at 457 m, a highly significant difference was found to exist ($p < .001$, Student's t-test).

Males outnumber females by two or three to one (Tables 4 and 5). Nonovigerous females constitute a relatively high percent of the total, usually greater than that of ovigerous individuals. H. laevigatus does not exhibit a well defined trend in sex ratio with respect to depth. A greater percentage of males were found at 549 and 610 m while ovigerous individuals were found in greatest abundance at 457 m.

Modal carapace length data for H. laevigatus indicate that ovigerous individuals were largest from fall through spring and males were smallest in summer (Fig. 30). The minimum reproductive size for H. laevigatus was 1.6 cm with a mean reproductive size of 3.4 cm. The increase in modal carapace length over time suggests that H. laevigatus grows at a rate of 1.2 cm per year, indicating maturation (smallest recruit size to mean reproductive size of females) in approximately 3.5 to 4.5 years. These growth rates are

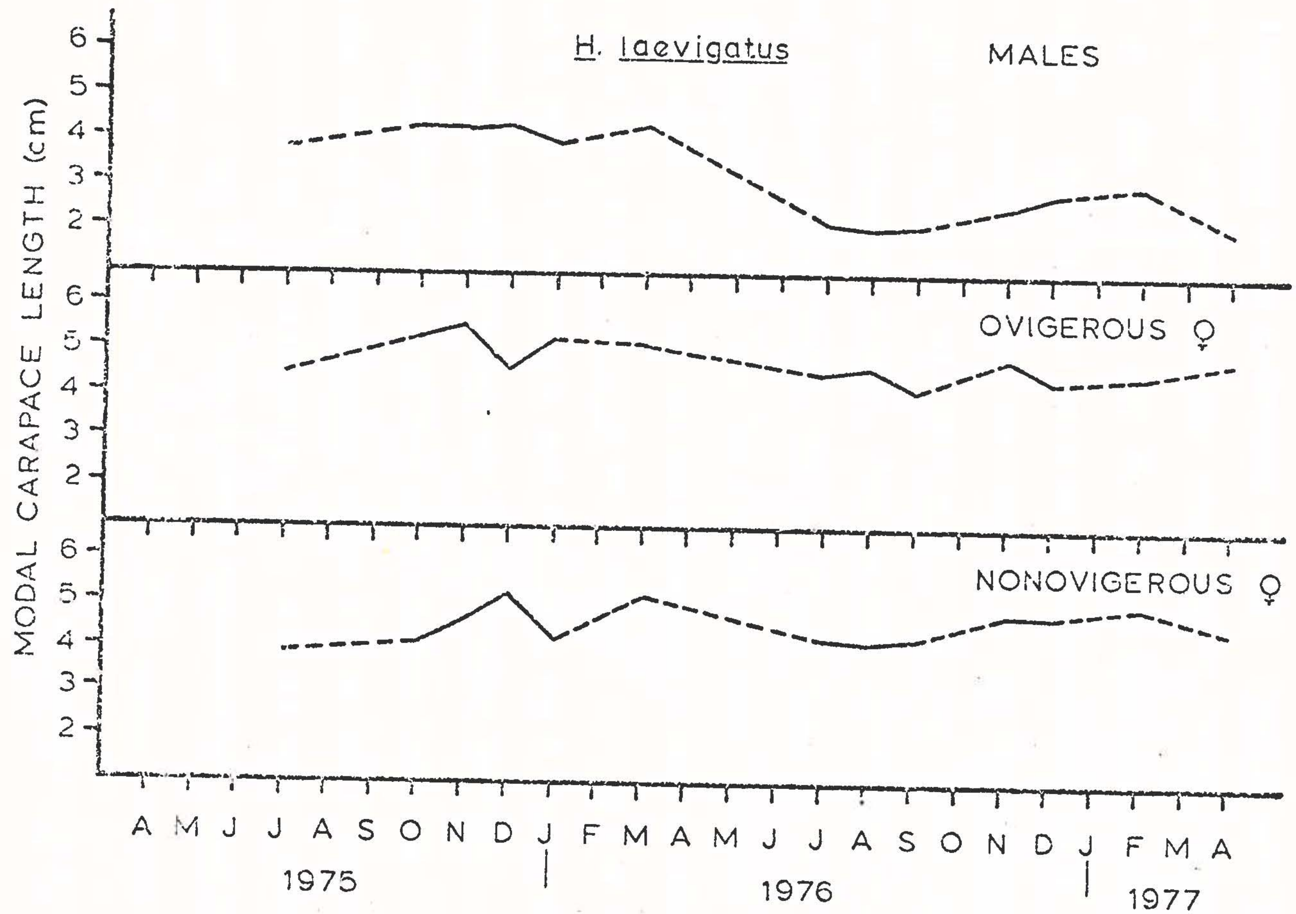

Figure 30. Variations in modal carapace length (cm) during the months April 1975 to April 1977. Dotted lines represent periods when no data were collected.

approximate since size increases with a change in sex from male to female.

There is evidence that inshore migration occurs for *H. laevigatus* on a nocturnal cycle. Preliminary day-night sets were effected in one area over a 24-hour period at 457 m. One trap was set for a full day beginning in the morning. Four 6-hour sets were made within 30 m of this set beginning at noon the same day. *H. laevigatus* were caught in only one of the regular sets at 457 m during the two year trapping study. During the day-night studies the four 6-hour sets caught two to eight times more *H. laevigatus* than did the single 24-hour set next to it which caught only two of this species. Ninety-four percent of all *H. laevigatus* were caught during the two sets from 6 p.m. to midnight and midnight to 6 a.m., suggesting inshore movement during the crepuscular periods.

Computerized length-weight regression analysis was conducted on *H. laevigatus* using 531 males (Fig. 31), 83 ovigerous individuals (Fig. 32), and 43 nonovigerous females (Fig. 33). The fitted exponential length-weight curve for each group is as follows:

Males: $\log W = 2.9739 \log CL - 0.3901$

$$W = 0.4073\ CL^{2.9739}$$

$$r^2 = 0.970$$

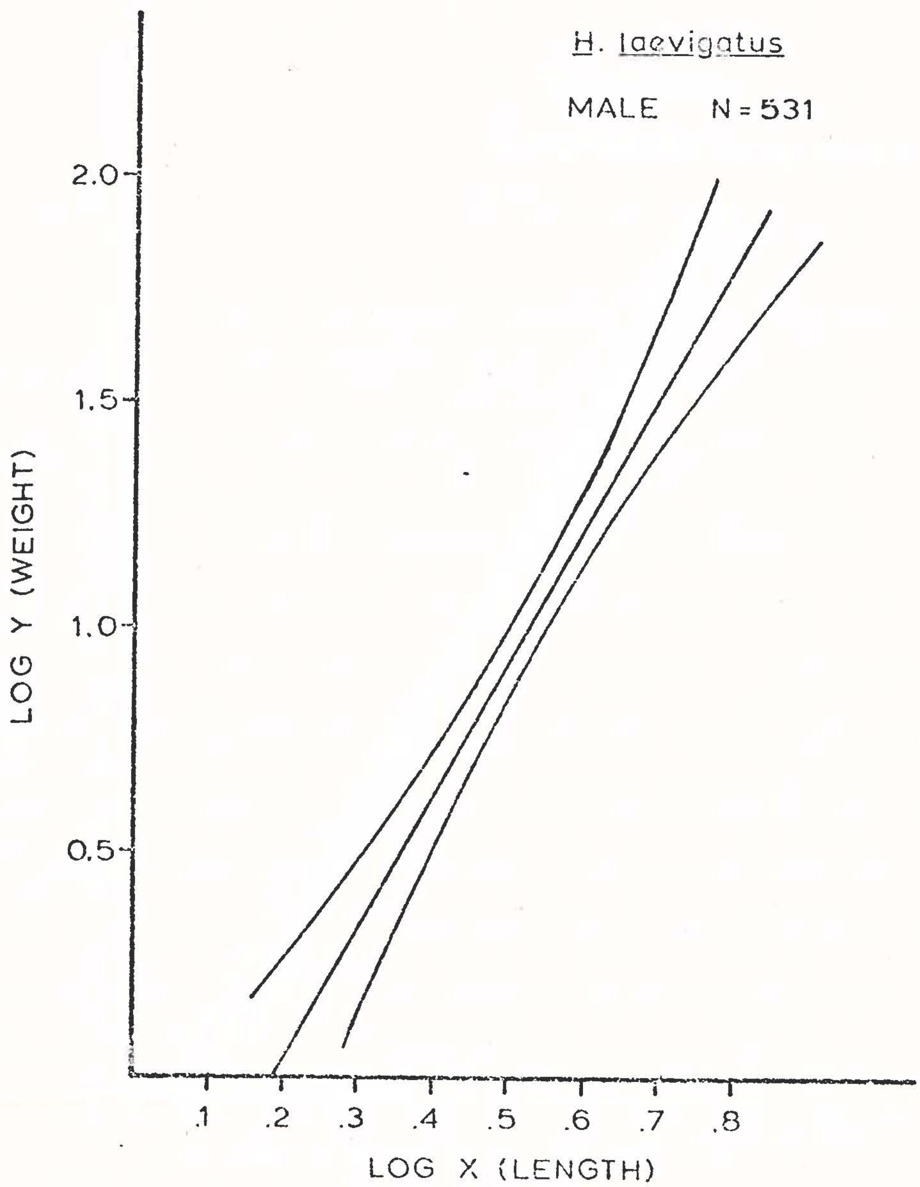

Figure 31. Length-weight regression line for 531 H. laevigatus males, with 95 percent confidence limits.

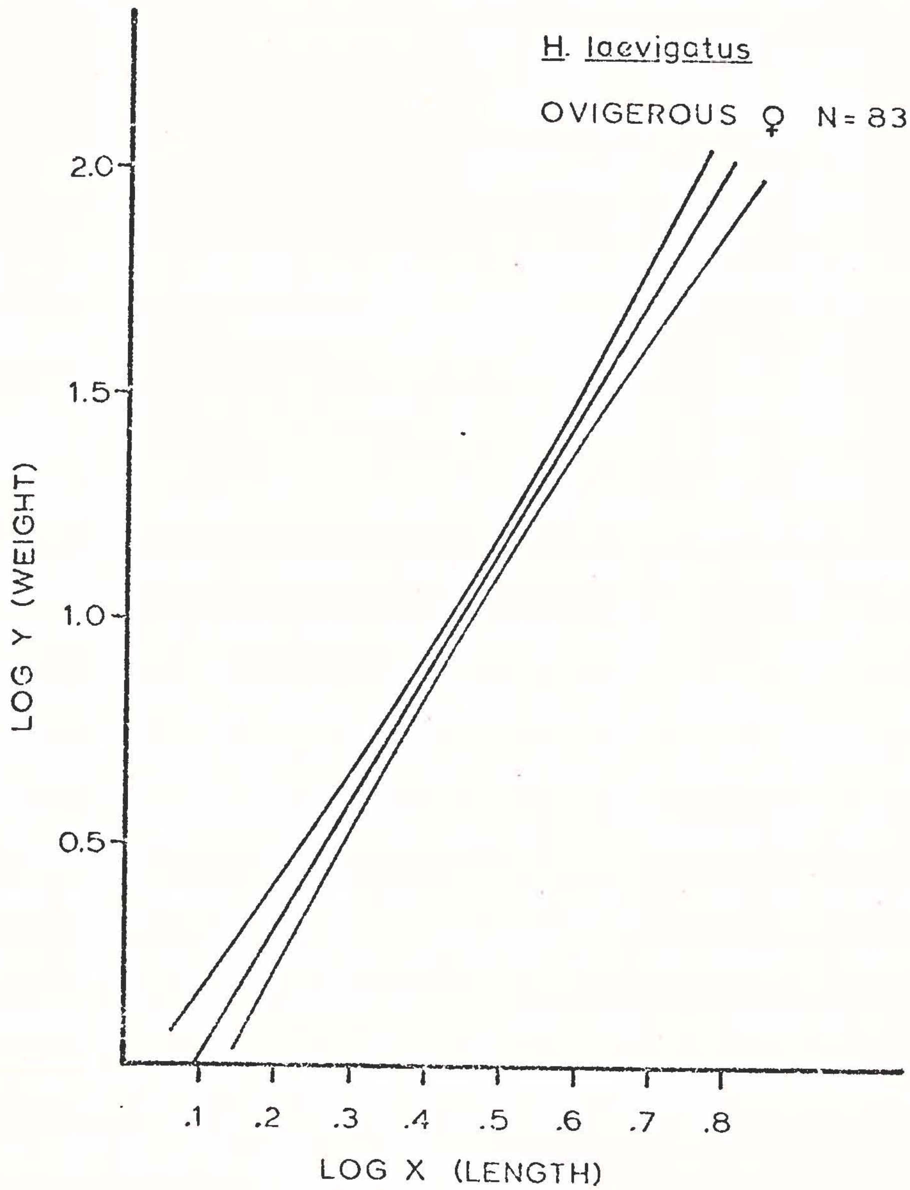

Figure 32. Length-weight regression line for 83 *H. laevigatus* ovigerous females, with 95 percent confidence limits.

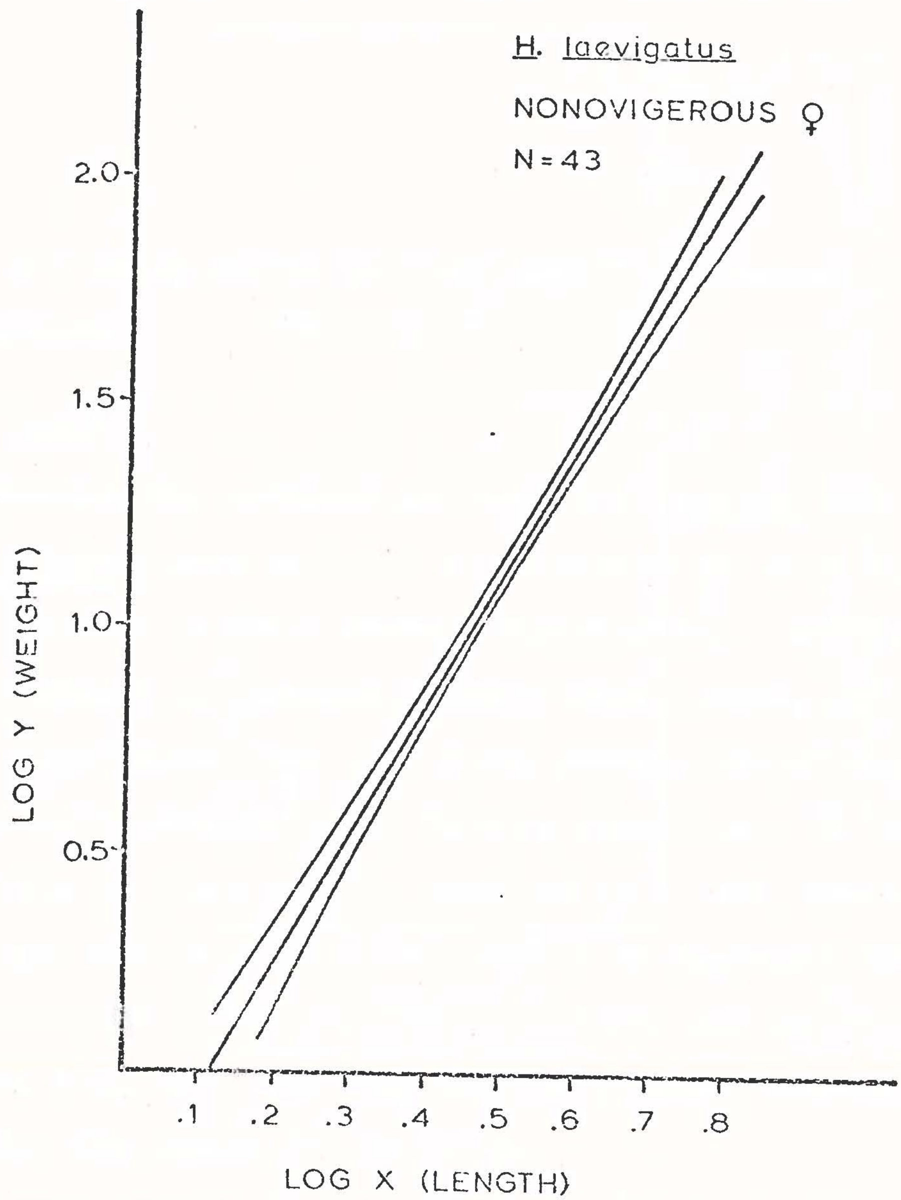

Figure 33. Length-weight regression line for 43 *H. laevigatus* nonovigerous females, with 95 percent confidence limits.

Ovigerous individuals: $\log W = 2.8496 \log CL - 0.2651$

$$W = 0.5431\ CL^{2.8496}$$

$$r^2 = 0.974$$

Nonovigerous females: $\log W = 2.9162 \log CL - 0.3427$

$$W = 0.4542\ CL^{2.9162}$$

$$r^2 = 0.953$$

where W = total weight in grams and CL = carapace length in centimeters.

Total Catch

Results for combined catches of H. ensifer and H. laevigatus were analyzed to determine the most significant factors in their overall distribution. Analysis by weight showed all primary factors--depth, area, and season--to be significant ($p < .01$, 3-way ANOVA). Depth and season is the only combination of factors significant to the distribution of these species combined ($p < .001$, 3-way ANOVA) by weight and ($p < .01$, 3-way ANOVA) by numbers. Data were analyzed in terms of mean catch per set for both species (Fig. 10), and they suggest a rather uniform biomass for the depths 305 to 732 m.

Approximately 42 percent of the total weight of males was comprised of tail weight (Fig. 34). Regression analysis indicated that there was no significant difference between the percentage of the total weight contributed by the tail

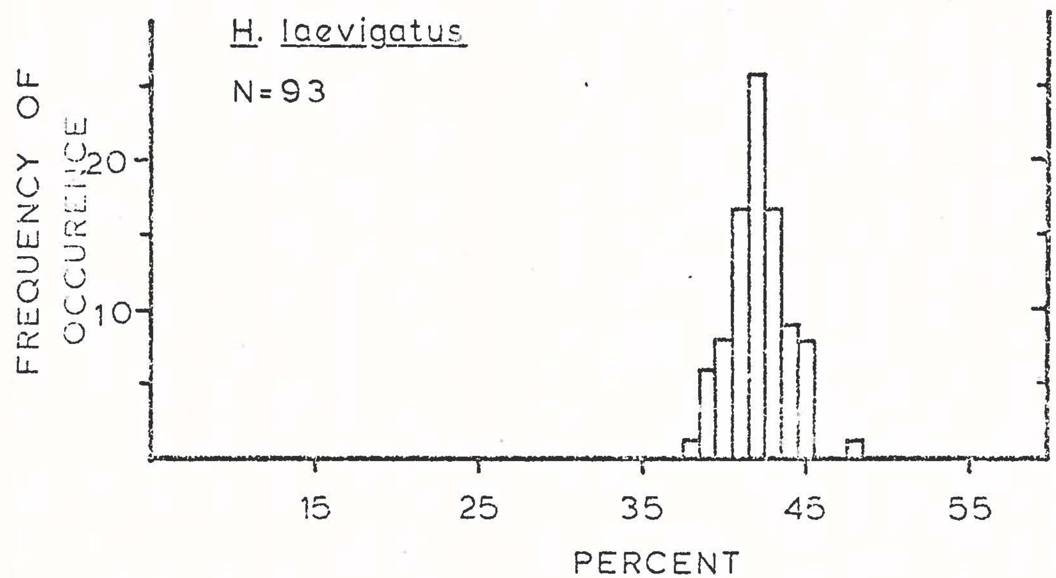

Figure 34. Weight of tail with shell as a percent of the total weight for 93 _H_. _laevigatus_ males.

with an increase in total size. Ovigerous individuals were not available for measurement when these tests were being carried out.

DISCUSSION

Depth Distribution

In Hawaii, H. *ensifer* is most abundant between 244 and 366 m (Clarke 1972, Struhsaker and Aasted 1974). My data indicate a slightly deeper depth of greatest abundance between 366 and 457 m. Clarke (1972) also collected H. *laevigatus* in Hawaiian waters as shallow as 366 m but stated that this is probably the upper limit in their distribution. Struhsaker and Aasted (1974) collected this species from 430 to 822 m and suggested the depth of greatest abundance between 440 and 684 m. My data again indicate a deeper depth of greatest abundance between 610 and 732 m.

Surface temperatures differ by approximately 2.5°C between Hawaii and Guam, approximately 25.0°C and 27.6°C, respectively (Jones et al. 1976). Charnell et al. (1967) collected extensive deep water temperatures in the Hawaiian Islands. Comparison of these data to mine (Table 1) indicate that temperatures are at least 2°C to 2.5°C greater at equivalent depths in Guam waters to 450 m. However, there does not appear to be significant change in temperature below this depth.

Gunderson et al. (1972) determined the amount of oxygen present in the water column to 1150 m in Hawaiian waters and stated that "a slight but consistent oxygen maximum was found near 100 m and a minimum, of about 1 mg O_2/liter, existed between 700 and 900 m" (p. 526). He also indicated that oxygen values to 7 mg O_2/liter were taken at the surface. The overall distribution of oxygen in Guam waters is consistent with that found in Hawaii. An oxygen inversion layer appears to exist between 305 and 457 m. Oxygen increases from 5.6 ppm at 305 m to 6.6 ppm at 457 m. The inversion layer corresponds with the depths of greatest abundance for H. ensifer.

Deep water salinity profiles to 1000 m were collected by Charnell et al. (1967) which indicate no appreciable difference between 240 and 700 m, approximately 34.6 ppt. My data indicate only slightly less salinity 34.2 ppt between these depths. I had expected to find some correlation between sediment size and abundance of shrimp, but this was not the case. The range of physical and chemical parameters in Hawaiian waters measured within the depth ranges of the two species are shown in Table 6. These can be compared with Guam data (Table 5). The similarity in physical parameters between Guam and Hawaii does not account for the slightly deeper depth distribution of H. ensifer and H. laevigatus. One critical parameter left unexamined which may explain this situation is the effect of available light known to be important in deep pelagic organisms (Marshall 1954).

Clarke (1972) demonstrated that the 274 to 366 m depth range was the zone where the largest size class of

Table 6. The range of physical and chemical parameters in Hawaiian waters within the depth ranges for *H. ensifer* and *H. laevigatus*.

Species	*H. ensifer*	*H. laevigatus*
Depth	146-732+m	366-822+m
Depth of greatest abundance	244-366 m	440-684 m
Temperature	21.5°-6.0°C	9.5°-5.1°C
Temperature in depth of greatest abundance	11.0°-9.5°C	8.4°-5.1°C
Salinity	34.3-35.3 ppt	34.4-35.3 ppt
Salinity in depth of greatest abundance	34.3-34.7 ppt	35.0-35.3 ppt
Oxygen	6.5-1.0 ppm	4.5-1.0 ppm
Oxygen in depth of greatest abundance	5.9-4.5 ppm	2.7-1.0 ppm

H. ensifer occurs and suggested that catches in deeper or shallower depths were comprised of a significantly greater portion of smaller individuals. My data indicate that the smallest individuals of *H. ensifer* occur to 366 m (Table 3). Larger individuals, along with small ones, occupy depths greater than 366 m. The largest size class for *H. laevigatus* is found at 457 m, and there does not seem to be any size trend with depth. Struhsaker and Aasted (1974) found the largest size class of *H. ensifer* usually numbered 75 to 100 per kg but did not determine the depth at which these were collected. My data (Table 3) indicate similar results where the mean number per kg was 98 at 732 m. The number per kg of *H. laevigatus* is least at the upper end of its depth distribution. It appears that these animals may be dispersed at specific depths based on their size, the smallest at the shallower end of the distribution and the larger at the deeper end of the distribution. This seems apparent for *H. ensifer* and less defined for *H. laevigatus*.

The percent of *H. ensifer* males in the total population is three to four times greater than females, with a trend toward more males at greater depths (Tables 4 and 5). Clarke (1972) also found this, and he also stated that the proportion of ovigerous females varies between 64 and 87 percent above 366 m and drops gradually to 35 percent at 640 m. I found the greatest percent of ovigerous females, 40 to 60 percent, between 305 and 366 m which corresponds closely to the depth of greatest abundance for *H. ensifer*.

Ecological theory of competition is often based on the unsubstantiated assumption that there is a definite, finite, limit to the total abundance of closely related species that can be supported in a given area (Odum 1971, MacArthur 1972). Unfortunately, I could not find any evidence of this for Heterocarpus while searching the literature. However, the data in this paper show that the mean weight of H. ensifer per catch decreases with depth while that of H. laevigatus increases (Fig. 10). The implication here is that the total biomass supported is remarkably constant. Another local example of this is holothurians on the reef flat in Yap (Amesbury et al. 1976). These examples may be very useful in examining the basis for the competition theory of ecology.

Seasonality in Reproduction

Clark (1972) offered the opinion that H. ensifer in Hawaii probably breeds and spawns between 305 and 366 m in the winter but is dispersed either deeper or pelagically during the rest of their life cycle. My data indicate that in Guam these animals also breed and spawn at approximately 305 to 366 m since the greatest percent of ovigerous individuals are found at these depths. Modal carapace length indicates a preponderance of small males during the fall (Fig. 18). Although there does not appear to be significant variation in the size of ovigerous individuals throughout the months, size does increase slightly during the winter. The apparent shift in depth distribution to deeper water from winter to spring (Figs. 14 and 15) suggest that at least large females may migrate to deeper water to breed. Clarke (1972) outlined similar reproductive migratory patterns for _H. ensifer_ in Hawaiian waters as did Rasmussen (1967) for the boreal species _Pandalus borealis_. Ovigerous individuals were also found in least abundance during the winter season and greatest abundance in late spring (Fig. 35). Analysis of mean catch results for area and season indicate very low catches in summer, increasing as fall approaches.

These data, although not conclusive, suggest that the breeding season begins in late winter or early spring when females were at their largest continuing through spring when females were most abundant. It is suggested that spawning occurs in late spring and summer when the lowest catch rates were recorded. New recruits were noticed in the fall when the largest catches of small males were recorded. These results appear to follow a similar pattern set forth by Clarke (1972) for the same species, although spawning occurs earlier in Hawaiian waters. Clarke further suggested that females probably die after spawning. My data also indicate that this may be the case since the modal carapace length of nonovigerous females is slightly less than ovigerous individuals (Fig. 30).

Heterocarpus laevigatus exhibits a more well defined breeding season than does _H. ensifer_. Modal carapace

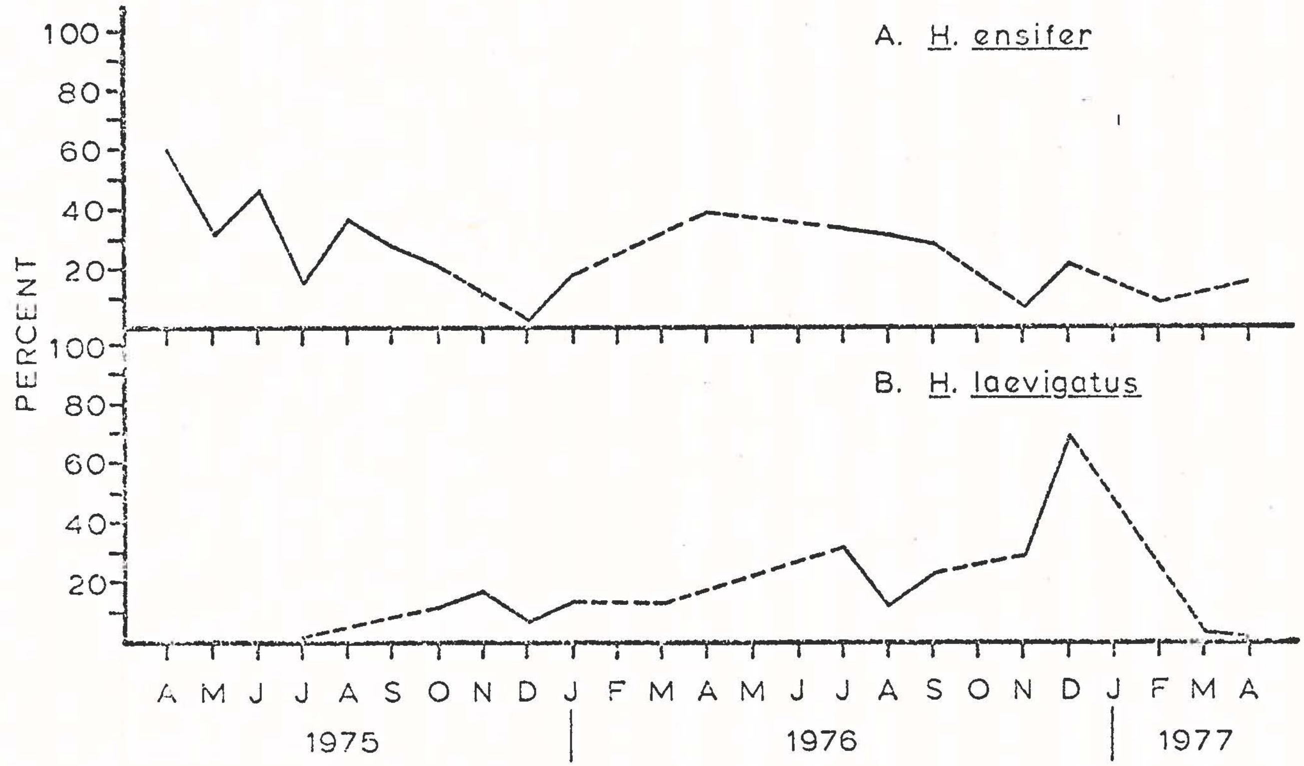

Figure 35. Seasonal changes in percent ovigerous females for both species. A. H. ensifer. B. H. laevigatus. Dotted lines represent periods when no data were collected.

length for males was at its lowest during late summer (Fig. 30). There did not appear to be a significant change in the size of ovigerous individuals throughout the months; however, it appears the peaks occur in late fall. Ovigerous individuals were found in least abundance during late spring and summer and in greatest abundance during the winter season (Fig. 35). Analysis of mean catch results for area and season indicate lowest catches in fall and winter increasing toward spring (Figs. 28 and 29). These data seem to indicate that breeding takes place during the winter when females were at their largest. Spawning occurs in early spring and new recruits can be observed in late spring and summer when carapace length for males was at its lowest.

Growth and Sex Reversal

The life cycle of most pandalids lasts from four to six years, however, most growth takes place in the first three years (Barr 1970). Extrapolation of the increase in modal carapace length over time suggests that *H. ensifer* grows at a rate of 1 cm per year (Fig. 18), and *H. laevigatus* at a rate of 1.2 cm per year (Fig. 30). Growth is fairly constant for all new recruits up to a certain size, at which time growth increases rapidly for those individuals which change sex (Butler 1964). With few exceptions, pandalids are protandric hermaphrodites, i.e., individuals mature as males but later transform to function as females.

The change in sex occurs gradually over a period of several molts. The transformation of male to female is permanent and the result is a breeding population that normally has several age groups of which the youngest are males and the oldest are females. Wenner (1972) indicated that the consistent lack of females in the smaller size class generally leads to the conclusion that sex reversal is a normal occurrence of a species. This pattern is clearly exhibited by both *H. ensifer* and *H. laevigatus* in Guam waters.

Rasmussen (1967) studied time of maturation and fecundity in the boreal species *Pandalus borealis* at different latitudes in the north Atlantic. He determined that individuals in the northernmost latitudes did not mature as fast as those in south latitudes. Fecundity was also greater for individuals in the southern latitudes. These data suggest that fecundity and maturation are directly related to temperature, i.e., greater fecundity and quicker maturation with higher temperatures. Struhsaker and Aasted (1974) determined the percent of the total weight comprised of eggs on *H. ensifer*. They found that approximately 5 to 10 percent of the total weight was comprised of eggs. My data suggest a much greater range, between 7 and 27 percent, with a mean of 16 percent (Fig. 22).

Just before spawning females molt into a shell specialized for carrying eggs (Barr 1970). The spawning shell has setae on the abdominal appendages which are larger, and pleura which are deeper to protect the eggs. The reduction in tail weight with increase in size of ovigerous females is probably a reflection of the accommodation to carrying eggs.

Struhsaker and Aasted (1974) also determined the percent of the total weight contributed by the tails of H. ensifer males and ovigerous individuals. Their data indicate that about 40 to 50 percent of the total weight is comprised of tail weight for the males and 45 to 55 percent for the females. My data agree with those of Struhsaker and Aasted indicating that approximately 45 percent of the total weight is comprised of tails for both males and females (Fig. 22). Only H. laevigatus males were examined for percent of total weight contributed by the tails (Fig. 34). Approximately 42 percent of the total weight was comprised of tail, slightly less than that found for H. ensifer.

Struhsaker and Aasted (1974) calculated length-weight curves for H. ensifer males and females based on the individuals total length (tip of rostrum to tip of telson): males, $\log_{10} W = 0.0162L - 0.8789$; females, $\log_{10} W = 0.0105L - 0.1947$. Clarke (1972) lumped 50 male and female individuals to determine a length-weight relationship. His measurement was based on the accepted standard measurement for crustaceans (carapace length): $W(gm) = 6.47 \times 10^{-4}$ CL (mm) 2.85. In both cases W = total weight in grams. In the former L = total length in mm. Measurement of the carapace length seems more appropriate since it is a standard length and does not change except upon molting. My length-weight data are based on the carapace lengths of males, ovigerous females and nonovigerous females for both H. ensifer and H. laevigatus. Length-weight data by Struhsaker and Aasted (1974) for both males and ovigerous individuals are quite close to my data for those animals of a size class close to the mean. However, animals smaller or larger than the mean do not show similar results. This is probably the result of the inherent variability in measuring the total length of these shrimp. The abdominal section of these shrimp can be compressed or stretched by three to five mm. Given a total length of 10 cm there can be a five percent resultant error when calculating the relationship of length to weight. My data indicate the relationship between carapace length and weight, based on linear regression of logarithms to be slightly less than that found by Clarke. His equation differs primarily by the larger exponent b. Royce (1973) stated that "when the exponent b in the equation log W = log a + b, log L equals 3.0, the animal is growing without change in shape or specific gravity, i.e., isometrically." The larger exponential value observed by Clarke is most likely related to the lumping of both males and ovigerous individuals.

Fisheries Potential

The results of this study indicate that both H. ensifer and H. laevigatus can be trapped in quantities which may support a "cottage" fishing industry. Mean catches of 1.45 kg for H. ensifer and 0.97 kg for H. laevigatus can be expected (Table 7). These catches are considerably higher than those experienced in Alaska where the boreal species Pandalus platyceros is commercially fished on an average of 0.5 kg per trap (John P. Doyle, pers. comm.). Clarke (1972) and Struhsaker and Aasted (1974) both reported catch rates lower than mine in the Hawaiian Islands. Struhsaker and Aasted (1974) estimate an annual yield of one or two metric tons/km^2 of Heterocarpus in Hawaiian waters. They suggested that a small shrimp fishery and possibly a processing plant might support itself on these estimates.

The commercial shrimping industry relies on the use of trawls for its greatest yield. However, certain conditions must exist in order to trawl effectively. The primary factors are shallow water with fairly smooth bottom and shrimp in adequate numbers to support the effort. In Guam there are no extensive smooth bottom areas within the depth range for these species perhaps prohibiting a trawl industry. Therefore, trapping appears to be the most effective means of catching sizeable quantities of these shrimp in Guam waters.

Based on an average catch per trap of 2.08 kg a fisherman setting three traps a day could expect an annual yield for Heterocarpus in Guam waters between two and three metric tons. A small commercial vessel could double or triple these estimates easily by setting numerous traps

Table 7. Total catch results for weight (kg) and numbers for *H. ensifer* and *H. laevigatus*, separately and combined. SE refers to standard error of the mean.

Species	Number of Sets	Weight (kg) Totals	$\bar{X}$ per set	SE	Number of Shrimps Totals	$\bar{X}$ per set	SE
H. ensifer and *H. laevigatus*	112	223.87	2.08	0.17	39,413	359.40	43.09
H. ensifer	112	162.86	1.45	0.18	35,542	317.34	43.73
H. laevigatus	65	61.01	0.94	0.14	3,871	59.55	10.32

on a more effective time schedule. Preliminary trapping on a day-night basis indicated increased catch rates at shallower depths during the crepuscular periods for at least *H. laevigatus*. It is possible that trapping during these periods could yield greater catches and therefore decrease the effort. Certainly more information in this area would benefit the fisherman.

CONCLUSIONS

1. Depth is the most significant factor in the distribution of these shrimp. *H. ensifer* was found at depths ranging from 213 to 732 m with the greatest abundance between 366 and 457 m. *H. laevigatus* was collected between 457 and 732 m with the greatest abundance between 610 and 732 m.
2. Area and season also affect the distribution of these shrimp, but these parameters account for considerably less of the variability in catches than does depth.
3. Mean size increases with depth for *H. ensifer*, and the largest individuals of both species seem to congregate at the deep end of their distribution.
4. Males outnumber females three or four to one for *H. ensifer*, and two or three to one for *H. laevigatus*.
5. Both species are protandric hermaphrodites.
6. The breeding and spawning season is well defined for *H. laevigatus* occurring in winter and spring. The seasonal breeding and spawning pattern for *H. ensifer* is less defined but appears to occur from late winter to summer.
7. I estimate an annual yield of two to three metric tons for both species for the total fishing grounds around Guam. These figures indicate that a small "cottage" fishery might support itself with the possibility of a processing plant. This estimate is based on three or four trap sets per day over a 365 day year.

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