

Trapping Surveys for the Deepwater Caridean Shrimps, *Heterocarpus laevigatus* and *H. ensifer*, in the Northwestern Hawaiian Islands

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Introduction

The caridean shrimps, *Heterocarpus laevigatus* Bate and *H. ensifer* Milne Edwards (Fig. 1), are deepwater species with a mid-latitude circumglobal distribution extending throughout the eastern and western Atlantic, Indo-west Pacific, Hawaii, and Indian Ocean (Holthuis, 1980). *Heterocarpus laevigatus* inhabits a deeper depth range than *H. ensifer* and, because of its larger size, is generally considered to have the greater commercial potential.

Experimental trapping surveys have shown that both species are widely distributed throughout the central and western Pacific. Exploratory trap fishing has been conducted in Hawaii (Clarke, 1972; Struhsaker and Aasted, 1974); Guam (Wilder, 1977; Moffitt, 1983); New Caledonia (Intès, 1978); Fiji (Brown and King, 1979); Western Samoa (King, 1980a); Vanuatu (King, 1980b, 1981c); Tonga (King, 1981a); and Papua New Guinea (King, 1982).

The available literature indicates that

ABSTRACT—Baited traps were used to assess the geographic and depth distribution of the deepwater caridean shrimps *Heterocarpus laevigatus* and *H. ensifer* in the Northwestern Hawaiian Islands. Traps were set in depths ranging from about 290 to 880 m. Both species occurred throughout the length of the chain. Catch rates varied markedly with depth. Highest catches of *H. laevigatus* were made in 500-800 m with a mean catch rate of 0.91 kg per trap-night. For *H. ensifer*, optimum trapping depths were 350-600 m with a mean catch rate of 1.66 kg per trap-night.

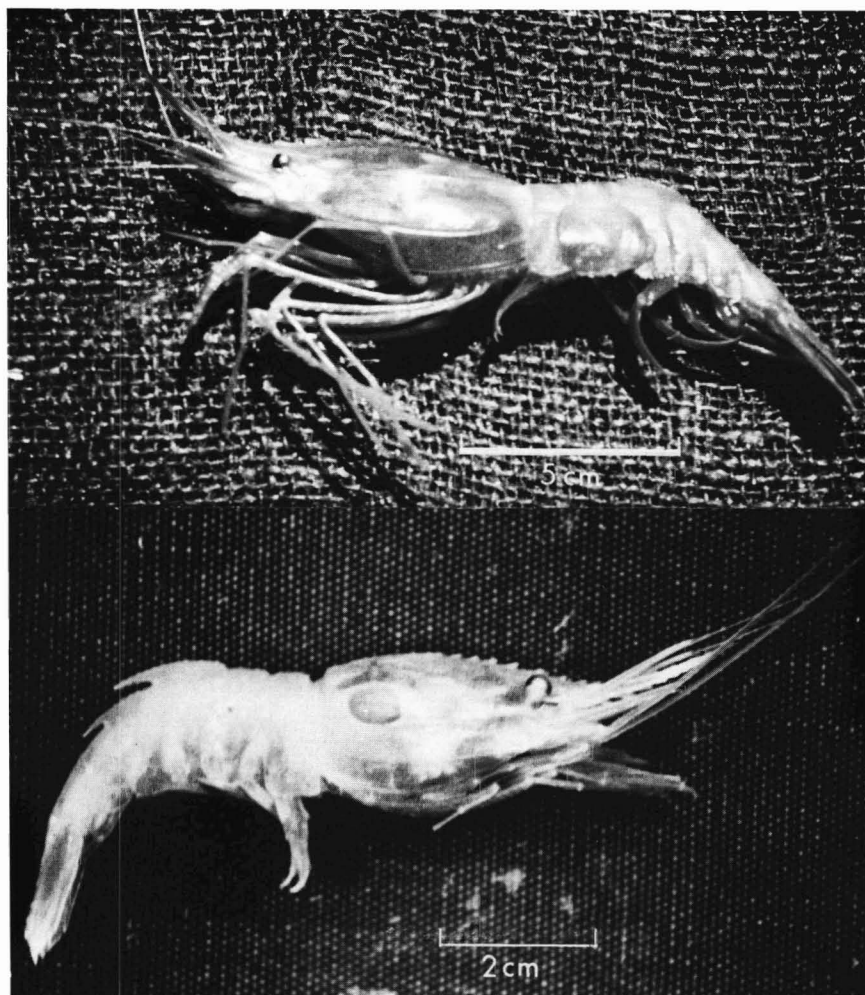


Figure 1.—*Heterocarpus ensifer* (top) and *H. laevigatus*.

in the Pacific outside of Hawaii *Heterocarpus* is commercially exploited only in a trawl fishery for *H. reedi* off

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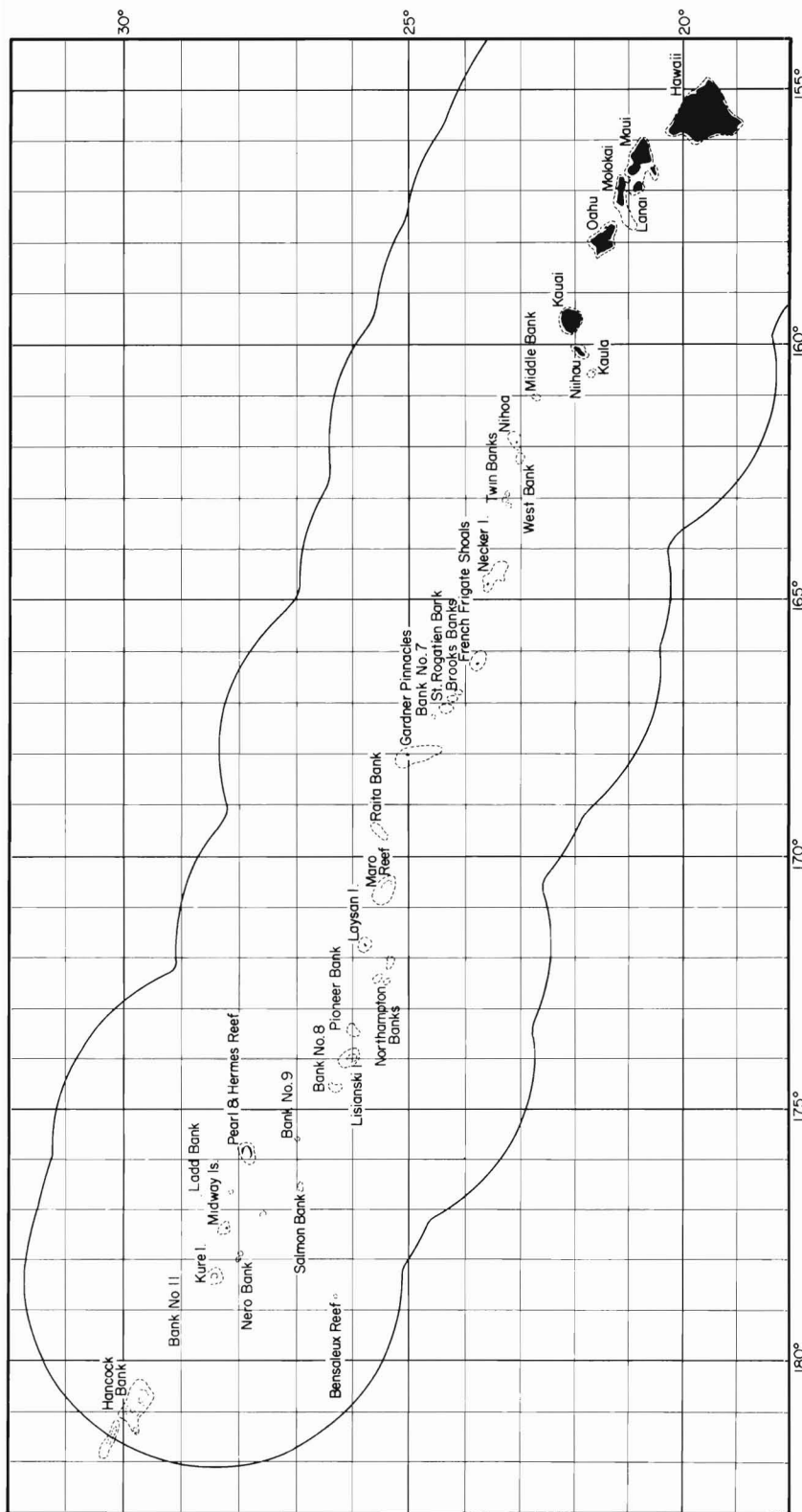


Figure 2.—The Hawaiian Archipelago including the Northwestern Hawaiian Islands.

Chile and Peru (Hancock and Henriquez, 1968; Longhurst, 1970) and in a fishery for *H. vicarius* off Costa Rica and Panama (Holthuis, 1980). Two commercial-scale projects have been conducted to determine the economic feasibility of a fishery for *H. laevigatus* and *H. ensifer* in the Hawaiian Islands (Oishi, 1983; Hawaiian Divers, Inc.¹). At present, private interests are endeavoring to develop a fishery for deepwater shrimp in the Hawaiian Islands (Schlais, 1983).

During exploratory trawling surveys for penaeid shrimp, *Penaeus marginatus*, conducted by the Honolulu Laboratory of the National Marine Fisheries Service's (NMFS) Southwest Fisheries Center (SWFC), in 1967-68 (Yoshida, 1972), *H. ensifer* and *H. laevigatus* were caught in small numbers (Struhsaker and Yoshida, 1975). Later experimental fishing in Hawaii between 1968 and 1973 (Clarke, 1972; Struhsaker and Aasted, 1974) showed that trapping rather than trawling was a more effective method of fishing for *H. ensifer* and *H. laevigatus*. Those early surveys indicated that the two species might constitute an unexploited resource of considerable commercial potential.

In response to recommendations from the Governor's Task Force on Oceanography of the State of Hawaii (Department of Planning and Economic Development, 1969, 1974), NMFS conducted exploratory deepwater shrimp trapping in various areas in the Hawaiian chain (Struhsaker and Aasted, 1974), including Necker Island, French Frigate Shoals, Laysan Island, and Pioneer Bank in the Northwestern Hawaiian Islands (NWHI) (Fig. 2). From 1975 to 1982, in a cooperative research effort with several other agencies to investigate NWHI marine and terrestrial resources, NMFS made extensive surveys of the offshore finfish and crustacean resources throughout the NWHI

¹Hawaiian Divers, Inc. 1983. Deepwater shrimp utilization study for Hawaii. Report prepared under NOAA Cooperative Agreement No. 80-ABH-00065 for the Southwest Region, Western Pacific Program Office, Natl. Mar. Fish. Serv., NOAA, P.O. Box 3830, Honolulu, HI 96812. 48 p. (On file at NMFS Southwest Fish. Cent., Honolulu, HI 96812.)

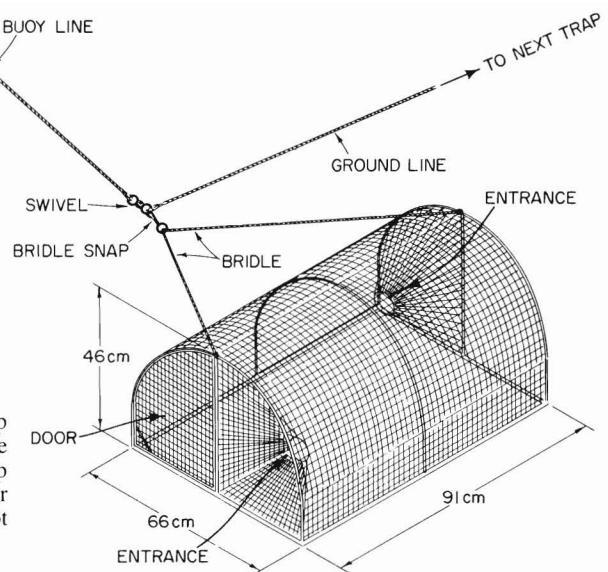
(Uchida et al., 1980). From 1978 to 1981 exploratory trapping for deep-water shrimps was conducted during nine cruises (TC-78-03, TC-79-03, TC-80-02, TC-80-03, TC-80-04, TC-80-05, TC-81-01, TC-81-02, and TC-81-04) of the NOAA ship *Townsend Cromwell*. This report is based on the data collected during that period.

Gear and Methods

The shrimp traps (Fig. 3) were half round, with a frame constructed of 1.27 cm reinforcing steel, covered with 1.27 × 2.54 cm mesh hardware cloth. At each end they had a quadrant-shaped entry of a mean width about 33 cm tapering to an inner opening 8-10 cm in diameter. A bait container (12 × 12 × 27 cm) made of the same mesh hardware cloth was located at the top of each trap near one entrance. On the basis of field tests which showed that covered traps out-fished uncovered traps by factors of from 2.5 to 10 (Struhsaker and Aasted, 1974), the tops of the traps were covered with black canvas or burlap. It is generally believed that covered traps may be more effective because the bait scent tends to be concentrated at the trap entrances and cannot easily diffuse through the trap mesh, as it might in uncovered traps. No tests were made during this survey to compare covered and uncovered traps; however, King (1981c) found no significant difference in the mean catch rates of *H. ensifer* between covered and uncovered traps. The number of traps and spacing on the ground line were not consistent throughout the survey. Most sets consisted of either four or five traps spaced 36 m apart. On a few sets, however, six trap strings were fished or traps were spaced at 18 or 45 m. The traps were usually weighted with about 5 kg of chain link, and an anchor was attached to the end trap of each string.

The ground line and buoy line were 1.27 cm polypropylene rope. The buoy line was made up of 92 or 185 m lengths, which were stored in 121 l (32-gallon) plastic garbage containers. This facilitated adjustment of the length of the buoy line appropriate to the depth. To minimize the possibility of marker buoy submergence due to current drag or to trap strings slipping into deeper water, at

Figure 3.—The shrimp trap used in the survey. The half-round top of the trap was covered with either black canvas or burlap (not shown in the diagram).



least a 2:1 and frequently a 3:1 scope ratio was used. The markers consisted of weighted bamboo flagpoles buoyed with either large spherical inflatable or rigid plastic floats. Another plastic float at the end of a short trail line provided reserve buoyancy and facilitated gear retrieval. The bait used throughout the survey period consisted of from two to three (about 1 kg) whole fish, usually either jack mackerel or Pacific mackerel. Trapping stations were occupied from 1600 to 1800 hours in the afternoon until 0800-1000 hours the following morning, allowing an overnight soaking time of 14-18 hours.

The combination of strong currents and precipitous dropoffs along the NWHI banks frequently made it difficult to locate suitable areas for trap stations. To keep gear loss to a minimum, depth sounding transects were always made before setting to determine areas where the slope was not too steep.

Results and Discussion

Fishing Effort and Geographic Distribution

Fifty-four fishing stations consisting of 458 trap-nights of fishing effort were occupied on 17 banks along the entire length of the NWHI. Totals of 199.06 kg of *H. laevigatus* and 479.69 kg of *H. ensifer* were trapped. The fishing effort was not evenly distributed. Some banks such as Necker, French Frigate Shoals,

Gardner Pinnacles, and Maro Reef were relatively well surveyed, whereas very little effort was expended on others. Table 1 shows the trapping effort, catch rates, and depth ranges for all banks sampled. Both species were taken at all of the survey areas except Brooks Banks, Raita Bank, Laysan Island, and Lisianski Island, where only *H. ensifer* were caught, and Ladd Bank, where neither species was caught. Some sets at those areas were in depths where *H. laevigatus* usually occurred in other areas sampled. Throughout the survey, however, there was considerable variation in catch rates among traps within a set, and between sets made in the same area at similar depths. Thus, on the basis of the data available, there is little reason not to assume that both species occur at appropriate depths on all the banks in the NWHI chain.

Depth Range

In this report, catch data are related to depth of capture. The distribution of shrimp is possibly related more directly to temperature; however, temperature data were not routinely collected. Depths ranging from 290 to 880 m were sampled; however, depths of <300 m and >800 m received relatively little effort. Figure 4 shows the effort and the catch per unit effort (CPUE) for 50 m depth zones for both species.

Our trapping effort clearly did not sample the shallowest depths at which

Table 1.—Fishing effort, depth range fished, total catches, and catch per unit effort for all areas surveyed in the Northwestern Hawaiian Islands.

Fishing area	Effort (trap-nights)	Depth range fished (m)	<i>H. laevigatus</i>		<i>H. ensifer</i>	
			Total catch (kg)	Mean catch per trap-night	Total catch (kg)	Mean catch per trap-night
Southern area						
Nihoa Island	23	368-600	1.38	0.06	25.07	1.09
West Bank	16	338-732	2.16	0.16	7.52	0.47
Twin Banks	6	468	4.44	0.74	20.28	3.38
Necker Island	88	289-867	45.76	0.52	127.60	1.45
French Frigate Shoals	53	368-733	17.49	0.33	129.85	2.45
Brooks Banks	20	329-485	0	0	11.00	0.55
St. Rogatien Bank	31	309-766	7.15	0.23	23.25	0.75
Bank No. 7	12	481-821	8.64	0.72	0.96	0.08
Northern area						
Gardner Pinnacles	70	68-758	83.30	1.19	48.30	0.69
Raita Bank	12	399-427	0	0	15.84	1.32
Maro Reef	74	287-772	25.90	0.35	48.10	0.65
Laysan Island	12	331-879	0	0	1.80	0.15
Northampton Bank	12	540-690	1.20	0.10	3.12	0.26
Lisianski Island	8	459-561	0	0	12.24	1.53
Salmon Bank	12	512-647	0.84	0.07	0.36	0.03
Ladd Bank	4	566	0	0	0	0
Kure Atoll	5	562	0.80	0.16	4.40	0.88

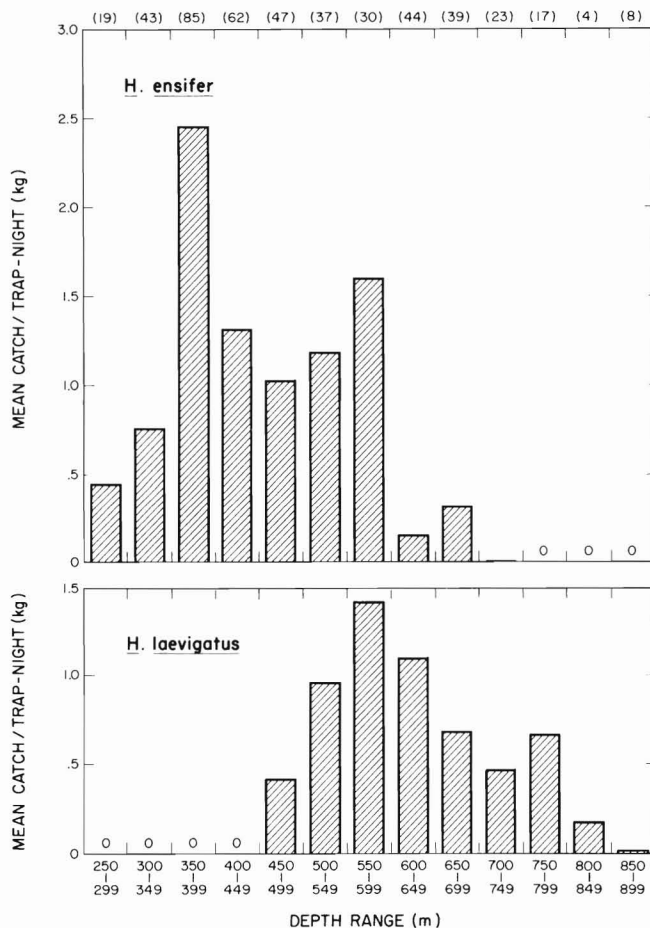


Figure 4.—Catch per trap-night of *Heterocarpus ensifer* and *H. laevigatus* per 50 m depth zone. Effort (trap-nights) is shown in parentheses.

H. ensifer probably occurs in the NWHI. In the main Hawaiian Islands, Clarke (1972) caught *H. ensifer* between 145 and 740 m, and Struhsaker and Aasted (1974) took *H. ensifer* in depths ranging from 137 to 660 m.

Heterocarpus laevigatus were trapped between 453 and 867 m (Fig. 4). Although there were small catches in the 850-899 m depth zone, it appears likely this was close to the maximum depth for this species in the NWHI. Clarke (1972) collected *H. laevigatus* from 365 to 728 m, and Struhsaker and Aasted (1974) caught them in depths from 430 to 825 m. Results obtained by investigators in other areas of the Pacific do not extend maximum depths below those we obtained. King (1981b) reported depth ranges in the southwestern Pacific islands of 285-760 m for *H. ensifer* and 380-860 m for *H. laevigatus*. In his surveys, the range of depth distribution for both species differed to some extent in the various island groups he surveyed. Wilder (1977) found *H. laevigatus* in depths ranging from 457 to 732 m off Guam, but apparently did not sample below the maximum depth he reported for the species.

Of more significance to a fishery are depths of optimum abundance. Figure 4 indicates that the approximate optimum depth range for trapping *H. ensifer* in the NWHI was 350-599 m. Struhsaker and Aasted (1974) found peak abundance of *H. ensifer* in depths of 365-440 m, and Clarke (1972) concluded they were most abundant in depths of 275-455 m. Comparison of the deep end of our optimum depth range with that found by the earlier investigations in the main Hawaiian Islands indicates, as first suggested by Struhsaker and Aasted (1974), that peak abundance of *H. ensifer* may occur deeper in the NWHI than in the main Hawaiian Islands. During exploratory shrimp trapping off the Island of Hawaii by the SWFC Honolulu Laboratory, the optimum depth range for *H. ensifer* was ²335-618 m, a range very similar to that found during the NWHI survey.

²Narrative report, Townsend Cromwell cruise 79-05. Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.

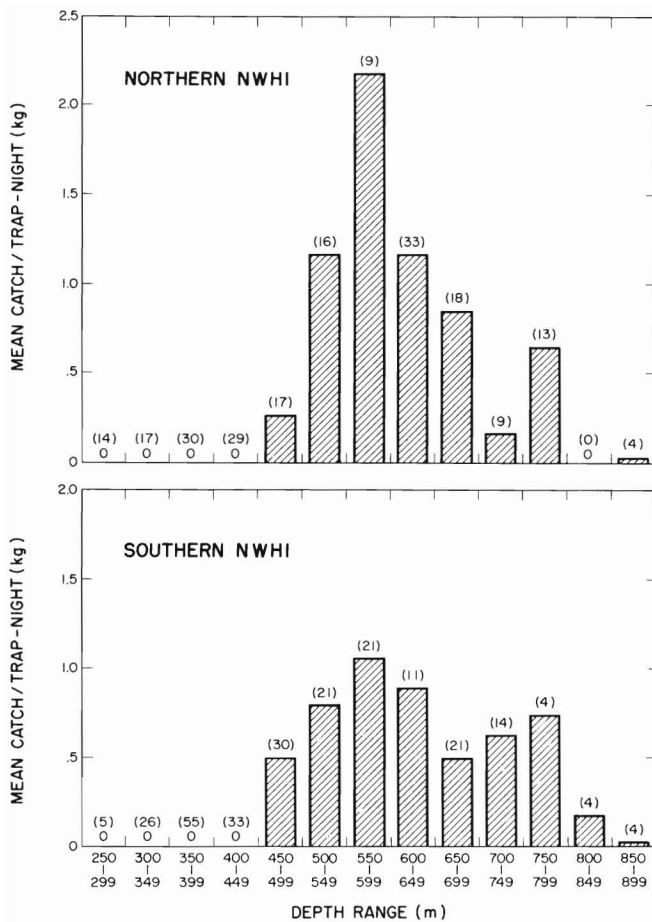


Figure 5.—Catch per trap-night of *Heterocarpus laevigatus* per 50 m depth zone for the northern and southern Northwestern Hawaiian Islands. Effort (trap-nights) is shown in parentheses.

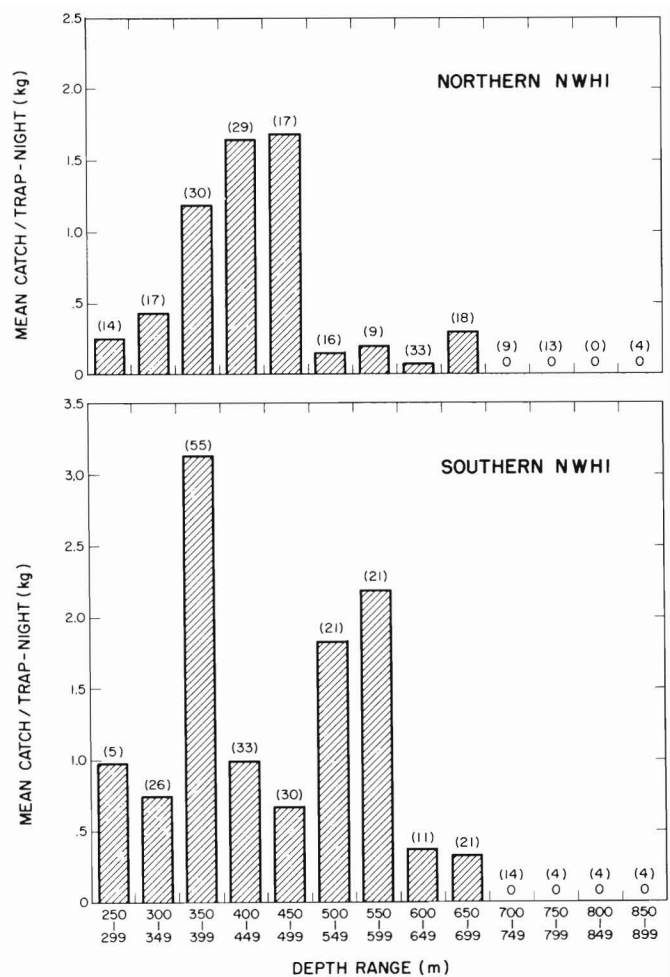


Figure 6.—Catch per trap-night of *Heterocarpus ensifer* per 50 m depth zone for the northern and southern Northwestern Hawaiian Islands. Effort (trap-nights) is shown in parentheses.

The optimum depth range for *H. laevigatus* was 500-799 m (Fig. 4), compared with a range of 440-684 m estimated by Struhsaker and Aasted (1974). The available data seem to indicate that *H. laevigatus* may occur at shallower depths in the main Hawaiian Islands than in the NWHI. During this survey, *H. laevigatus* were not caught in < 453 m whereas they have been taken at 365 m (Clarke, 1972), 430 m (Struhsaker and Aasted, 1974), and 391 m (footnote 2). At Kure Atoll, the most northerly area sampled, the CPUE of *H. laevigatus* was low at a trapping depth of 562 m (Table 1) which was in the depth

zone of peak catches for the overall NWHI survey. However, no other depths were sampled at Kure Atoll. Commercial fishing interests have also found that both *H. laevigatus* and *H. ensifer* occur deeper in the NWHI than in the main islands³.

Northern and Southern Areas

The data did not allow an examination of south to north trends within the

NWHI. In an attempt to determine if there were any obvious differences in catch rates and depth distribution of the two species between southern and northern sections of the survey area, the catch data were segregated for Nihoa Island to Bank No. 7 (southern area) and Gardner Pinnacles to Kure Atoll (northern area) (Fig. 5, 6). The two areas were chosen on the basis of more or less equally distributed sampling effort. A total of 249 trap-nights were fished in the southern area and 209 trap-nights in the northern area.

There was no indication that within the NWHI the peak abundance of *H.*

³M. D. Dailey, Hawaiian Islands Shrimp Co., 737 Bishop Street, Suite 2910, Honolulu, HI 96813. Pers. commun., January 1984.

laevigatus occurred any deeper in the northern part of the survey area. Figure 5 shows that the depth distributions for that species were very similar in the southern and northern sections. The CPUE peaked at the 550-599 m depth zone in both areas; however, catch rates were higher for nearly all the depth zones in the north.

For *H. ensifer* in the northern area (Fig. 6), the highest catch rates were confined to depths ranging from 350 to 499 m, whereas in the south the better catches were spread across a wider range of depths (250 to 599 m). Again, for this species there is no indication that peak abundance occurred any deeper in the north. Indeed, the available data indicate the opposite.

Size by Depth

Previous investigators have demonstrated that the maximum mean size of *H. ensifer* occurs within the depth range of peak abundance, and smaller shrimp occur at shallower and deeper depths (Clarke, 1972; Struhsaker and Aasted, 1974; King, 1981c). During the NWHI survey, length data were not routinely collected. However, total number of individuals and total weight of the two species were recorded, allowing calculation of mean individual weight per trap.

For *H. ensifer*, the NWHI data are in partial agreement with those of other surveys. There was a trend toward decreasing size as depth increased from 450 m to the maximum depth (Fig. 7), which paralleled the sharply declining CPUE over the same depth range (Fig. 4). However, at the depth of peak abundance (350-399 m), there was actually a decline in mean individual weight and an increase towards the shallowest depth sampled. It is possible that had shallower depths been sampled, there may have been a decline in shrimp weight towards the shallowest end of the depth range.

As with *H. ensifer*, the NWHI data for *H. laevigatus* indicate a decline in shrimp size only from the depth range of peak abundance towards deeper water. Figures 4 and 7 show that relatively large *H. laevigatus* were caught at the shallowest end of their range, and that the largest weight class occurred at the depth zone of maximum abundance (550-599

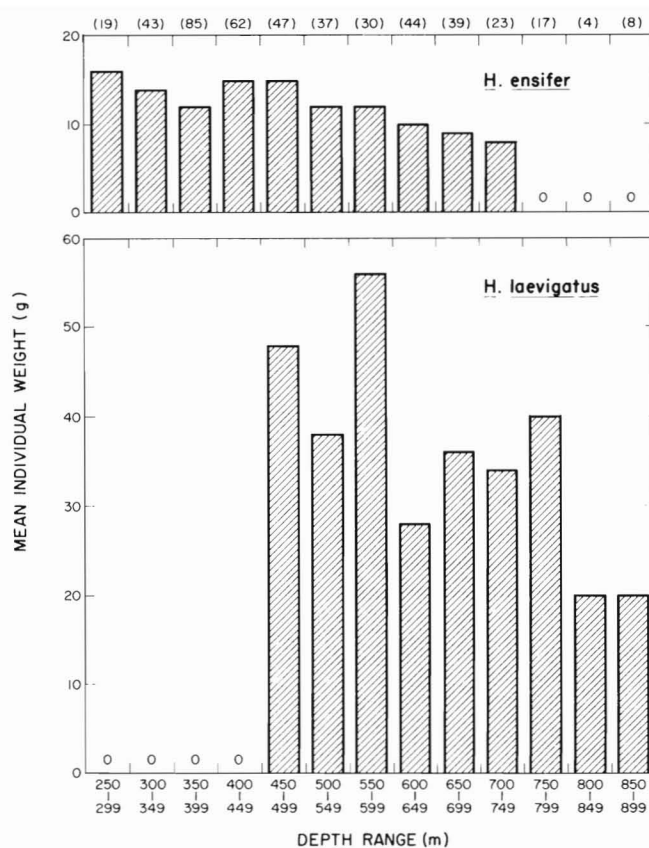


Figure 7.—Mean individual weight of *Heterocarpus ensifer* and *H. laevigatus* per 50 m depth zone. Effort (trap-nights) is shown in parentheses.

m). Net mean individual weight declined with CPUE towards the deep end of the range.

The relationship between CPUE (in terms of weight) and depth was not significantly affected by variations in mean weight of the shrimp. Figure 8 shows numbers of shrimp per trap-night per depth zone. The only marked change in the overall picture when the data are presented this way is that for *H. laevigatus* there was a shift in peak abundance from the 550-599 m to the 600-649 m depth zone, further emphasizing the sharp decline in the weight of *H. laevigatus* between the two zones (Fig. 7).

Catch by Season

Clarke (1972) did not get a clear picture of seasonal change, based on data

from single trap sets off Kaneohe, Oahu, at 1-month intervals from January to October. His very limited data indicated that all low catches and no really large ones were made between March and September, suggesting lower abundance during the summer. In Fiji, King (In press) found that catch rates did not change significantly with season.

During the NWHI survey, the trapping effort was not well distributed over all months or even seasons. The mid-summer months received a large proportion of the effort whereas the midwinter months received relatively little effort. However, when the data are segregated on a two-season basis, the distribution of effort is reasonably good (273 trap-nights during April-September, and 185 trap-nights during October-March). Figure 9 shows the CPUE and mean

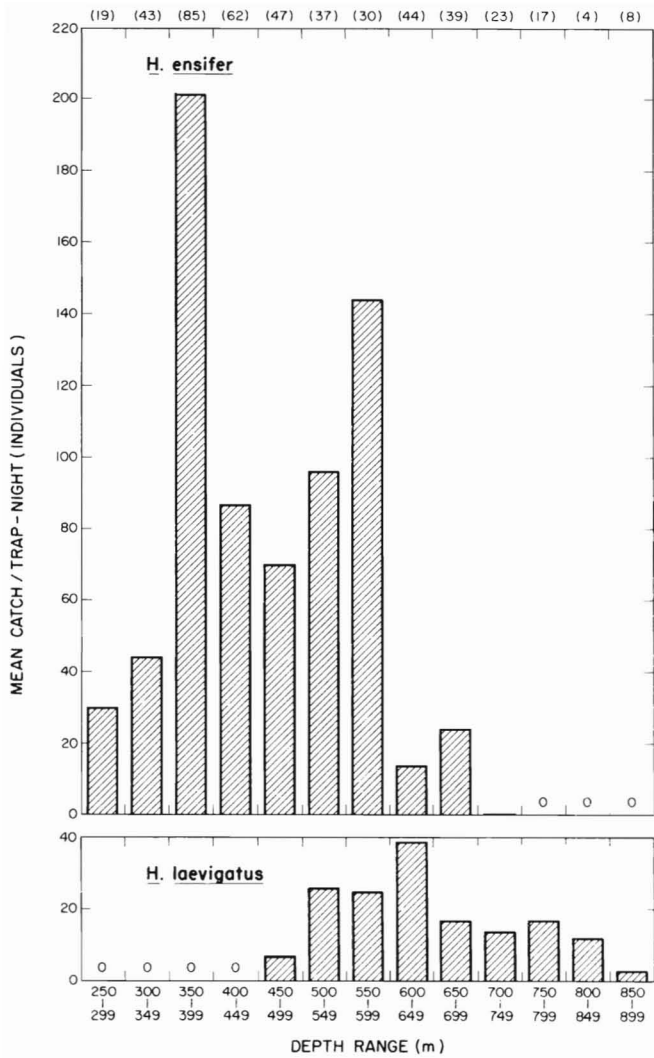


Figure 8.—Mean catch per trap-night (individuals) per 50 m depth zone. Effort (trap-nights) is shown in parentheses.

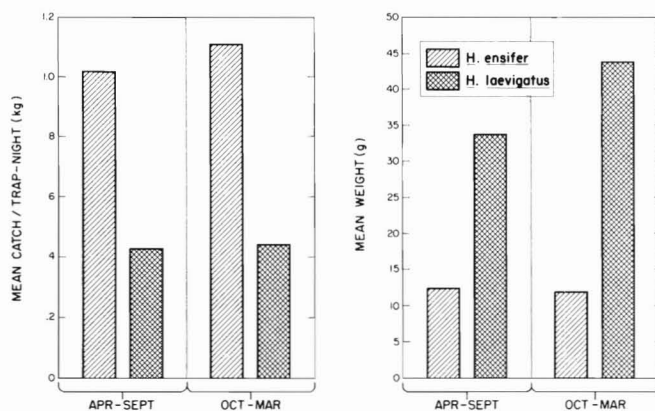


Figure 9.—Mean catch per trap-night and mean individual weight of *Heterocarpus ensifer* and *H. laevigatus* for spring-summer and fall-winter seasons.

weight of catch for spring-summer and fall-winter seasons. The CPUE for both species of *Heterocarpus* was almost identical for both periods. There was no difference in the mean weight of the catch of *H. ensifer* taken in April-September, compared with October-March. The mean weight of *H. laevigatus* was larger in the October-March catches than in the April-September catches. Figures 10 and 11 show the mean catch rate of each species per 50 m depth zones for spring-summer and fall-winter periods. It is interesting that the high catch rates of *H. laevigatus* in depths of 550-599 m were experienced only during the October-March period. Otherwise, there is no indication that the depth range of optimum abundance for either species differed significantly between the two seasons.

Comparison With Commercial Shrimp Trapping

As part of a study to define the distribution and magnitude of *Heterocarpus* resources in the Hawaiian Islands, in 1981 two commercial fishing vessels were chartered to conduct shrimp trapping at Maro Reef (Oishi, 1983). They set a total of 9,914 traps, and had a mean catch rate of 2.47 kg of both species per trap-night. It is of interest to compare such a relatively intense effort on a commercial scale with results obtained during this survey at the four areas most intensely sampled: Necker, French Frigate Shoals, Gardner Pinnacles, and Maro Reef. The catch rates given in Table 2 are based only on trap sets made at optimum depth ranges for each

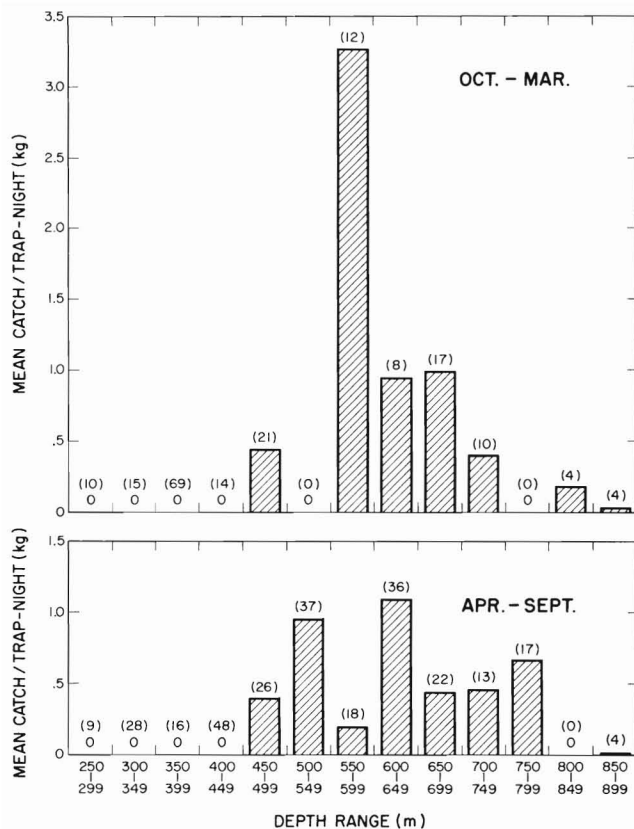


Figure 10.—Catch per trap-night of *Heterocarpus laevigatus* per 50 m depth zone for spring-summer and fall-winter seasons. Effort (trap-nights) is shown in parentheses.

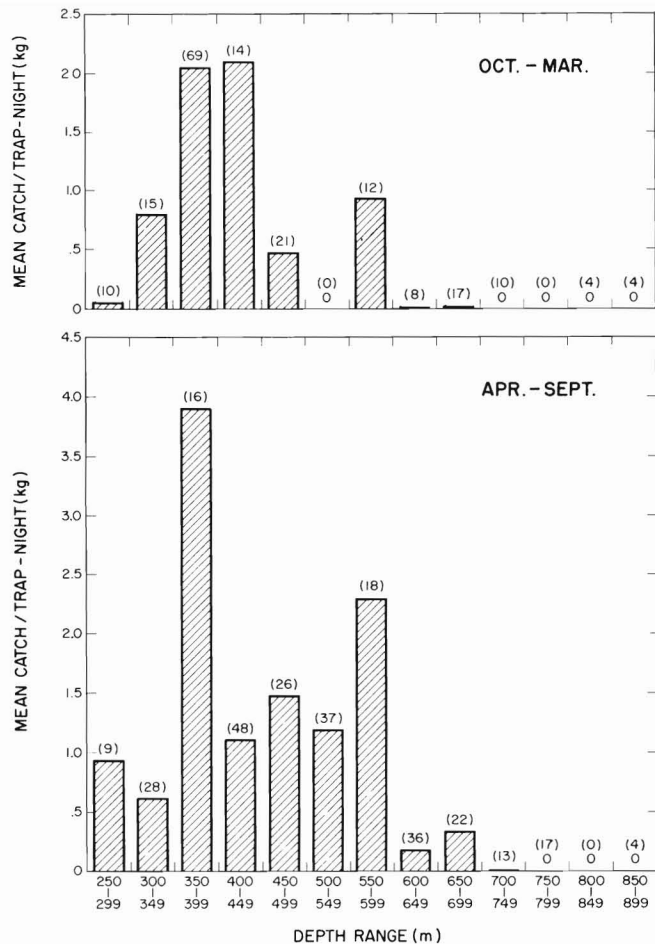


Figure 11.—Catch per trap-night of *Heterocarpus ensifer* per 50 m depth zone for spring-summer and fall-winter seasons. Effort (trap-nights) is shown in parentheses.

Table 2.—Mean catch per trap-night (kg) at optimum depth range¹.

Area	<i>H. ensifer</i>	<i>H. laevigatus</i>	Both species
Necker Island	1.65	1.18	2.83
Fr. Frigate Shoals	3.77	0.37	4.14
Gardner Pinnacles	1.17	2.09	3.26
Maro Reef	1.16	0.97	2.13

¹350-599 m for *H. ensifer*; 500-799 m for *H. laevigatus*.

species. Highest total CPUE was obtained at French Frigate Shoals where the total mean catch as 4.14 kg per trap-night. At French Frigate Shoals 75 percent of the trapping effort was within the optimum depth range for *H. laevigatus*. Despite this, catch rates for that species

were very low. The catch rate at Maro Reef was the lowest for the four fishing areas. However, the CPUE of 2.13 kg at Maro Reef was quite similar to the CPUE of 2.47 during the commercial survey in the same area. Private interests are presently conducting extensive commercial trapping for *H. laevigatus* in the NWHI. No information from these operations was available at the time of writing.

Summary

During exploratory fishing operations for the deepwater caridean shrimps *H. laevigatus* and *H. ensifer* from 1978 to 1981, both species were trapped

throughout the NWHI. Based on catch rates, peak abundance occurred at depths between 500 and 799 m for *H. laevigatus* and 350 and 599 m for *H. ensifer*. For both species there was an apparent decline in size as the depth range increased from that of peak abundance to maximum depth. There was no evidence that for either species the depth range differed significantly between the northern and southern banks of the chain, or between spring-summer and fall-winter seasons.

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