Deepwater Shrimp Trapping in the Hawaiian Islands

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ABSTRACT—The results of preliminary deepwater shrimp trapping surveys in the Hawaiian Islands consisting of 82 sets involving totals of 306 traps and 3,960 h of fishing time in the 75 to 450-fathom (135-825 m) depth range are discussed. A variety of traps, bait containers, and baits were tested. Attempts to capture the penaeid shrimp, Penaeus marginatus, *in substantial numbers were unsuccessful. More success was experienced in trapping the caridean shrimps* Heterocarpus ensifer *and* H. laevigatus. *For these species, it was found that traps covered with burlap cloth outfished uncovered traps by factors of 2.5 to 10.* H. ensifer *was found to be most abundant in depths of 200-250 fathoms (365-455 m) where catches with optimum trap and bait combinations ranged from 15 to 63 pounds (6.8 to 28.6 kg) per trap for sets of less than 24 h duration. Seventy traps set overnight during spring 1973 off the south coast of Oahu produced a total of 1,015 pounds (460 kg) for an average of 14.5 pounds (6.6 kg) per trap. The larger* H. laevigatus *was found to be most abundant in depths of 240-375 fathoms (440-685 m), where catches ranged up to 34.8 pounds (15.8 kg) for 4 traps. It is speculated that the various species of* Heterocarpus *represent an unexploited world resource of considerable magnitude.*

INTRODUCTION

During 1967 and 1968 the National Marine Fisheries Service (NMFS) devoted four cruises of the RV *Townsend Cromwell* to demersal resource surveys in the Hawaiian Islands. The primary sampling gear utilized were shrimp trawls, although a few shrimp trap stations were effected. These surveys demonstrated that the penaeid shrimp, *Penaeus marginatus* Randall, was available in modest amounts and amenable to harvest by shrimp trawls in depths of 60-125 fathoms (110-230 m)[1] (Yoshida, 1972; Struhsaker, Yoshida, and Shomura[2]). Two species of caridean shrimps, *Heterocarpus ensifer* Milne-Edwards and *H. laevigatus* Bate (Fig. 1), were also taken in moderate numbers with the trawls between 150 and 400 fathoms (275 and 730 m). However, the initial investigations indicated that trapping, rather than trawling, was perhaps a more effective method for capturing these latter species.

[1] Metric equivalents are approximate.
[2] Struhsaker, P., H.O. Yoshida, and R.S. Shomura, Exploratory shrimp trawling in the Hawaiian Islands, unpubl. ms., Southwest Fisheries Center, Honolulu Laboratory, Honolulu, HI 96812.

Clarke (1972) conducted trapping surveys during 1969 and 1970 at several locales off the Hawaiian island of Oahu. The sampling gear consisted of several trap types, but all were uncovered traps constructed of 0.5-inch (13-mm) mesh wire screens. This work provided data on the biology and depth distribution of *H. ensifer* and *H. laevigatus* and indicated that *H. ensifer* might be present in sufficient quantities to support a commercial fishery.

Further trapping trials were intermittently conducted by NMFS during 1971-73 at various localities in the Hawaiian Islands. These trials were of a preliminary nature, and various combinations of traps, bait containers, and baits were utilized. Most of the data were obtained during fall 1972 and it became apparent at this time that burlap-covered traps were more effective in capturing *H. ensifer* than were uncovered traps. Attempts to trap *P. marginatus* in substantial numbers were unsuccessful. Follow-up cruises with more extensive trapping

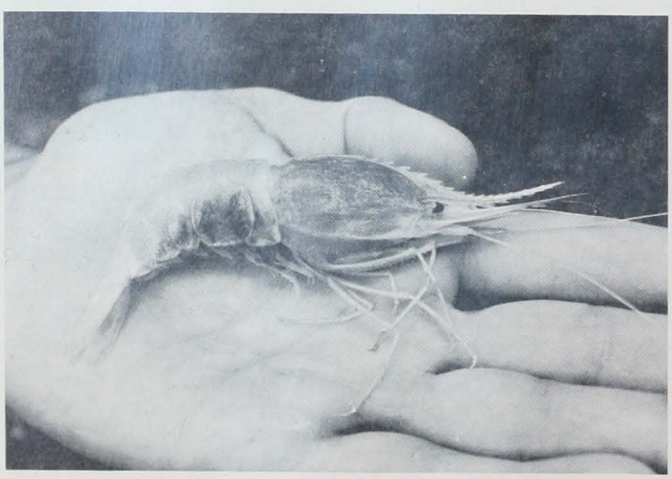


Figure 1.—A fresh specimen of *Heterocarpus ensifer* (A, left) about 115 mm total length. Note ocellus on the side of the cephalothorax ("head") and the strong backwardly projecting spines on the third and fourth segments of the abdomen ("tail"). A fresh specimen of *Heterocarpus laevigatus* (right, B) about 175 mm total length.

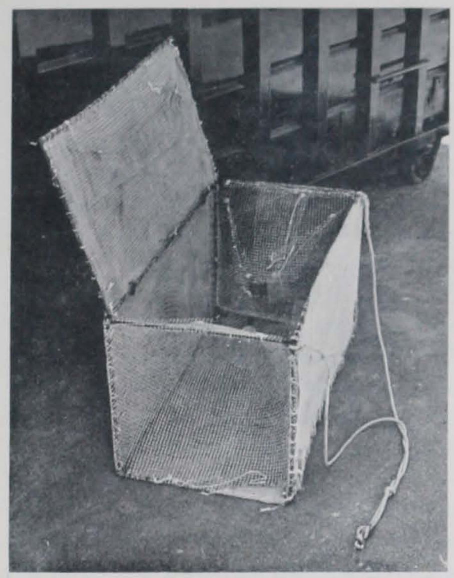


Figure 2.—A covered square trap. This trap type produced the best catches of *Heterocarpus ensifer*.

trials scheduled for 1973 were cancelled.

GEAR AND SAMPLING EFFORT

Gear

The "square trap" (in reference to its square cross-section) produced the best catches of *Heterocarpus*. It measures 2×2×4 feet (60×60×120 cm) (Fig. 2). The frame is constructed of ⅜-inch (10-mm) diameter steel bar and is enclosed with 0.5-inch square mesh galvanized wire screen. The sides, top, and bottom are then covered with burlap. The tunnels (one at each end) are also constructed with the screen (but are uncovered) and taper to approximately 3-inch (75-mm) diameter openings about one-third the distance in from each end. Covered and uncovered traps of similar construction, but enclosed with 1-inch (25-mm) (bar-to-bar) hexagonal wire screening were also tested.

"Flat traps" (Fig. 3), constructed similarly to the square traps, but measuring 1×2×4 feet (30×60×120 cm), were utilized most often in the shallower depths surveyed. It was felt that the lower ramp angles of the tunnels might prove to be more effective in capturing *P. marginatus*. Captive specimens of *P. marginatus* held in large tanks ashore tended to maintain close contact with the bottom and usually did not undergo exploratory swimming behavior off the bottom such as has been observed for Alaskan pandalid shrimps in the vicinity of traps (Kessler, 1969).

Collapsible round shrimp traps (Fig. 4) were also tested to a limited degree. They are 14 inches (36 cm) high, 24 inches (60 cm) in diameter at the top, 34 inches (86 cm) in diameter at the bottom and have shallow tunnels leading to four entrances. The webbing consists of 1.25-inch (31-mm) stretched mesh nylon.

Finally, an experimental collapsible "tent trap" (Figs. 5, 6, and 7) was tested on one occasion. Each of the three frames making up the bottom, side, and lid of the trap measures 2×4 feet (60×120 cm) and is enclosed with 0.5-inch wire mesh screen. The three frames are joined with split links of a size that permit folding of the frames and are covered with a single piece of burlap. A bridle attached to the corners of the lid runs through the outside corners of the bottom frame (Fig. 6). When closed, the lid is secured with a rubber strap and S-hooks. The triangular end frames are attached to the bottom of the trap by split links and have two half-links welded on the leg articulating with the side frame (Fig. 7). The tunnels are constructed with 1.5-inch (38-mm) mesh (stretched) nylon webbing and are secured to entrance rings 3 inches (75 mm) in diameter. The tunnels are held in place by a rubber strap and S-hook (Fig. 6).

Several bait containers were tested. Containers constructed of 0.5-inch mesh screen measuring about 4×4×6 inches (10×10×15 cm) were generally superior to plastic containers of the same size perforated with 0.25-inch (6-mm) holes or bait wrapped in cheese cloth. From 1 to 2 pounds (0.5-1 kg) of bait were sufficient for sets of 12-14 h. The bait containers were suspended near the center of the trap.

Figure 3.—An uncovered flat trap.

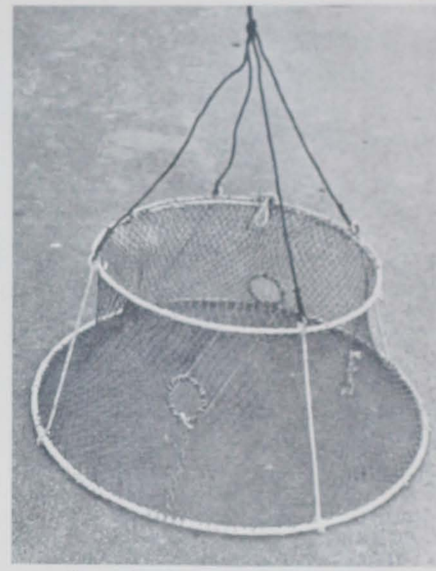


Figure 4.—A collapsible shrimp pot.

Each trap has a 7-foot (215-cm) bridle of 0.25-inch diameter polypropylene rope attached to two corners on the top of the trap. Although this results in considerable drag when hauling back the gear, it is felt that this arrangement may, in the case of square traps, eliminate the possibility of the trap landing on end when being set. It was also thought that this would reduce the number of shrimp washed out through the entrances when hauling back. The bridle has a snap at the center for attachment to the ground line. The ground line and buoy line consist of 0.5-inch polypropylene rope. The traps are spaced at 10-fathom (20-m) intervals, and the first and last traps on a string have 5- or 10-pound (2.3 or 4.5-kg) anchors attached by a short wire to a trap corner. We usually fished 4-6 traps to a string. Our buoy lines are made up into 100-fathom (185-m) lengths, and these are stored in plastic garbage containers of approximately 32-gallon (120-liter) capacity. This arrangement provides the flexibility required when conducting surveys encompassing a wide depth range.

The ground line is made by forming loops for each trap at 10-fathom intervals on the distal portion of the first 100-fathom section. The proper number of 100-fathom sections are then added as the traps are set in order to give an excess amount of buoy line on the order of 50-150 fathoms (90-275 m) greater than the depth of water being fished. A chain weight is snapped onto the buoy line about 25-50 fathoms (45-90 m) below the end of the last section to assure that the polypropylene line does not float at the sea surface. The set is retrieved with a line-hauling power block; the 100-fathom sections are stowed directly into their containers as the line comes aboard.

Because of the buoyancy of the polypropylene line, minimal flotation for the marker buoy is required. Our buoys consisted of either simple bamboo poles with two or three plastic longline floats or a more elaborate buoy consisting of an 18-foot (5-m) flag and light staff of 2.5-inch (64-mm) diameter conduit piping which fits into a weighted frame which is floated with a large inner tube. These buoys remained at the surface even in areas where the currents approached 3 knots. A 4-fathom (7-m) pickup line with a small float is attached to the buoy.

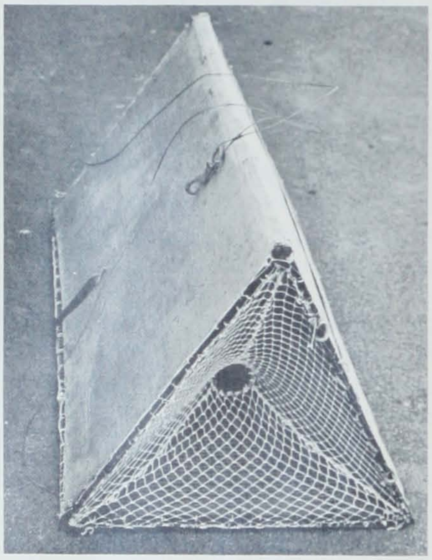


Figure 5.—A collapsible tent trap ready for fishing.

Distribution of Sampling Effort

From March 1971 to August 1973, 82 exploratory shrimp trapping sets involving totals of 306 traps and about 3,960 h of fishing time were effected in various areas of the Hawaiian Islands. The distribution of sampling effort by depth was as follows: 75-130 fathoms (135-235 m), 24 sets; 130-200 fathoms (235-365 m), 2 sets; 200-300 fathoms (365-550 m), 47 sets; 300-400 fathoms (550-730 m), 7 sets; 400-450 fathoms (730-825 m); 2 sets. Most sampling effort was expended in depths of 75-130 fathoms and 200-300 fathoms where *P. marginatus* and *H. ensifer*, respectively, are most abundant.

Most of the trapping effort for *P. marginatus* took place in the Pailolo Channel where this species is most abundant (Struhsaker et al., unpubl. ms.). The deeper depth ranges explored with the RV *Townsend Cromwell* were off the north coast of Oahu, the north edge of Penguin Bank, off northern Maui, and the west coast of the island of Hawaii off Kawaihae. During spring 1973, 21 sets were made off the south coast of Oahu with our gear by personnel of the Hawaii Institute of Marine Biology (HIMB) utilizing the FV *Valiant Maid*. During August 1973, 9 sets were made with the RV *David Starr Jordon* in the Leeward Islands of the Hawaiian Archipelago near Necker Island, French Frigate Shoal, Laysan Island, and Pioneer Bank.

Because the trapping experiments were interspersed with other vessel activities, most sets were made at dusk and retrieved at dawn. However, we do have a few data for daytime sets. We trapped on a variety of bottom types, avoiding only steeply sloping areas and rough-bottom grounds where the traps might have been snagged.

RESULTS

Trapping for *Penaeus marginatus*

Attempts to trap *P. marginatus* in substantial numbers were unsuccessful, but the sampling effort was of a very preliminary nature. After generally negative results obtained during spring 1971, experiments with captive shrimp were conducted at the NMFS Kewalo Basin facility. Response of the shrimp was noted during hours of light and darkness to baited and unbaited flat traps (all uncovered) equip-

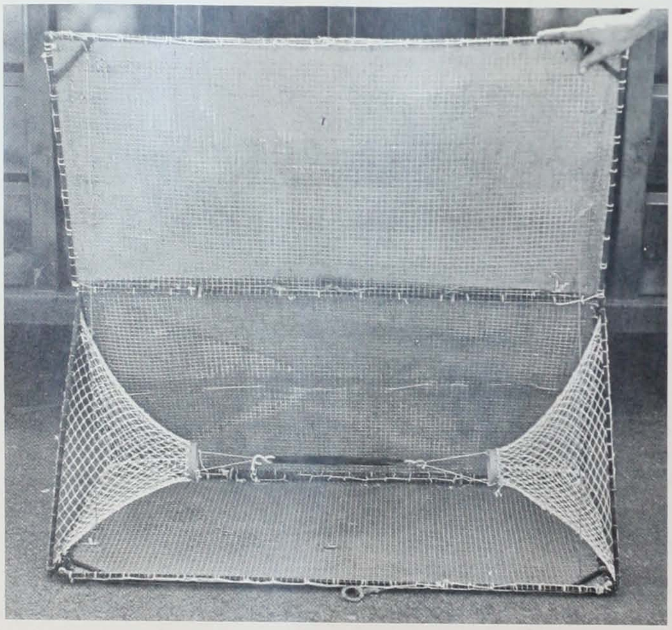
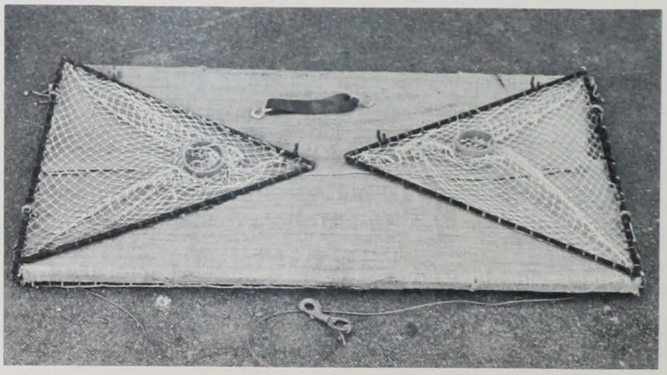


Figure 6.—A tent trap with raised lid.

Figure 7.—A collapsed tent trap. The end frames fold outward, over the bottom panel.



ped with a variety of entrances. Rather surprisingly, there were no major differences in the catch rates between the various combinations of the trap types and baits tested. These results were probably confused by abnormal temperature and light conditions. Although adult *P. marginatus* appear to be negatively phototactic (Struhsaker et al., unpubl. ms.), best capture results were obtained by suspending a light over an unbaited trap. This resulted in all of the available shrimp (18-20) in a test tank 24 feet (7 m) in diameter entering the trap within 15-20 minutes.

Further field trials conducted during fall 1972 were inconclusive, aside from determining that flat traps outfished square traps on the same string. Traps containing a deep-sea diving light captured shrimp on three occasions when the other traps on the string did not take any shrimp (maximum single trap catch, five shrimp). However, the best catch of nine shrimp for an overnight set was in an uncovered flat trap baited with finely ground fish. Three sets of traps fished during daylight hours produced low catches similar to night sets.

Clarke (1972) reported a best catch of this species as 26 individuals in eight traps in 60 fathoms (110 m) off the north coast of Oahu. We feel that concerted trapping trials for this species might result in a viable fishing strategy that could produce catches of commercial value for small vessels.

Trapping for *Heterocarpus ensifer*

During fall 1972 several types of traps, bait containers, and baits were tested in various combinations on sets of 4-6 traps per string. These preliminary trials were not designed for the results to be subjected to statistical evaluation, but the main trends of the effectiveness of the various trap combinations in capturing *H. ensifer* were readily apparent.

Square traps with 0.5-inch mesh wire screen were more effective than the other types tested. The catches of square traps with 1-inch mesh wire screen were less, apparently owing to escapement. Catches from the flat traps and round traps were consistently lower than for the square traps.

Figure 8.—A 123-pound (56-kg) catch of *Heterocarpus ensifer* produced by four traps.

The performance of burlap-covered and uncovered square traps with 0.5-inch mesh were directly compared on eight occasions when strings of alternating trap types were set. The covered traps always outfished the uncovered traps by factors of 2.5 to 10.

Because most catches of *H. ensifer* were made at night in deep water, it would seem that they are not differentially entering the covered traps to seek shelter. We agree with Butler (1963) that possibly the covered traps are rendered more effective in that the bait scent is concentrated at the trap entrances, rather than diffused through the sides in addition to the entrances in the case of uncovered traps.

Five general types of bait were tested: finely ground fish, squid, shrimp (*H. ensifer*), and coarsely shopped fish and shrimp. Fish and shrimp were superior to squid and the coarsely chopped fish and shrimp outfished the finely ground containers of these species. This finely ground bait probably dispersed too rapidly. Bloody and oily fishes such as skipjack tuna (*Katsuwonus pelamis*), boarfish (*Antigonia* spp.) and *Aulopus* were found to be superior to lizardfishes (Synodontidae), flatfishes (Bothidae), and smelt (Osmeridae).

Catch rates of *H. ensifer* obtained during fall 1972 were highly variable due to the variety of traps, containers, and baits tested and the depths sampled. At this time the best catches ranged between 15 and 63 pounds (6.8 and 28.6 kg) per trap on overnight sets. One of the better catches made at this time was off the north shore of Oahu in 240 fathoms (440 m) where 122.7 pounds (55.8 kg) of *H. ensifer* were taken with four square traps baited with fish (Fig. 8). Two covered traps accounted for 108.6 pounds (49.3 kg), while two uncovered traps captured 14.4 pounds (6.5 kg).

The best single catch of *H. ensifer* was 63 pounds (28.6 kg) from a fish-baited, covered square trap during a 24-h set in 225 fathoms (410 m) north of Maui. Another covered square trap on this string, baited with shrimp, produced 24 pounds (10.9 kg), while the remaining two covered square traps also baited with fish and shrimp produced only 1.5 and 1.0 pounds (0.7 and 0.5 kg), respectively. This great disparity in the catches indicates to us that the latter two traps (which were positioned in the middle of the string) landed on end or were not fishing for some other reason.

During spring 1973, two overnight sets of six covered square traps on a string were made in 225 fathoms (410 m) off the north coast of Oahu to provide shrimp for test marketing. One string produced a total of 134 pounds (60.5 kg) of *H. ensifer*, with three traps baited with skipjack tuna accounting for 102.25 pounds (46.5 kg), and three traps baited with whitebait smelt (*Allosmerus elongatus*) taking 31.75 pounds (14.0 kg). The second string produced a total of 118.5 pounds (53.9 kg), the three skipjack tuna baited traps producing 80.5 pounds (36.6 kg), while the three whitebait smelt traps captured 38 pounds (17.3 kg). The tent trap was also tested on this string (baited with skipjack tuna) and produced an additional 12.5 pounds (5.7 kg). This was the single test of this trap type, and inasmuch as a square trap is about 2.1 times the volume of the tent trap, we feel that this design might eventually prove to be practical.

During August 1973, six sets of covered square traps baited with tuna were made in the 200-250 fathom (365-460 m) depth range in the Leeward Islands. The results indicated that the peak abundance of *H. ensifer* may occur deeper there than in the main group of the Hawaiian Islands. Four traps produced totals of 46.5-50 pounds (21.1-22.7 kg) at each of three sets between 225 and 250 fathoms (410 and 460 m) near Necker Island. A 6-h daytime set here in 200 fathoms (365 m) with two traps produced only 10 individual shrimp. Only 2-3 pounds (0.9-1.4 kg) of *H. ensifer* were taken in two overnight sets of four traps in 205 and 215 fathoms (375 and 390 m) near Laysan Island.

Our covered square traps were tested in a more uniform and extensive manner during May 1973 by HIMB personnel when 19 overnight sets (of 21) were made in the 200-220 fathom (365-415 m) depth range off the south coast of Oahu between Waikiki Beach and Sand Island. Four traps were fished to a string and were baited with a mixture of two species of smelt (primarily *Thaleichthys pacificus* and, to a lesser extent, *Hypomesus pretiosus*). Catches varied from 2 to 34.9 pounds (0.9 to 15.9 kg) per trap. Total catch from 70 traps (complete data not available for six traps) was about 1,015 pounds (461 kg) for an average of 14.5 pounds (6.6 kg) per trap. These data also reflect our impression that considerable variation occurs between localities and depths and even between identical trap arrangements on the same string. This is probably due to local variation in the abundance of *H. ensifer* and variation in placement of the bait container and in the trap tunnel entrances occurring during the original construction or after modification due to damage.

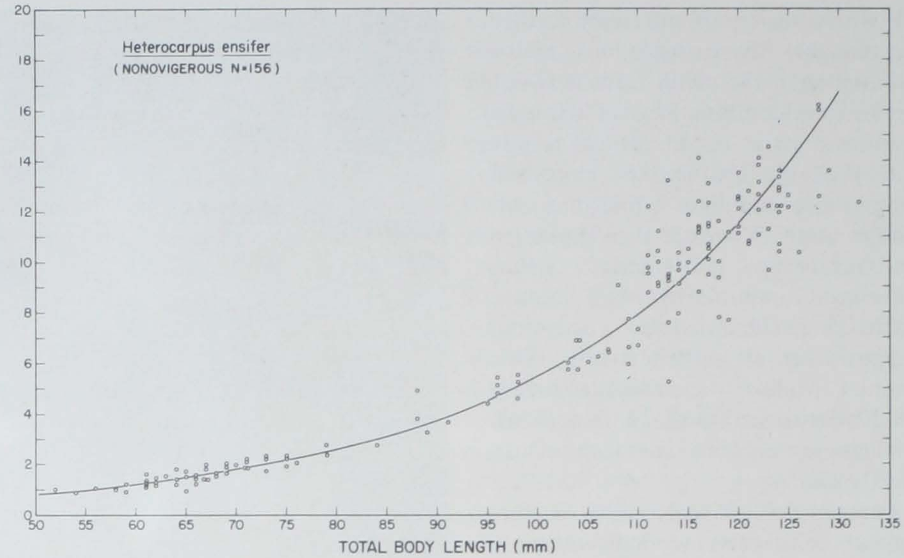


Figure 9.—Length-weight curve for 156 nonovigerous *Heterocarpus ensifer*.

These catches of *H. ensifer* with covered traps generally exceeded those experienced by Clarke (1972) with uncovered traps outside Kaneohe Bay on the northeast coast of Oahu during November 1970. Catches there for nine quantitative sets in the 150- to 250-fathom depth range varied from 0.6 to 11.9 pounds (0.3 to 5.4 kg) per trap and averaged 4.5 pounds (2.0 kg). At that time the best catch obtained was a respectable 96 pounds (43.6 kg) from eight traps fished in 200 fathoms (365 m).

We have taken *H. ensifer* in depths ranging from 76 to 360 fathoms (137 to 660 m). Clarke (1972) took the species between 80 and 400 fathoms (146 and 730 m) but concluded that it is most abundant between 150 and 250 fathoms (275 and 455 m). Our results indicate a peak abundance between 200 and 240 fathoms (365 and 440 m), but we have few stations in depths between 150 and 200 fathoms (275 and 365 m). Quite probably the depths of peak abundance for *H. ensifer* vary locally according to variations in the temperature structure. In the main group of the Hawaiian Islands, bottom temperatures are about 14°C at 150 fathoms (275 m), 9.5°C at 200 fathoms (365 m), and 8°C at 250 fathoms (455 m).[3]

[3] Unpublished data, Southwest Fisheries Center, National Marine Fisheries Service, Honolulu, HI 96812.

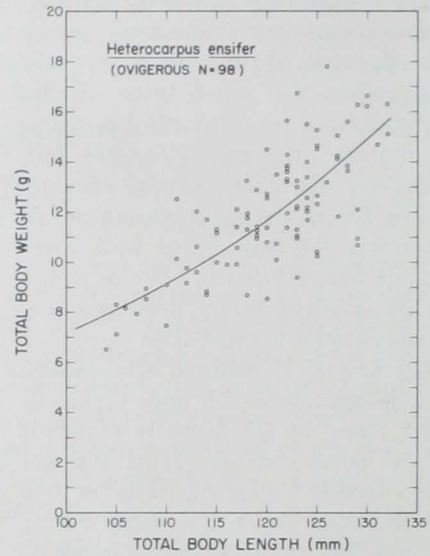


Figure 10.—Length-weight curve for 98 ovigerous *Heterocarpus ensifer*.

Clarke (1972) also demonstrated that the 150- to 250-fathom depth range was the zone where the largest size-class of shrimp occurred. The catches in greater and lesser depths were comprised of a significantly greater portion of smaller individuals. We did not collect extensive length-frequency information, but estimations of the size composition of the catches also indicate that smaller shrimp are found above and below the depths of peak abundance.

Clarke (1972) pointed out that *H. ensifer* seems to exhibit protandrous hermaphroditism (sex change from male to female with growth), but that the situation seems to be more complex than for some of the commercial pandalid shrimps in that a large portion of the males reach near-maximum size without transforming and that many small individuals (below egg-bearing size) are females. A large proportion of the larger females taken are ovigerous (gravid, or "berried") throughout the year. Clarke (1972) presented data that indicated that this condition varied with depth and that the proportions may vary seasonally.

The largest size-group of *H. ensifer* taken in our traps usually weighed about 35 to 45 individuals per pound (75 to 100/kg) with the heads on, although the largest individuals taken run 28-30 per pound (62-66/kg). We obtained total length (tip of rostrum to tip of telson) and weight data for 156 nonovigerous *H. ensifer* (Fig. 9) and 98 ovigerous females (Fig. 10). Data were obtained from specimens frozen less than a month, thawed, and damp-dried. The fitted exponential length-weight curve for the nonovigerous individuals is: $\log_{10} W = 0.0162\, L - 0.8789$, where W = total weight in grams, and L = total length in millimeters; $r^2 = 0.972$. The equation for the ovigerous individuals is: $\log_{10} W = 0.0105\, L - 0.1947$, where $r^2 = 0.589$, W = total weight in grams, and L = total length in millimeters.

We also determined the percentage

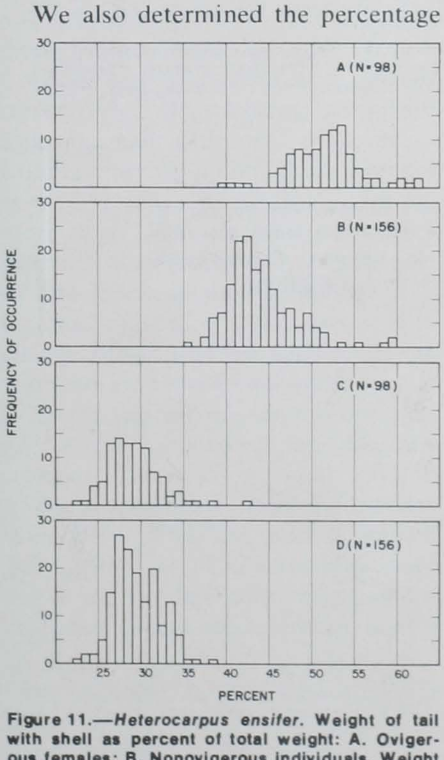


Figure 11.—*Heterocarpus ensifer*. Weight of tail with shell as percent of total weight: A. Ovigerous females; B. Nonovigerous individuals. Weight of tail without shell as percent of total weight: C. Ovigerous females; D. Nonovigerous individuals.

of the total weight contributed by the tails of ovigerous and nonovigerous individuals, both with and without shell and eggs (Fig. 11). The majority of ovigerous individuals have total tail weights making up about 45-55 percent of the total weight, whereas the tail weights of most of the nonovigerous individuals were about 40-50 percent of the total weight (Fig. 11A and B). These data indicate that the egg mass is about 5-10 percent of the total body weight. With the shell and eggs removed, the tail muscle of both ovigerous and nonovigerous individuals make up about 25-35 percent of the total weight (Fig. 11C and D).

Trapping for *Heterocarpus laevigatus*

H. laegivatus (Fig. 1) is a large species of *Heterocarpus* inhabiting a deeper depth range than *H. ensifer*. Clarke (1972) collected this species between 200 and 400 fathoms (365 and 730 m), while we have obtained it in depths ranging from 235 to 450 fathoms (430 to 825 m). We have rather limited coverage in the deeper portion of this depth range, but several catches indicate that this species can be taken in sufficient quantities to support a commercial fishery. Our initial catches with uncovered traps were not encouraging, and were similar to those experienced by Clarke (1972) where yields were usually on the order of 1.5 pounds or less per trap.

Some of the better catches of *H. laevigatus* we obtained with covered traps are as follows. South coast of Oahu: 18 pounds (8.2 kg), three traps, 246 fathoms (450 m); 10.6 pounds (4.8 kg), two traps, 255 fathoms (465 m). North coast of Oahu: 11.1 pounds (5.0 kg), two traps during a 4-h daytime set, 285 fathoms (520 m). Kawaihae, Hawaii: 7 pounds (3.2 kg), two traps, 238 fathoms (435 m). Leeward Islands: 15 pounds (6.8 kg), four traps, 320 fathoms (585 m), Pioneer Bank; 34.8 pounds (15.7 kg), four traps, 360 fathoms (660 m), French Frigate Shoal; 7 pounds (3.2 kg), four traps, 440 fathoms (805 m), Pioneer Bank. Although the data are rather fragmentary, it would appear that this species is most abundant in depths of about 240 to 375 fathoms (440 to 684 m).

The proportion of large and small individuals of *H. laevigatus* taken in the traps also seems to vary between catches, but the pattern is not yet clear. Large individuals of this species attain lengths of 200-220 mm total length, but most of the individuals comprising the largest size-group range from 150 to 175 mm total length and average 8-11 individuals per pound (heads on).

FURTHER CONSIDERATIONS

One problem encountered with *H. ensifer* is cannibalism of a certain percentage of the trapped individuals. We have no precise data on this phenomenon, but rough estimates indicate that as little as 1 percent to as much as 15 percent of all the individuals in a trap may be affected. Subjectively, it seemed that the highest rates of cannibalism occurred in sets of long duration or in traps in which the bait supply was exhausted. Larger individuals are most often affected, and, if ovigerous, the eggs and swimmerets are removed first. Then the viscera, and, finally, the tail musculature are attacked. This results in the problem of sorting the husks and partially devoured individuals which contaminate the catch. Culling of cannibalized and small shrimp was most easily effected in a bath of seawater.

We point out that the traps used in these preliminary trials evolved during usage, and certainly do not represent what may become the optimum design and construction. Probably any container utilizing the principle of the covered trap with a long tapered tunnel would be suitable. The mesh size of the tunnels should be increased to about 0.75 inch (19 mm) to permit escapement of small shrimp. Possibly a trap with an entrance on one end and a flat screen on the other end would permit escapement of small individuals during hauling of the trap, thus reducing the amount of sorting on the fishermen's part and preventing the premature harvest of young shrimp.

The tail meat of the two species of *Heterocarpus* tends to break down rapidly when the shrimp are improperly chilled aboard the vessel. The shrimp must be immediately placed in crushed ice or chilled seawater. This will provide an acceptable product for up to about 3 days after capture. We found that cooking the shrimp right after capture resulted in chilled shelf life of 3 to 4 days. One test of immediate freezing of raw shrimp in a brine solution at about −20°C resulted in an acceptable product. After freezing, the shrimp were placed in a conventional freezer and tested at intervals over a 2-week period. Very little salt was taken up by the shrimp and the product did not seem to deteriorate during the brief test period.

Care must be taken not to overcook these species. Boiling times of 2-4 min are adequate for the frozen *H. ensifer*. The tail meat can be shelled easily for other methods of preparation by briefly thawing in running water or after a 30-sec blanch.

The only present commercial fishery for a species of *Heterocarpus* (*H. reedi* Bahamonde) exists primarily off Chile, and to a lesser extent, Peru. In this highly productive region of upwelling, a trawl fishery produces about 10,000 metric tons annually (Hancock and Henriquez, 1968). It has been estimated that the total available grounds are about 1,600 km^2 in extent and that production could reach about 20,000 metric tons annually (Gulland, 1971). This indicates an annual production of about 12.5 metric tons/km^2.

In Hawaii, it appears that the abundance of *H. ensifer* is greatly underestimated by sampling with 41-foot shrimp trawls. Our maximum catch rate for this species was 240 kg/km^2 although most catches were less than 10 percent of this. It is perhaps best at present to not speculate on the area effectively fished by a single shrimp trap, but rather point out again that traps are a much more efficient means of harvesting *H. ensifer* in Hawaii. We feel that an annual yield of 1 or 2 metric tons/km^2 for Hawaiian waters does not seem like an unreasonable estimate. The total area of the optimum depth range for *H. ensifer* in the main group of the Hawaiian Islands has not been precisely determined, but probably exceeds 1,000 km^2.

It would seem that *H. ensifer*, an almost entirely cosmopolitan species occurring from Hawaii to the western central Atlantic, is about as abundant in other parts of its range as in Hawaii. In the western Atlantic, exploratory trawl catches by the NMFS were of the same magnitude as were those in Hawaiian waters.[4] Limited trapping near Guam in the western Pacific[5] have produced catches similar to those reported here.

Using data presented by Moiseev (1969), it was calculated that the 200- to 1,000-m depth zone of the world continental and insular slopes in regions where species of *Heterocarpus* may occur has a total area of about 5 million km^2. We assume that the area of the 200-600 m depth range is about half this: 2.5 million km^2. Assuming that 10 percent of this area is fishable and supports concentrations of shrimp, we have a potential fishing area of approximately 250,000 km^2. If yields on the order of 1-10 metric tons/km^2 are realistic, then it seems probable that *H. ensifer* and other members of this genus represent an unexploited resource of considerable magnitude.

[4] Data from Pascagoula Fishery Products Technology Laboratory, Pascagoula, MS 39567.
[5] L. G. Eldridge, University of Guam, Agana, Guam 96910. Pers. comm.

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