Deepwater Shrimp Resources in Vanuatu: A Preliminary Survey off Port Vila

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Introduction

Natantian decapod custaceans represent one of the world's most commercially valuable group of marine species. This group consists of two large subgroups: 1) Penaeid shrimps which form the basis of valuable trawl fisheries in many tropical and subtropical countries, and 2) carid shrimps, which are more widely distributed but less commonly exploited. Interest in the exploitation of deepwater carid shrimps has recently developed, however.

Carid biology is not well known, although a few species, which form the basis of commercial fisheries, have been studied. Many carids are deepwater, benthic species living on the sea floor and may make vertical diel migrations up into the mid-water masses. The females carry the eggs externally (in contrast with penaeid shrimps) under the abdomen on the pleopods, which are especially adapted for the purpose. The life cycle of carid shrimps appears to be more extended than that of most penaeids.

Carids are caught commercially off Alaska (Barr, 1970), California (Dahlstrom, 1970), and Chile (Hancock and Henriquez, 1968). In several other areas experimental trapping for deepwater shrimps has been carried out: Hawaii (Struhsaker and Aasted, 1974), Guam (Wilder, 1977), New Caledonia (Intès, 1978), Fiji (Brown and King, 1979), and Western Samoa (King, 1980).

The distribution of deepwater carids in the above countries suggests that similar resources may exist in other Pacific Islands with suitable offshore bathymetry. This preliminary survey was undertaken in April 1980 to examine deepwater shrimp resources near Vanuatu (previously known as the New Hebrides).

Vanuatu, including the Banks and Torres group of islands, consists of about 40 mountainous islands, besides numerous islets and rocks. They lie approximately between lat. 13° and 20½°S and long. 166½° and 170°E (Fig. 1). Vanuatu appears to be situated on a bank with depths of about 650-750 m and which runs approximately in a northwest to southeast direction (Pacific Islands Pilot, 1969).

Vanuatu is of volcanic origin and coral formations are generally restricted to isolated and fringing reefs rather than barrier reefs. In many islands, depths drop to over 200 m within less than 1 n.mi. from the coast. For logistic reasons,

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ABSTRACT—Baited traps were used to survey deepwater shrimps in Vanuatu in the Southwestern Pacific. Two-entrance box traps (some covered with hessian sacking; the others uncovered) were set in depths from 229 m to 650 m out from Port Vila. Shrimp catch weight did not differ significantly between covered and uncovered traps but differed markedly with depth. Mean catch rates varied from 0.04 kg per trap in the 200-300 m depth range to 2.83 kg per trap in the 500-600 m depth range. Seven species of carid shrimp were provisionally identified from the catch. In terms of abundance, Plesionika longirostris, Heterocarpus ensifer, *and* H. laevigatus *had the greatest commercial potential.*

Ovigerous specimens of *Plesionika longirostris.*

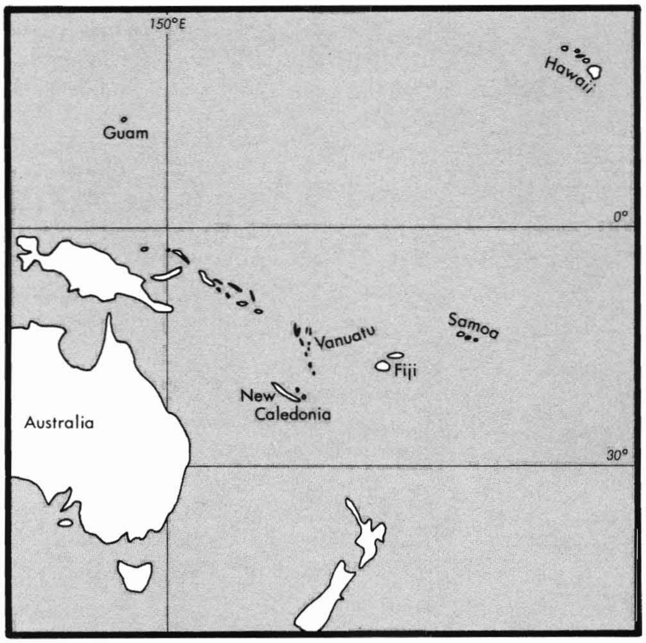


Figure 1.—Vanuatu and other island countries mentioned in the text.

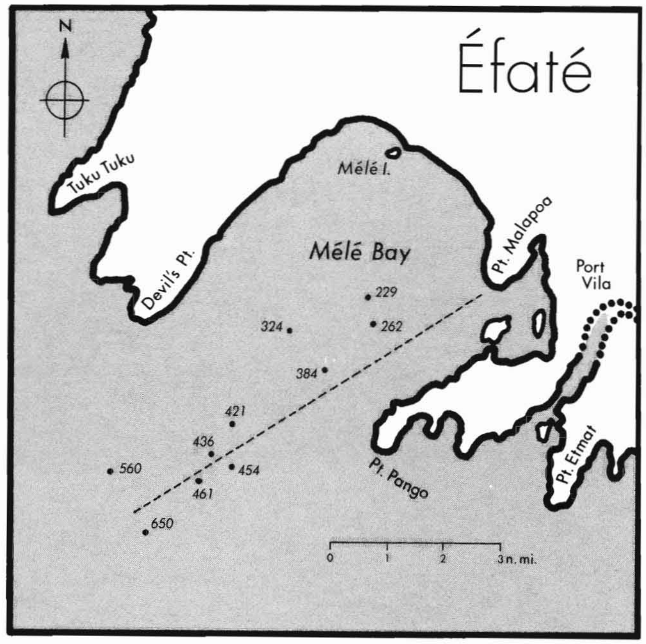


Figure 2.—The survey area near Port Vila. The position of the depth profile presented in the results (Fig. 5) is indicated by the broken line. Trapping locations are marked with black dots and the depth in meters. (Source: Chart 4787, Service Hydrographique de la Marine, Paris.)

the preliminary survey was confined to waters adjacent to Port Vila the capital of Vanuatu on the Island of Éfaté (Fig. 2).

Éfaté is a mountainous island, especially in the northwest, with Mount Macdonald reaching 672 m, and sloping down to Éfaté Bay on the southern part of the island. Port Vila is a well sheltered harbor on the inner (northeast) part of Mélé Bay.

Fishing Gear and Methods

Traps

The basic trap design was that of a box 80×70 cm and 40 cm deep (Fig. 3). The trap framework was welded from 8 mm diameter steel rod, reinforced by two diagonal cross bars on the base and one longitudinal rod, to which the access gate was hinged on the top. The entry cones at each end were tapered in from the edges and extended about 24 cm into the interior of the trap. The inner opening of the cone was 10 cm in diameter.

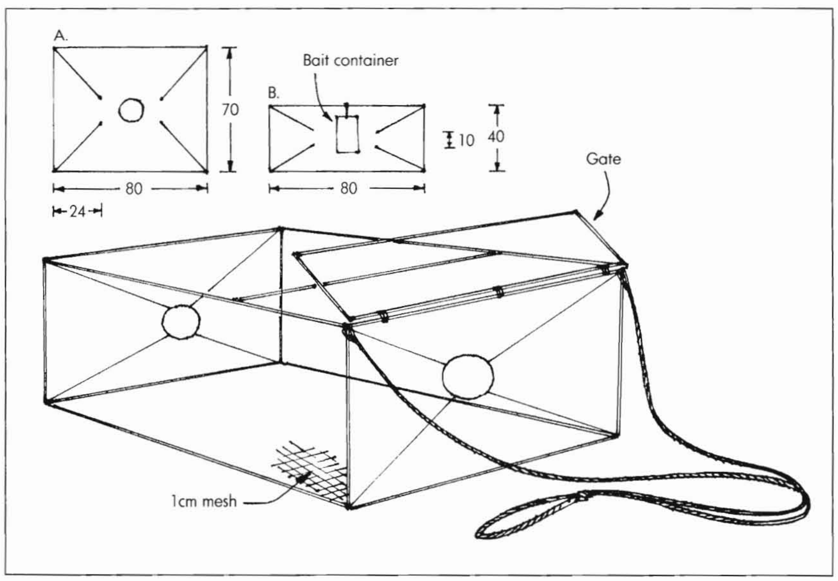


Figure 3.—The basic trap design used in the survey. A and B represent the top plan and the side view of the trap, respectively.

The trap frames and cones were covered with molded plastic screen with an oval mesh size of 10 mm maximum diameter. On about one-third of the traps,

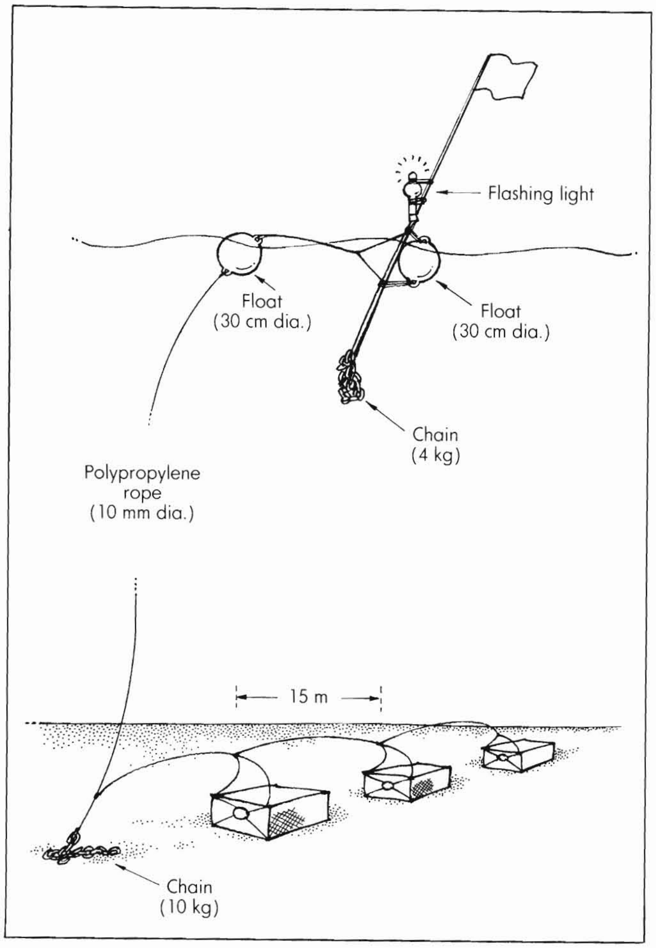


Figure 4.—The arrangement of the trap fishing rig used in the survey. The length of drop line used (i.e., between buoys and bottom weight) was equivalent to the depth of the water plus an excess of 25 percent (minimum).

the sides, bottoms, and tops (i.e., excluding the cones) were covered with hessian sacking. It has been claimed that "covered" traps (i.e., covered with hessian or burlap) are more efficient in catching shrimp than "uncovered" traps (Struhsaker and Aasted, 1974). Reasons for this could include the hessian cover, either concentrating substances from the bait at the entrances of the traps, or providing additional shelter for the shrimps (i.e., acting as "habitat" traps).

The Fishing Rig

The trap fishing line consisted of two parts: A drop line from the marker buoys and a bottom line from which the traps were strung (Fig. 4). The top of the drop line was attached to a 30 cm diameter buoy which was itself attached to a second marker buoy. The second marker buoy was lashed to a 3 m wood or bamboo pole fitted with a brightly colored flag and a 4 kg scrap chain weight (Fig. 4). The buoy was attached approximately 1.8 m from the top of the pole. A "man-overboard" flashing light was attached to the pole above the buoy.

The drop line was of 10 mm diameter polypropylene and was made from coils (about 210 m in length) which were joined together as necessary. At one end of the bottom line, 4 loops were spliced into the rope at 15 m intervals, the last loop being an eyesplice at the end of the rope. This spacing was incorporated to decrease competitive effects between the traps. The last three loops were used to attach the trap lines and, from the fourth loop, a 10 kg weight was attached via a short length of rope to prevent the traps from being lifted by the pressure of wind and current against the floats and rope.

Fishing Vessel and Equipment

The boat used was a 8.5 m wood and plywood catamaran powered by a 25 h.p. (18.7 kw) outboard engine. The winch concisted of a 3 h.p. Briggs and Stratton[1] 4-stroke engine which powered a geared trap hauler via a belt drive. The trap hauler was of the type used in the Australian rock lobster trapping fishery (i.e., in which the trap line is firmly gripped by a pulley, and stripped off by a metal peeler).

A skipper model 603 echo sounder fitted with a narrow-beam ferrite transducer was used to obtain depth profiles and measure the depth at each trap drop. The echo sounder was rigged as a portable unit with a separate 12-volt lead-acid battery and the transducer was mounted on the end of a length of pipe. A hand compass was used to fix the position from shore marks at each drop location.

Bait

I intended to use the same bait throughout the survey, preferably skipjack tuna, *Katsuwonus pelamis,* as this was the most successful of several baits tested in Fiji[2]. However tuna was not always available in Vanuatu and, in the initial trap sets, a variety of baits was used including bonefish, *Albula vulpes;* Indian mackerel, *Rastrelliger kanagurta;* and sardines, *Sardinella* spp. Sardines were the most easily obtained local bait and this species was used throughout the remainder of the survey. About 500 g of bait was placed in plastic netting containers (about 10 mm mesh size) and suspended in the center of each trap (Fig. 3).

The Fishing Operation

Except during the initial trap construction stage and during certain peri-

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.
[2]King, M. G. University of the South Pacific, P. O. Box 1168, Suva, Fiji. Unpubl. data.

ods of maintenance, two strings of three traps each were used. Each string of traps was left in the sea overnight and hauled in, emptied, and rebaited before being reset in a new location on the following day.

At each location the traps and weight were lowered over the windward side of the boat. With the motor off, the boat would drift off to leeward with the trap acting as a sea anchor during the drop. Pressure was always kept on the drop line as the ropes were let out to avoid tangling the traps. On the rare, windless days, the boat's motor was used at the lowest possible speed to keep the pressure on the drop line. During the drop, additional coils of rope or half coils were successively added to the drop line to provide sufficient rope for the depth of water (equivalent to the depth of water plus a minimum of 25 percent). At the end of the coil, the float buoy and marker buoy were attached and cast off from the boat.

On the following morning, the recorded landmarks were used to locate the marker buoy. Rope was hauled in and flayed down in bins or directly into the catamaran floats. Once on deck, the catch from each trap was placed in separate plastic bags and labelled before storing on ice.

The FAO-designed catamaran used in the Vanuatu deepwater shrimp survey.

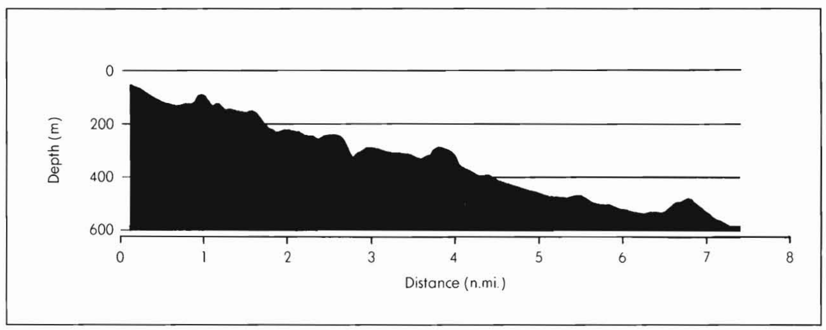


Figure 5.—A depth profile measured by the echo-sounder trace made along the transect indicated in Figure 2.

Survey Area and Method

Initial depth soundings were made in several areas and a full depth profile was recorded along a transect running out at 238° true bearing from Point Malapoa in Mélé Bay (Fig. 1).

The survey was conducted by setting traps at various depths along the transect. Two strings of three traps were intended to be set over each night in predetermined depths (at 50 m depth intervals) from 200 to 700 m, but the program had to be modified due to gear and weather problems.

At each set location the depth was recorded both at the time of setting and hauling; the mean of these was used to define the "estimated fishing depth." Also, at each set location, a hand compass was used to record the bearings of shore marks. These and other details were recorded at sea on a daily log sheet.

The catch from each individual trap was placed in a labelled plastic bag and stored in a portable ice box. Once ashore, shrimp were separated according to species and into ovigerous (egg-bearing) and nonovigerous groups, before being counted and weighed. A large sample, usually the catch from one trap in each string, was set aside for measuring. Shrimp carapace lengths (distance between the postorbital eye socket and the posterior median edge of the cephalothorax) were recorded to the nearest millimeter.

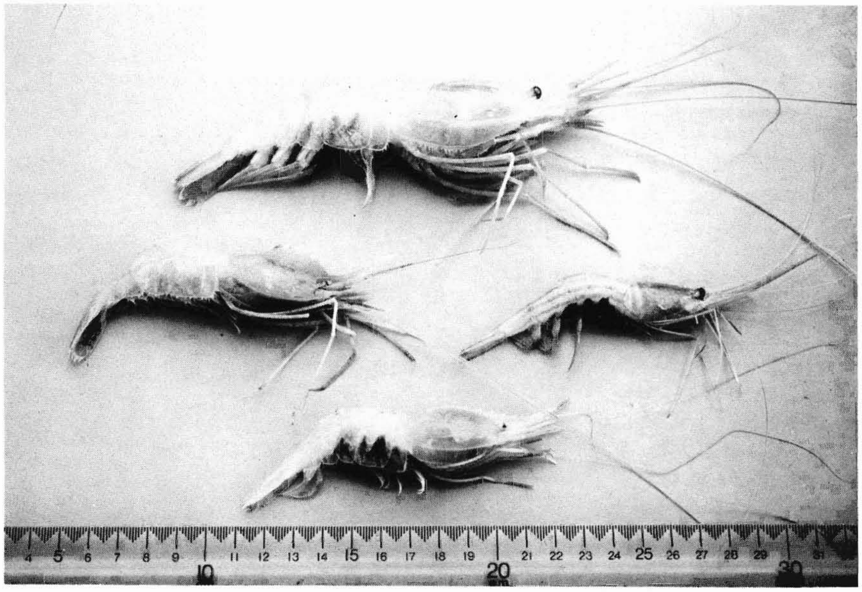
Results

Offshore Bathymetry

The echosounder was used to record the depths and sea bottom profiles in several areas offshore from Mélé Bay. The bottom profile along the selected transect shown in Figure 2 is presented in Figure 5, which is drawn from the echosounder recording paper.

Temperature

Temperatures were recorded on a



Deepwater shrimps, clockwise from top, are *Heterocarpus laevigatus*, *Plesionika longirostris*, *H. ensifer* and *H. gibbosus*.

Table 1.—Provisional list of scientific and common names of deepwater shrimps found in Vanuatu waters. One additional species is, so far, unidentified.

Scientific name	Common name
Parapandalus serratifrons	Pyjama shrimp
Plesionika ensis	Striped gladiator shrimp[1]
Plesionika longirostris	Stars and stripes shrimp
Heterocarpus ensifer (sibogae?)	Armed nylon shrimp
Heterocarpus gibbosus	Humpback nylon shrimp[1]
Heterocarpus laevigatus	Smooth nylon shrimp[1]

[1]Standard FAO name (Holthuis, 1980).

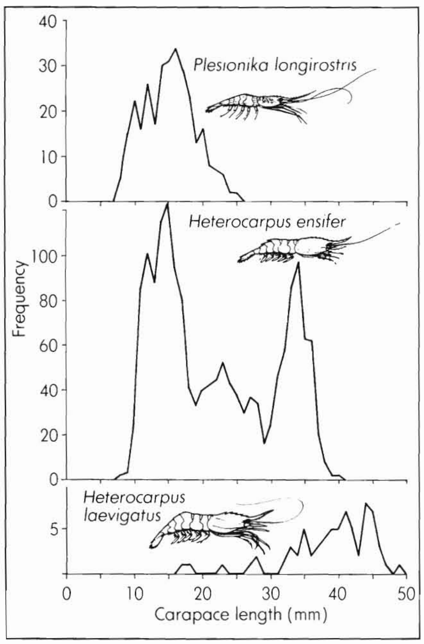


Figure 6.—Length-frequency diagrams of the three most abundant species of deepwater shrimp (samples from all depths combined).

modified maximum/minimum thermometer attached to one of the traps used at each depth. These ranged from 17.5°C at the shallowest depth surveyed (229 m) to 7.5°C at the deepest depth (650 m).

Depth (m)	Minimum temperature (°C)
229	17.5
384	11.0
454	9.5
650	7.5

Species Caught

During the survey, seven species of carid shrimps were provisionally identified from the catch. All belonged to the family Pandalidae and at least three genera: *Heterocarpus, Plesionika,* and *Parapandalus.* In common with other deepwater shrimps, these are characteristically colored pink to deep red and the ovigerious females often carry blue eggs.

The species found are listed in Table 1 in approximate order of increasing size. Scientific names are provisional and common names are from Holthuis (1980) where possible or from King (1980). One species found has not yet been identified and the name of another species, *Heterocarpus ensifer,* is provisional. *Heterocarpus ensifer* is distinguished from *H. sibogae* only by the presence of dorsal carina on the first and second abdominal pleura in the latter species; however, this character appears to be highly variable.

On the basis of this preliminary survey it appears that three of the species found may be present in sufficient quantity to be of commercial interest. These include the two abundant *Heterocarpus* species, *H. ensifer* and *H. laevigatus,* as well as the smaller *Plesionika longirostris.* The length frequencies (from all depths combined) of these three species are shown in Figure 6.

Catch Analyses

As *Heterocarpus ensifer* occurred over the entire depth range surveyed, it was decided to analyze the catches of this species by both depth and trap type. All catch data were grouped into three depth ranges: Shallow (<350m); middle (350-450m); deep (>450m). After culling suspect data from damaged traps, the mean catch weights were tabulated in a 3×2 matrix of 3 depth ranges and 2 trap types.

An analysis of the variance in the data presented in Table 2 is shown in Table 3. There was no significant difference in the mean catch rates of *H. ensifer* between covered and uncovered traps (F=0.01, P>0.05) but catch rates varied significantly with depth (F= 22.50, P<0.05).

Depth Distribution

Analyses presented in the previous section indicated that the catch weight of *H. ensifer* varied significantly with depth. Using all catch data from the survey, the contribution of various shrimp species to the total catch at each depth was calculated. These contribu-

Table 2.—Mean catch (kg) per trap of *Heterocarpus ensifer* and variance for each trap type at each of 3 depth ranges.

Depth range		Covered	Uncovered	Row means
Shallow (<350 m)	$\bar{X}$	0.06	0.04	0.05
	S^2	0.05	0.04	
Middle (350-450 m)	$\bar{X}$	0.95	1.23	1.09
	S^2	0.89	0.26	
Deep (>450 m)	$\bar{X}$	1.50	1.20	1.35
	S^2	0.67	0.16	
Column means		0.84	0.82	

Table 3.—A two-way analysis of variance in catches (kg/trap) of *H. ensifer* by trap type and depth range.

Source	df	S.S.	*F*
Columns (traps)	1	2.67	0.01 ($P>0.05$)
Rows (depths)	2	1.89	22.50 ($P<0.05$)
Error	2	0.08	

Table 4.—Species composition by weight expressed as a percentage of the total shrimp catch in each depth.

Depth (m)	*P. longirostris*	*H. ensifer*	*H. Laevigatus*	Other species
229	15	54		31
262	51	48		1
324	47	49		4
384	27	73		0
421	<1	99		<1
436	<1	99		<1
454	2	98		0
461	<1	99		<1
560		57	43	0
650		68	32	0

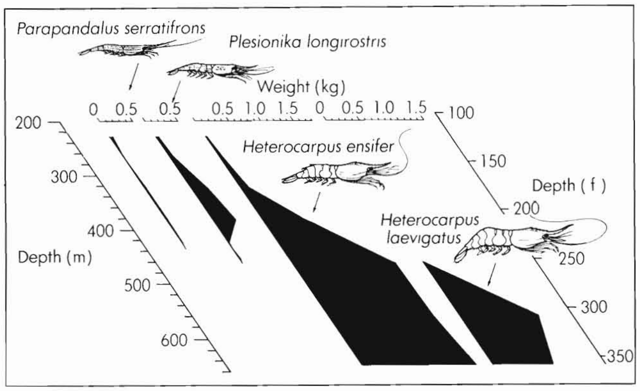


Figure 7.—The depth distribution (mean catch per trap) of the four most abundant deepwater shrimp caught during the trapping survey.

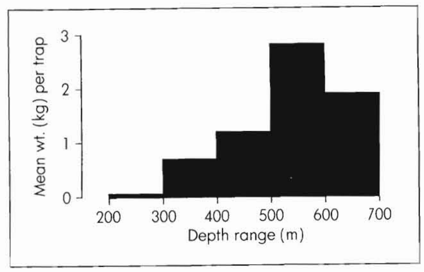


Figure 8.—Mean catch per trap (kg) per 100 m depth.

tions expressed as percentages are given in Table 4.

Species such as *Parapandalus serratifrons* and *Plesionika ensis* which occurred in low trap abundance are grouped together as "other species." *Plesionika longirostris* accounted for up to about half the shallow water catch. *Heterocarpus ensifer* occurred throughout the whole sampled depth range and, from about 400 to 500 m, the catches consisted almost exclusively of this species. In the deepest depths sampled the proportion of *H. laevigatus* in the catch increased with a corresponding decrease in the proportion of *H. ensifer.*

Other species of shrimp usually accounted for <5 percent of the total catch in any depth. An exception was in the shallowest depth sampled (229 m) where the small shrimp *Parapandalus serratifrons* accounted for 31 percent of the small catch.

The distribution of each species of shrimp by depth was estimated by using the mean catch weight per trap as an index of relative abundance. Indices for the four major species are shown in Figure 7. These data are from a limited geographical area and collected over a short time scale; the figure may therefore not represent the general distribution throughout Vanuatu or over a complete seasonal cycle.

Catch by Depth

The catch data were also examined to determine how the total biomass of shrimp caught relates to depth. These data were grouped in 100 m depth ranges and are presented as a histogram in Figure 8.

The histogram indicates that total mean catches were low in shallower water but increased with depth to a maximum in 500-600 m. At this depth range the mean catch rate was 2.83 kg per trap. Beyond 600 m, trap abundance of shrimp appears to decrease. Taking into account the limited nature of the present survey, however, further research is necessary to discover how shrimp abundance alters in depths >600 m.

Size by Depth

Length-frequency data were examined to determine whether the size of shrimp changed with depth. *Heterocarpus ensifer* was the only species caught in all of the depth samples; length-frequency data from selected depths are shown in Figure 9. This shows that shrimp size differed markedly with depth, with a greater proportion of large shrimp in the middle part (421-461 m) of the depth range sampled.

Although the total length-frequency diagram (samples from all depths combined) presented in Figure 6 show possibly 3 major size classes (i.e., at modal lengths of 14, 23, and 33 mm) for *H. ensifer,* Figure 9 shows that the proportion of the shrimp in each size class differs with depth. Samples from shallower water (e.g., 324 m) consisted almost entirely of small shrimp from the first and second size class. In middle range depths (e.g., 461 m) shrimp in the smaller size classes were not abundant but appeared again in samples from deeper water.

Surveys carried out in Hawaii (Struhsaker and Aasted, 1974) also indicated that smaller *H. ensifer* are found above and below the depth of maximum abundance.

Sexuality

As *H. ensifer* was obtained over a large size range (8-40 mm carapace length) it was possible to determine the proportion of ovigerous (egg bearing) individuals in each size class for this species. Figure 10 combines data from all depths (n=1,846) and shows the number of ovigerous individuals, expressed as a percentage of the total number, in each size class. At about 30 mm carapace length, half the population consists of ovigerous females; at >35 mm, the population consists entirely of ovigerous females. Both *H. ensifer* and *H. laevigatus* may be protandrous hermaphrodites, existing initially as small males before changing sex to become females.

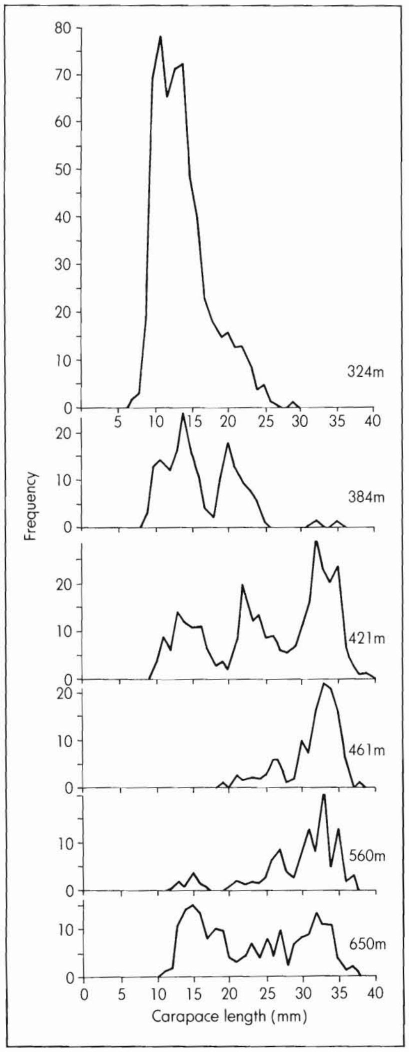


Figure 9.—Length frequency of samples of *H. ensifer* from selected depths. The depth is indicated at the right of each graph.

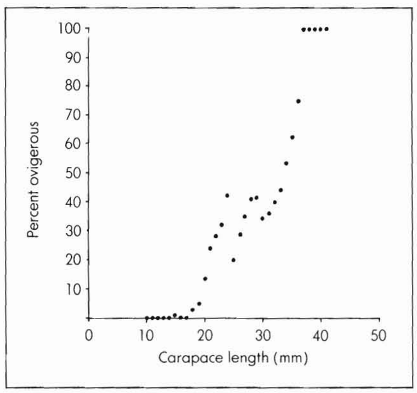


Figure 10.—The percentage of ovigerous females in each size class (data from samples taken at all depths combined: n=1,846.

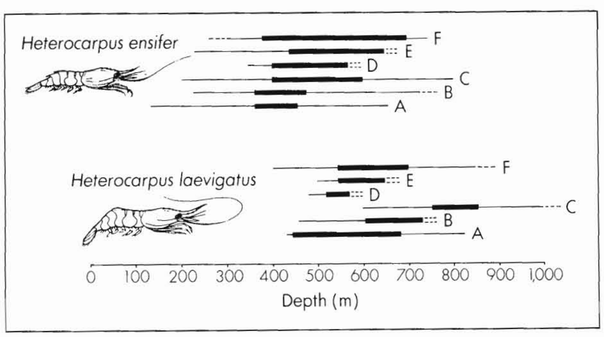


Figure 11.—The depth distribution (light line) and depth of greatest abundance (heavy line) of *H. ensifer* and *H. laevigatus*. References are: A) Hawaii (Struhsaker and Aasted, 1974); B) Guam (Wilder, 1977); C) New Caledonia (Intès, 1978); D) Fiji (Brown and King, 1979); E) this paper; and F) Western Samoa (King, 1980). Dotted lines indicate the limits of the respective surveys.

Discussion

At least six of the seven species of pandalid shrimps found in the Vanuatu survey have been obtained in other Pacific countries including Fiji (Brown and King, 1979), New Caledonia (Intès, 1978), Guam (Wilder, 1977), Hawaii (Struhsaker and Aasted, 1974), and Western Samoa (King, 1980). Although much of this literature makes no reference to the smaller shrimp, there is some information on the larger *Heterocarpus* species. The depth distribution of *H. ensifer* and *H. laevigatus* in these countries is shown in Figure 11. *Heterocarpus gibbosus,* which accounts for a substantial proportion of the catches in Fiji (at about the 400-500 m depth) was only found in very small numbers in the Vanuatu survey.

Taking into account the limitations of this preliminary survey, the catches of shrimp obtained were sufficient to encourage a further examination of the fisheries potential. In deciding on a fishing strategy, it is not only necessary to consider catch weight but also the size of individual shrimps. In *H. ensifer,* for example, the highest proportion of larger individuals (from the third size class, Fig. 9) was found in depths of about 450-550 m. Although catch weight was still high in depths greater than this, a large proportion of the deeper catch consisted of smaller shrimp (first and second size classes). Trapping in depths of about 550 m appears ideal in that reasonable weights of larger individuals of *H. ensifer* (>1.5 kg per trap) as well as *H. laevigatus* (>1.0 kg per trap) were obtained. The greatest weights of shrimp (all species combined) obtained during the survey was in the 500-600 m depth range where the mean catch rate was 2.83 kg per trap.

Plesionika longirostris, although smaller than *Heterocarpus* spp., is worth some consideration from a commercial point of view. This species has a higher "recovery rate" (the weight of high-value tail meat expressed as a percentage of total weight) than the other species; it is also obtained in shallower water (about 350-400 m) where fishing costs are obviously less than in deeper water. During this survey, however, catches of *P. longirostris* were always <0.5 kg per trap. Further work is needed to determine the trap abundance and depth distribution of this species in Vanuatu.

The economics of any proposed shrimp trapping fishery should be carefully examined. It would be desirable to use small locally made fishing craft. The 8.5 m catamaran used in the preliminary survey was suitable for setting traps because of its deck space and high initial stability. However, such a boat may not be able to carry the total number of traps needed for a commercial operation. Due to the close proximity of the fishing grounds, it may be possible to relay smaller numbers of traps (e.g., strings of 15 traps at a time) out to the drop locations. The development of collapsible traps would also help in this respect.

In Fiji, when traps were sometimes left set longer than for the usual 18-hour (overnight) period there was considerable cannibalism. Results from a series of 24-hour stations suggest that *H. ensifer* and *H. laevigatus,* in spite of their depth of distribution, only enter traps during the night (footnote 2). Cannibalism was not evident in traps set overnight in my Vanuatu study.

Other than the fishing boat itself, there are several other expensive items of fishing equipment required including rope, an echo-sounder capable of detecting the depths involved, and a mechanical or hydraulic pot-hauling winch. It would be possible to use shore bearings in place of the echo sounder to determine fishing locations and depths but this method would depend on the availability of charts with accurate soundings; the method would be less reliable where the sea bottom profile is as undulating as that found during this survey (Fig. 5).

Any examination of the costs involved should include special reference to the increase of costs with fishing depth and the likely incidence of trap loss due to heavy weather, shark attack, etc. During the present survey two traps were damaged, presumably by sharks. One set of traps was lost during the survey, possibly due to an incorrectly tied knot at the float buoy. The cost of bait may also be considerable, although sardines, *Sardinella* spp., were caught by cast-net and successfully used as bait in this survey.

From experiences in Fiji it has been found that the handling of deepwater shrimp requires considerable care—more so, for example, than finfish. Immediately after being caught, shrimp must be placed in crushed ice or chilled brine, and sodium metabisulphite may be used as a dipping solution to extend the cold storage life of the shrimp. Cooking time for deepwater shrimp must be kept short; approximately 2 minutes in boiling water, usually suffices.

In conclusion, it has been established that deepwater carid shrimps are present in Vanuatu waters. Catch rates made during the preliminary survey off Port Vila were high enough to consider carrying out commercial trials. Further work would be necessary to elucidate several points regarding the biological, economic, handling, and marketing aspects of any proposed fishery.

Acknowledgments

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