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# Observations of Deepwater Shrimp, *Heterocarpus ensifer*, From a Submersible off the Island of Hawaii

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## Introduction

In Hawaii and other Pacific island groups there has been considerable interest in the commercial potential of deepwater caridean shrimps of the genus *Heterocarpus*. Exploratory trapping surveys have shown that deepwater shrimps are widely distributed throughout the central and western Pacific (Clarke, 1972; Struhsaker and Aasted, 1974; Wilder, 1977; Intes, 1978; Brown and King, 1979; King, 1980, 1981a, 1981b, 1982, 1984, 1986; Moffitt, 1983; Gooding, 1984; Dailey and Ralston, 1986; Ralston, 1986; Moffitt and Polovina, 1987).

The Southwest Fisheries Center's (SWFC) Honolulu Laboratory of the National Marine Fisheries Service, has conducted surveys of deepwater shrimp resources in Hawaii (Gooding, 1984) and the Mariana Islands (Ralston, 1986; Moffitt and Polovina, 1987).

Despite the recent economic failure of a large commercial endeavor that was engaged in a trap fishery for *Heterocarpus laevigatus* in Hawaii, (Schlais, 1982, 1983) the deepwater shrimp resource continues to offer promise for commercial exploitation in Hawaii and indeed throughout the southern and western Pacific islands. In the Hawaiian Islands *H. laevigatus*, which occurs most abundantly in depths of 450-700 m and *H. ensifer* which has a shallower preferred depth range of 300-600 m (Clarke, 1972; Struhsaker and Aasted, 1974; Gooding, 1984; Dailey and Ralston, 1986), have been targets of trap fisheries. However, *H. laevigatus* is generally considered to have the greater commercial potential because it is larger.

At present there is no Fishery Management Plan (FMP) for deepwater shrimps. The Western Pacific Regional Fishery Management Council (Council) has identified the *Heterocarpus* resource as one in need of further basic research for effective future management[1]. The Honolulu Laboratory is presently conducting "intensive fishing experiments" on isolated *H. laevigatus* grounds to acquire estimates of absolute and relative abundance of exploitable stocks (Ralston, 1986). For management purposes there is a need for research into population biology and stock assessment, growth rates and natural mortality, and migration patterns. Commercial catch and effort data and research survey data from surface vessels provide much of this information. Visual observations from a research submersible can give a valuable insight into areas such as general behavior and microdistribution relative to types of fishing gear and the nature of the bottom (Ralston et al., 1986). Such direct observations may be very useful in interpreting data acquired by other means and in developing more efficient gear and fishing techniques.

In February 1984, we had the opportunity to use the Hawaii Undersea Research Laboratory (HURL) submersible, *Makalii* (Fig. 1), to make observations of *H. ensifer* off the northeast coast of the Island of Hawaii. The project was confined to *H. ensifer* grounds because the maximum operational depth of the *Makalii* is less than the depth at which *H. laevigatus* occurs. The objectives of the dives were to: 1) Determine factors that might cause variation in *H. ensifer* catch rates within a string of five traps, 2) observe the behavior of shrimp in the vicinity of two different trap designs, 3) document observed distribution and abundance of shrimp relative to type of substrate, 4) set bait on the bottom as an attractant to acquire further insight into shrimp density relative to type of substrate, and 5) collect shrimp specimens, bottom sediment, and water samples for a laboratory assay of incident bacteria. A problem for the shrimp industry that has limited the marketability of *Heterocarpus* spp. has been a rapid deterioration in the meat, so-called "mushy tail." This is believed to be caused by bacteria of the genus *Vibrio*. Four species of the genus had been identified by one of the authors (Dailey) in cultures of shrimp landed from commercial traps. We hoped to determine if these bacteria are either always on the shrimp and cause no problem for the living animal, or are subsequently picked up in the upper water column, or even after the shrimp has been landed on the vessel.

Because the *Makalii* became available

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[1]Western Pacific Regional Fishery Management Council. 1984. Draft assessment of resources, existing and potential fisheries, and management needs for selected crustacean species in the Western Pacific region. Rep. on file at Western Pacific Regional Fishery Management Council, 1164 Bishop Street, Suite 1405, Honolulu, HI 96813.

for the project on very short notice, we were able to fabricate and transport only six shrimp traps to Hawaii from Oahu. Four traps were lost early in the project so we were unable to acquire any information on the catch of similar traps on a string in relation to substrate variations.

## Methods

The *Makalii* is a two-man, battery-powered, one-atmosphere submersible owned and operated by HURL, University of Hawaii, and funded by the National Oceanic and Atmospheric Administration (NOAA), National Undersea Research Program (NURP). It is 4.8 m long and has a spherical capsule 1.5 m in diameter. With a pilot and one observer and up to 95 kg payload, it has an operational depth capability of about 366 m and a dive duration of 4-5 hours with emergency life support for 72 hours. Normal operating speeds range from 1 to 3 knots.

During this study, equipment that was used included: Hydraulic manipulator, two-color video cameras with monitors, recorders, and video lights, externally mounted 35 mm still camera and strobe, current and temperature meters, dictaphone tape recorder, directional antenna, and sonic pingers for site relocation. A Motorola Mini-Ranger Falcon[2] navigation system provided very precise (within 15 m) position fixes for the support vessel which tracks the submersible with an Edo Western submersible tracking system. The *Makalii* is also equipped with a Neil Brown environmental monitoring package for continuous recording of temperature, salinity, conductivity, pH, oxygen, and depth.

While on the bottom, observations were continuously video- and voice-recorded and still photographs were frequently made with the 35 mm camera and strobe.

Observations were made on two types of traps. The first was a half-rounded design with an entrance at each end (Fig. 2). This design has been used during past shrimp surveys by the SWFC Honolulu Laboratory (Gooding, 1984). The second

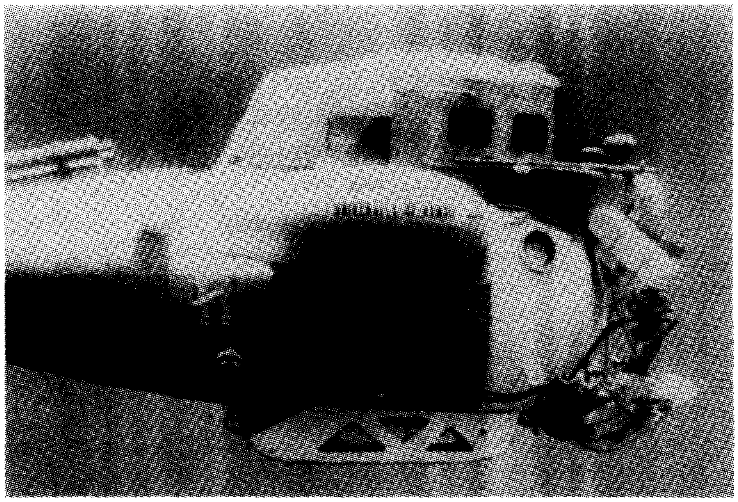

Figure 1.—The NOAA submersible, *Makalii*.

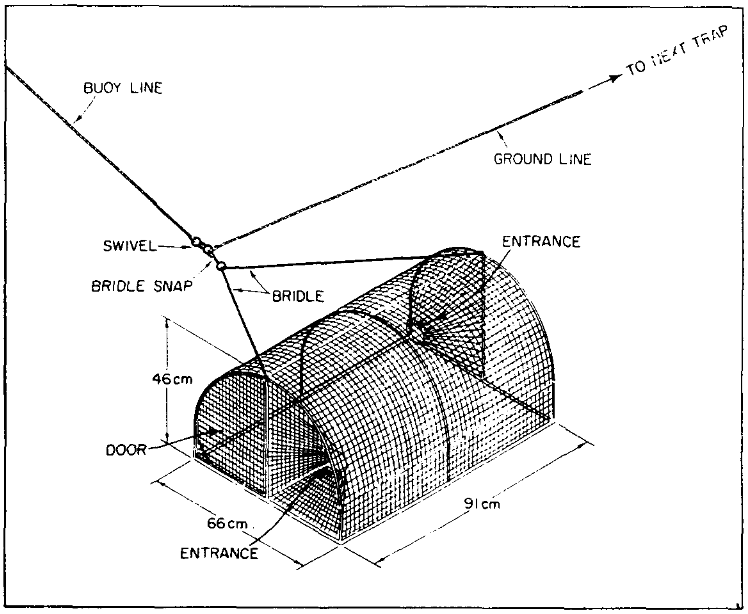


Figure 2.—Half-round shrimp trap.

trap was a larger pyramid-shaped design with a single entrance at the apex (Fig. 3). This was the preferred trap used in the former Hawaiian commercial fishery (Schlais, 1983). Traps were baited with Pacific mackerel, *Scomber japonicus*, and were set from the submersible support vessel. Attached sonic pingers en-

[2]Mention of trade names or commercial firms does not imply endorsement by the authors or the National Marine Fisheries Service, NOAA.

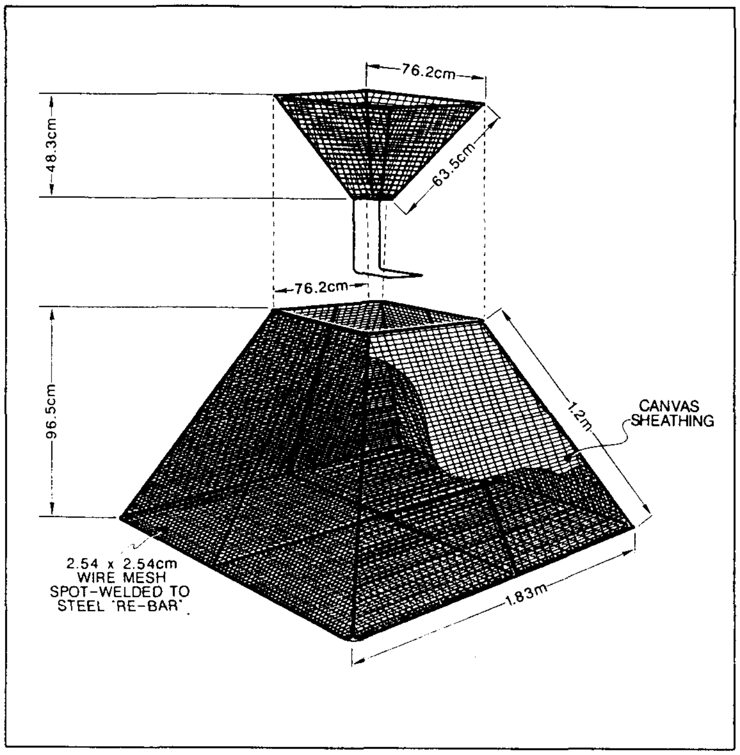


Figure 3.—Pyramid shrimp trap.

abled the submersible to locate them when it reached the bottom. Submersible observations were made on trap sets shortly after setting (1.5-5 hours) or about 24 hours after setting. The traps were retrieved after either 24 or 48 hours on the bottom. After removal from the traps the catches were held in crushed ice until later processing at dockside. Individual shrimps were not weighed. Mean individual weights were derived by dividing total weight of catch by number of shrimp.

The density of shrimp in an area was estimated by monitoring the number of shrimp aggregating to a can of tuna with numerous small punctures on all its surfaces during 10-minute intervals. The cans were sealed in plastic bags and carried in the submersible's sample storage basket. They were placed on the sea floor and the plastic bag torn away with the manipulator.

For the bacteriological tests, individual *H. ensifer* were collected from the bottom with the submersible suction collector. A bottom sediment sample was collected from the area in which shrimp were located and a sample of water close to the bottom was collected in a modified Van Dorn bottle. In the laboratory 0.1 ml of raw inoculant from each of the samples was plated on TCBS to determine total *Vibrio* and on marine agar to determine total bacteria.

The submersible observations were conducted on the Mauna Kea ledge about 12 n.mi. northeast of Hilo harbor. This general area was recommended by Edith Chave of HURL who had seen numerous *H. ensifer* there on an earlier *Makalii* dive.

## Results and Discussion

Figure 4 shows the location of the dive sites. Depths ranged from 345 to 380 m, and bottom temperature was 7°-8°C. Within these narrow ranges, temperature and depth were not correlated with either the apparent abundance of *H. ensifer* as observed from the submersible or the size of trap catches. Bottom currents were 0.2-0.3 knot (10-17 cm/second). The dives showed that for the most part the bottom was a flat basalt plain largely consisting of a shallow layer of brownish silty sand overlying volcanic lava flows. Occasionally the nearly flat relief was interspersed with small areas of low lava outcrops covered with limestone cement rising to about 20 cm above the sand. Although there was considerable amount of sediment and apparent turbidity in the upper and midwater column, water clarity at the bottom was very good except when the fine silt was disturbed by the submersible.

## Trap Observations

Five dives (*Makalii* dive No. 216-220), totaling 16.75 hours of bottom observation time, were made during 5-13 February 1984. Table 1 summarizes the schedule of dive and trapping operations. Prior to the arrival of the traps from Honolulu, on dive No. 216 we conducted a preliminary survey to determine a suitable area for subsequent trap sets and observational dives. The area surveyed on dive No. 216 consisted almost entirely of silty sand overlying a hard flat substrate. There was a high incidence of *H. ensifer* widely distributed throughout the region traversed by the *Makalii*. Shrimp densities were estimated at up to 1 per $m^3$ in some areas. Subsequent operations were conducted in the same general vicinity.

During the following four dives (217-220) we made observations on *H. ensifer* in relation to varying combinations of trap configuration, trap soak time, and bottom type.

1) Dive 217. A string of five half-round traps, spaced 16 m apart. All of the traps in the string landed upright in a depth of 347 m. They were clustered closely together on flat rubbly substrate interspersed with low outcrops. During

the observation period the traps had been on the bottom for from 1.5 to 4 hours. Only a few scattered *H. ensifer* were seen in the vicinity of the traps and the largest catch in any one trap appeared to be about four shrimp. A survey in the vicinity of the site showed the traps had landed on contiguously rocky rubbly ground apparently devoid of silty sand substrate in the vicinity. *Heterocarpus ensifer* were not seen on the rocky ground but unidentified striped shrimp were visible in small caves in the substrate. These probably were *Plesionika longirostris* which were subsequently identified on dive 219. During retrieval of the traps the following day, the groundline broke and four of the traps in the string were lost. The recovered trap contained 69 *H. ensifer* (not weighed).

2) Dive 218. A single pyramid trap which landed upright on sandy bottom at a depth of 349 m. No rocky areas were seen in the vicinity. The first observations were made about 24 hours after the trap had been set. The trap contained a large number of *H. ensifer* with many shrimp climbing up the sides, and in the funnel entrance. Many others were on the bottom surrounding the trap. The average size of the shrimp seemed so large that at first the observers thought that despite the relatively shallow depth, some of them were *H. laevigatus*. The trap was hauled the following morning after a soak-time of about 48 hours. It contained 914 *H. ensifer* weighing 16.8 kg with a mean individual weight of 18.4 g. No *H. laevigatus* were found in the catch.

3) Dive 219. A pyramid trap and a half-round trap spaced 15 m apart were deployed together. Both traps landed upright on very fine silty sand overlying a hard substrate. They were about 10 m apart at a depth of 347 m. The traps had been set the previous morning so they had been on the bottom for about 24 hours when observations began. Both traps were filled with shrimp. *Heterocarpus ensifer* were walking over the half-round trap and on the sides of the pyramid trap (Fig. 5). The surrounding sandy bottom was covered with *H. ensifer*. As had been observed during the previous trap set, the average size of the *H. ensifer* was uniformly large with very few small individuals in or around the traps. Shrimp

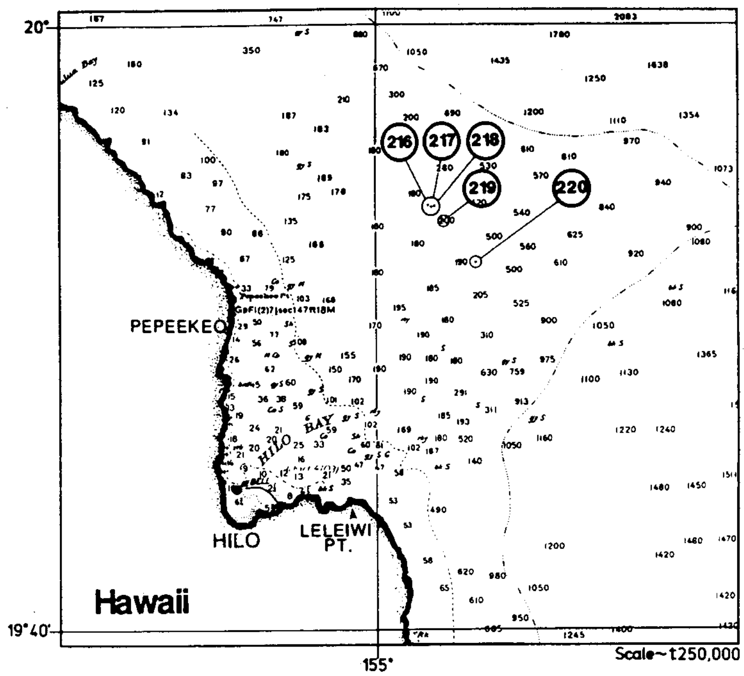


Figure 4.—Dive sites off the Island of Hawaii (soundings are shown in fathoms).

**Table 1.—Trapping observations of *Heterocarpus ensifer* during *Makalii* dives off Hawaii.**

| Observation | Dive number | | | | |
|---|---|---|---|---|---|
| | 216 | 217 | 218 | 219 | 220 |
| Depth of traps (m) | 375-385[1] | 347 | 349 | 347 | 347 |
| Bottom type | Silty sand over hard substrate | Lava rubble and low outcroppings | Silty sand over hard substrate | Silty sand over hard substrate | Silty sand over hard substrate |
| Trap soak time when observed (h) | No traps set | 1.5-4 | 24-27 | 24-27 | 1.5-4 |
| Trap soak time when hauled (h) | | 26 | 48 | 48 | 21 |
| Abundance of *H. ensifer* observed in the area | High | Low | High | High | High |
| Abundance of *H. ensifer* observed in pyramid trap | | | High | High | High |
| Abundance of *H ensifer* observed in half-round trap | | Very few | | High | High |
| No. of *H. ensifer* landed in pyramid trap | | | 914 | 1,497 | 1,676 |
| No. of *H. ensifer* landed in half-round trap | | 69 | | 1,016 | 1,110 |

[1]Range of depths observed during the dive.

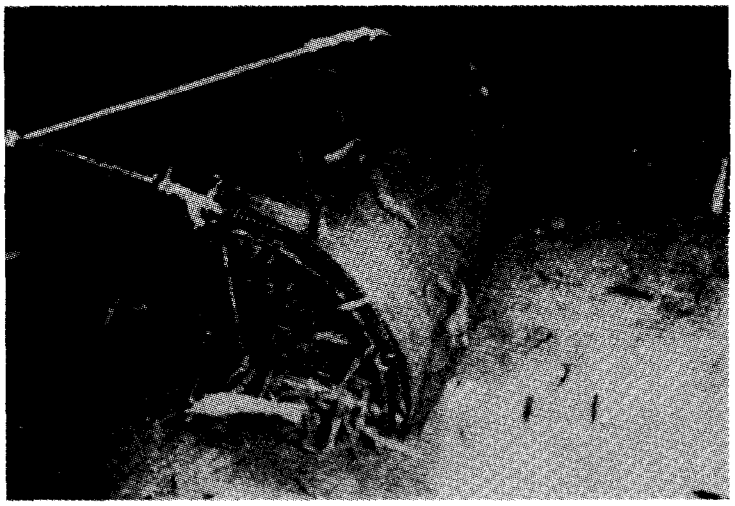

Figure 5.—Half-round trap on the bottom in a depth of 347 m; dive 219.

were frequently seen both entering and exiting the half-round trap. When they entered the conical entrance, which on this type of trap was at ground level, they usually climbed in. However, they also were observed swimming in and out. Although shrimp sometimes swam to heights approaching 2 m above the bottom, none was observed swimming into the apical entrance of the pyramid trap. They were observed in various stages of climbing up the sides of the trap towards the entrance, and into the entrance. No shrimp were observed exiting the pyramid trap. A survey of the bottom in the vicinity around the traps showed it consisted mostly of silty sand. The exception to the otherwise flat sandy topography was a small area of lava outcrops about 30 m from the trap site. There solitary striped shrimp, *P. longirostris*, were in holes and cracks in the hard substrate. The traps were hauled the following morning after being in the water for about 48 hours. The pyramid trap caught 1,497 *H. ensifer* weighing 28 kg. The half-round trap caught 1,016 *H. ensifer*, weighing 19 kg, and 7 *P. longirostris*. The mean individual weight of *H. ensifer* taken in each trap was 18.7 g.

4) Dive 220. A pyramid trap and a half-round trap spaced 15 m apart. Both traps landed on typical silty sand ground about 10 m apart in a depth of 347 m. The half-round trap was upright but the pyramid trap was on its side. The *Makalii* reached the traps about 1.5 hours after they had been set earlier that morning. The surrounding area was already covered with *H. ensifer* and shrimp were crawling over both the traps. Despite a soak time of less than 2 hours they both appeared to contain more shrimp than we had thus far seen. As on the previous dive, shrimp were both entering and exiting the half-round trap. Unfortunately, because of the danger of becoming fouled in the groundline, we were unable to get into a position to observe the entrance of the pyramid trap which in its overturned position lay close to the bottom.

During the 2.5-hour period between the first and last observations of the half-round trap there did not seem to be a noticeable increase in *H. ensifer* around or inside the trap. When it was hauled 21 hours later, the catch, although substantial, did not appear to be much different from what we had observed from the submersible. The pyramid trap caught 1,676 *H. ensifer* weighing 32 kg and the half-round trap caught 1,110 *H. ensifer* weighing 21 kg. The mean individual weights of *H. ensifer* were 19.1 g in the pyramid trap and 18.9 g in the half-round trap.

These observations showed that *H. ensifer* are attracted very rapidly to baited traps, and that a large percentage of the animals within olfactory range (depending on current conditions) may enter a trap within 2-3 hours of setting. Both traps with top entrances and those with entrances close to the substrate are efficient in allowing *H. ensifer* to enter. However, if the shrimps are satiated or the bait depleted, they apparently can more easily exit a trap with a horizontally oriented entrance near the bottom than one with a vertical top entrance. Thus small traps with bottom entrances may be more suitable for relatively short soak periods. For instance, an early morning set, and haul before noon. For longer soaks (overnight) a taller trap with a top entrance may hold the catch more efficiently.

King (1981) cited data which suggests that *H. ensifer* and *H. laevigatus* only enter traps during night. In surveys by the SWFC Honolulu Laboratory, good catches of *H. laevigatus* were made during daylight sets[3]. From deepwater photo sequences of baited traps made off Palau, Saunders (1984) found that the upper range of *H. ensifer* appeared to be strongly influenced by daily photic fluctuations. They were abundant in night sequences at 150-250 m depths, but were not recorded in daylight sequences shallower than 274 m. However, at greater depths there appeared to be no differences in either activity or numbers of individuals in day versus night photo sequence. Our trap sets were all well below 274 m. It is also likely that photic penetration is relatively limited off the east coast of Hawaii, which is subjected to considerable natural runoff as well as sugar factory effluent compared with Palauan waters. This study showed conclusively that, during peak daylight hours at the depths observed, *H. ensifer* are active feeders and will readily enter traps.

[3]Honolulu Laboratory, Southwest Fisheries Center, 2570 Dole St., Honolulu, HI 96822-2396. Unpubl. data.

However, we are not aware of any investigation which has rigorously compared the relative merits of day and night trapping for *Heterocarpus* spp. The shrimp catches in both trap types were *H. ensifer* with the exception of the seven *P. longirostris* caught in the half-round trap observed on dive 219. No *H. laevigatus* were found in any of the catches.

We were impressed by the uniformly large size of *H. ensifer* viewed from the submersible and caught in the traps. The mean individual weights of *H. ensifer* from the two types of traps were virtually identical, at about 18.8 g. This was quite large when compared with a mean weight of 12 g for *H. ensifer* taken during trapping surveys in the NWHI (Gooding, 1984), and a maximum weight for *H. ensifer* of about 16 g reported by Struhsaker and Aasted (1974). Some studies have indicated that large *H. ensifer* occur within the depth range of maximum abundance, with smaller animals occurring both shallower and deeper (Clarke, 1972; Struhsaker and Aasted, 1974; King, 1981a). However, Moffitt and Polovina (1987) found no significant change in the size of *H. ensifer* with depth. Our observations were made at the shallow end of the range of maximum abundance for *H. ensifer* found by Gooding (1984). The submersible surveys revealed virtually no small individuals in the vicinity of the traps or the surrounding area. Thus we speculate that smaller size classes were occupying other habitats. The shrimp were not methodically sexed but inspections of the catches showed the presence of both sexes with a high incidence of berried females.

On *H. laevigatus* surveys in the Mariana Islands, Ralston (1986) found that pyramid traps outperformed half-round traps by a ratio of nearly 6:1. In this study, for the two sets (dive 219 and 220), when pyramid and half-round traps lay adjacent to one another on the same type of ground, the pyramid traps caught only 1.5 times (60 kg) the catch of the half-round traps (40 kg).

On dive 220 the pyramid trap that was lying on its side fished equally well relative to the attached half-round trap as did the upright pyramid observed on dive 219.

Figure 6.—*Heterocarpus ensifer* aggregated around tuna can in a depth of 347 m; dive 220.

Table 2.—Rate of *Heterocarpus ensifer* aggregation to a punctured tuna can as the number of animals observed over a 10-minute period.

| Elapsed time (min.) | Rocky outcropped bottom | | | Sandy rubble bottom | Silty sand bottom | | |
|---|---|---|---|---|---|---|---|
| | Dive 219 Test 1 | Dive 219 Test 2 | Dive 220 Test 1 | Dive 219 Test 3 | Dive 219 Test 4 | Dive 220 Test 2 | Dive 220 Test 3 |
| 1 | 1 | 0 | 0 | 1 | 2 | 2 | 7 |
| 2 | 1 | 0 | 0 | 1 | 5 | 8 | 14 |
| 3 | 1 | 0 | 0 | 1 | 9 | 13 | 20+ |
| 4 | 1 | 0 | 0 | 1 | 12 | 20 | 30+ |
| 5 | 1 | 0 | 0 | 2 | 20+ | 30+ | |
| 6 | 1 | 1 | 0 | 2 | 30+ | | |
| 7 | 1 | 1 | 0 | 2 | | | |
| 8 | 1 | 1 | 0 | 2 | | | |
| 9 | 1 | 1 | 0 | 2 | | | |
| 10 | 1 | 1 | 0 | 2 | | | |

## Tuna Can Observations

Punctured tuna cans (Fig. 6) were deployed on three substrate types: Silty sand, rocky outcroppings, and sandy rubble. Table 2 lists the number of *H. ensifer* which aggregated to the bait in each test during 10 minutes of observation. The *H. ensifer* were apparently following the odor gradient and invariably approached the can from the down-current direction. On one rocky ground test the can was placed about 2 m directly up-current of an outcropping in which we could see several *P. longirostris*; however, none of them left their holes to approach the can. On the sandy ground there was initially a rapid increase in the aggregation rate of *H. ensifer* with time which appeared to start leveling off after about 7-8 minutes. We were unable to make counts beyond about 30 animals. These crude tests clearly indicate a much higher density of *H. ensifer* on the sandy silt substrate than on the two others.

## Other Behavior

*Heterocarpus ensifer* apparently were neither attracted, repelled, nor affected in any way by the lights from the submersible. When, after a period of total darkness, the flood lights were turned on to large aggregations of *H. ensifer* gathered around traps, we were unable to discern any changes in their behavior. On dive 220 we had the opportunity for just a few seconds to observe *H. ensifer* in something approaching an undisturbed natural state. As the *Makalii*, following its descent from the surface, approached to within about 3 m of the flat sandy bottom, we were able to see *H. ensifer* all over the sandy surface out to the limits of visibility. They were solitarily distributed, about 1 per $m^2$. As the submersible settled on the bottom, some of the shrimp which were within about 1-2 m from the *Makalii* swam vertically to as high as about 2 m from the bottom. More distant shrimps, although suddenly subjected to greatly increased light, remained undisturbed. Our impression was that the disturbed *H. ensifer* were reacting to the sudden physical presence of the submersible in their midst rather than to the light.

We did not see any burrowing in the sand by *H. ensifer* on this occasion or during other observations. This supports aquaria observations which indicated that *Heterocarpus* sp. did not burrow in the substrate (King, 1986).

It is well known from the condition of shrimp in trap catches that *Heterocarpus* are cannibalistic. We did not usually observe any overt aggressive behavior amongst shrimp under the various conditions of our study. However, in two instances it was shown vividly that an *H. ensifer* that finds itself at a disadvantage to its fellows quickly becomes fair game. When the tails of animals within a trap protruded through the mesh, shrimp on the outside would start feeding on the tail, and on one occasion during observations of shrimp attracted to a tuna can, an *H. ensifer* which was injured by the submersible's manipulating arm was immediately attacked by other shrimp in the area.

## Bottom Habitat

Our observations from the *Makalii*, the subsequent trap catches, and the tuna can aggregation tests showed that of the two distinct types of substrate we encountered on Mauna Kea ledge, i.e., low profile outcropping and silty sand overlying flat substrate, the preferred type of ground for *H. ensifer* was clearly the latter. Of the six traps we recovered, the two half-round traps that landed on flat sand had a mean catch rate of 20 kg per trap whereas the half-round trap observed on rocky ground caught only 69 *H. ensifer* (probably about 1.2 kg). The three pyramid traps, all of which were on sand, had a mean catch rate of 25.6 kg per trap. Conversely, with the exception of a single *P. longirostris* observed on the bottom in front of the half-round trap on dive 219, we did not see any other of this species on sandy ground. Seven *P. longirostris* were caught in the trap which was lying about 30 m from an area of exposed hard substrate on which *P. longirostris* were seen under ledges and in small holes. No *P. longirostris* were caught in the pyramid trap on the same string. However, the half-round trap on dive 217 that lay on rocky ground where we had seen *P. longirostris*, did not catch any *P. longirostris*. Unfortunately, the other four traps on the same string were lost.

## Bacterial Tests

The results of the bacteriological culture assays (Table 3) indicate that *Vibrio alginolyticus* and another *Vibrio* sp. found commonly in and on both *H. ensifer* and *H. laevigatus* are apparently not acquired in the trap during hauling or after the shrimp are landed on the vessel.

**Table 3.—Results of bacteriological tests to determine the distribution of *Vibrio* sp.**

| Item | TCBS | Marine agar |
|---|---|---|
| Shrimp | 4+ *Vibrio alginolyticus* and one other *Vibrio* sp. (not identified) | 4+ |
| Bottom sediment | 2+ One *Vibrio* sp. found. The same as the unidentified species from the shrimp | 4+ |
| Water column | 0 No *Vibrio* sp. recovered. | 4+ |

1+ = 100 colonies/ml.
2+ = 100-500 colonies/ml.
3+ = 500-2,000 colonies/ml.
4+ = 2,000 colonies/ml.

The indication of a 4+ growth on the *H. ensifer* compared with a 2+ growth in the surrounding bottom material implies that the shrimp are likely a primary substrate for the *Vibrio*. A 4+ on the marine agar indicates other bacteria, primarily *Pseudomonas* spp. are ubiquitous on the bottom as well as in the water column.

*Vibrio alginolyticus*, *V. parahaemolyticus*, and *Vibrio* sp. have also been found commonly on marine mammals inhabiting the upper water column (Dailey, 1985). This would tend to verify that animals rather than the water column or bottom serve as the primary substrate for these microorganisms.

## Conclusions

Because of various logistic factors the observations and tests conducted during these dives were somewhat limited in scope and sophistication. Nevertheless, the results show that valuable insights into trap siting and trap design relative to deepwater shrimp ecology and behavior and also more general aspects of the biology of shrimp can be acquired using a research submersible. This type of information can complement and supplement data collected by more conventional methods.

The HURL has recently acquired the *Pisces V*, a three-man, one-atmosphere submersible that can reach depths of 2,000 m. Planned SWFC Honolulu Laboratory studies on *H. laevigatus* from the *Pisces V* will provide information about this potentially more valuable species which, we hope, will contribute to the development and management of deepwater shrimp fisheries in Hawaii and other Pacific island areas.


## Acknowledgment

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## Literature Cited


Brown, I. W., and M. G. King. 1979. Deepwater shrimp trapping project. Report on Phase I. Minist. Agric. Fish., Fish. Div. Tech. Rep. 1, Fiji, 20 p.

Clarke, T. A. 1972. Exploration for deep benthic fish and crustacean resources in Hawaii. Univ. Hawaii, Hawaii Inst. Mar. Biol., Honolulu, Tech. Rep. 29, 18 p.

Dailey, M. D. 1985. Diseases of marine mammalia: Cetacea. *In* O. Kinne (editor), Diseases of marine animals, p. 805-846. Biol. Anstalt Helgol. Hamburg. 14(2), Chapter 7.

________ and S. Ralston. 1986. Aspects of the reproductive biology, spatial distribution, growth, and mortality of the deepwater caridean shrimp, *Heterocarpus laevigatus*, in Hawaii. Fish. Bull. (U.S.) 84:915-925.

Gooding, R. M. 1984. Trapping surveys for the deepwater caridean shrimps, *Heterocarpus laevigatus* and *H. ensifer*, in the Northwestern Hawaiian Islands. Mar. Fish Rev. 46(2):18-26.

Intes, A. 1978. Deep trap fishing in New Caledonia and adjacent islands. Preliminary experiments (Peche profonde aux casiers en Nouvelle Caledonie et iles adjacentes. Essais preliminaires.) O.R.S.T.O.M. (Noumea) Rapp. Sci. Tech. 2, 10 p.

King, M. G. 1980. A trapping survey for deepwater shrimp (Decapoda: natantia) in Western Samoa. Rep. Inst. Mar. Resour., Univ. South Pac., Suva, Fiji, 26 p.

________. 1981a. Deepwater shrimp resources in Vanuatu: A preliminary survey off Port Vila. Mar. Fish. Rev. 43(12):10-17.

________. 1981b. The deepwater shrimps of Tonga: A preliminary survey near Nuku'alofa. Rep. Inst. Mar. Resour., Univ. South Pac., Suva, Fiji. 28 p.

________. 1982. Report on the South Pacific Commission deepwater shrimp assessment consultancy in Papua New Guinea. South Pac. Comm., Noumea, New Caledonia, 24 p.

________. 1984. The species and depth distribution of deepwater caridean shrimps (Decapoda, Caridea) near some southwest Pacific islands. Crustaceana 47(2):174-191.

________. 1986. Fishery resources of Pacific island countries. Part 1. Deepwater shrimps. FAO Fish. Tech. Pap. 272.1, 45 p.

Moffitt, R. B. 1983. *Heterocarpus longirostris* MacGilchrist from the Northern Mariana Islands. Fish. Bull. (U.S.) 83:434-436.

________ and J. J. Polovina. 1987. Distribution and yield of the deepwater shrimp *Heterocarpus* resource in the Marianas. Fish. Bull. (U.S.) 85:339-349.

Ralston, S. 1986. An intensive fishery experiment for the caridean shrimp *Heterocarpus laevigatus* at Alamagan Island in the Mariana Archipelago. Fish. Bull. (U.S.) 84:927-934.

________, R. M. Gooding, and G. M. Ludwig. 1986. An ecological survey and comparison of bottom fish resource assessments (submersible versus handline fishing) at Johnston Atoll. Fish. Bull. (U.S.) 84:141-154.

Saunders, W. B. 1984. The role and status of Nautilus in its natural habitat: Evidence from deep-water remote camera photosequences. Paleobiology 10:469-486.

Schlais, J. F. 1982. Deepwater shrimps, a new Pacific fishery. Sea Frontiers, Nov.-Dec.

________. 1983. Fledgling Hawaiian shrimp fishery could someday rival the Gulf catch. Natl. Fisherman 64(3):8.

Struhsaker, P., and D. C. Aasted. 1974. Deepwater shrimp trapping in the Hawaiian Islands. Mar. Fish. Rev. 36(10):24-30.

Wilder, M. J. 1977. Biological aspects of the fisheries potential of two deep water shrimp, *Heterocarpus ensifer* and *H. laevigatus* in waters surrounding Guam. M.S. Thesis, Univ. Guam, 79 p.