Remote Camera and Trapping Survey of the Deep-water Shrimps *Heterocarpus laevigatus* and *H. ensifer* and the Geryonid Crab *Chaceon granulatus* in Palau

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Introduction

Deep-water bottom-dwelling communities of the Indo-Pacific are not well known, owing to their relative inaccessibility. Most available information has been derived from trapping-based surveys which, for the most part, have been pilot efforts directed at evaluating economic potential of deep-water shrimps (King, 1980, 1982, 1984; Struhsaker and Aasted, 1974; Gooding, 1984). These surveys have generated information on species identifications, geographic dispersal, and depth ranges, as well as population characteristics such as size-distribution, sex ratios, etc. More sophisticated analyses of larger trapping data bases have been used to describe reproductive biology, growth, and mortality (Dailey and Ralston, 1986), and to calculate potential exploitable biomass and sustainable yields under intensive fishing pressure (Polovina et al., 1985; Ralston, 1986; Moffitt and Polovina, 1987; Tagami and Ralston, 1988). Only recently has it been logistically possible to attempt to study the deepwater habitat directly, and several recent efforts using a submersible show much promise (Ralston et al., 1986; Moffitt and Parrish[1].

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ABSTRACT—Time-lapse remote photosequences at 73-700 m depth off Palau, Western Caroline Islands, show that the caridean shrimp Heterocarpus laevigatus *tends to be a solitary animal, occurring below ~350 m, that gradually accumulates around bait sites over a prolonged period. A smaller species,* H. ensifer, *tends to move erratically in swarms, appearing in large numbers in the upper part of its range (<250 m) during the evening crepuscular period and disappearing at dawn. Trapping and photosequence data indicate the depth range of* H. ensifer *(during daylight) is ~250-550 m, while* H. laevigatus *ranges from 350 m to at least 800 m, along with the geryonid crab* Chaceon granulatus. *Combined trapping for* Heterocarpus laevigatus *and* Chaceon granulatus, *using a three-chamber box-trap and extended soak times (48-72 h), may be an appropriate technique for small-scale deep-water fisheries along forereef slopes of Indo-Pacific archipelagoes.*

In Palau, Western Caroline Islands, a series of remote camera investigations of the chambered nautilus, which inhabitats the deep forereef slope at depths of 100-500 m, revealed the presence of large numbers of the deep-water caridean shrimps *Heterocarpus ensifer* and *H. laevigatus* (as many as 150 shrimps in a single photographic frame), plus the marketable geryonid crab *Chaceon granulatus*[2] at depths below 400 m (Saunders, 1984). These findings suggested that it would be worthwhile to utilize a remote camera in conjunction with a conventional trapping survey to study shrimp behavior and trap effectiveness as part of an effort to evaluate the potential for a small-scale deep-water shrimp fishery in Palau (Saunders et al., 1989[3]).

Procedures

Trapping

A total of 103 traps was set between 170-900 m depth at five sites around Palau (Fig. 1) during May-October 1987 and 1988. The following trap designs were used during the survey: 1) A small collapsible trap (60 x 40 x 20 cm); 2) a large pyramidal trap (2 m square at the base x 1.5 m high); 3) a traditional fish trap design (1.5 x 1 x 1 m); 4) a covered box trap (1.5 x 0.5 x 0.5 m); 5) a small box-shaped trap (1 x 1 x 1 m) attached to a camera frame for photographic purposes; 6) a large box trap (2 x 1 x 1 m) with 25 cm diameter funnels at each end (this design was used for quantitative data and is referred to as the "standard trap"); and 7) a modified standard "combined" trap containing a central chamber with two additional (10 cm diameter) funnels (Fig. 2). About 1 kg of bait (tuna, shark, clams or deep-water eels), was placed in a fine wire-mesh bait bag or wrapped in chicken wire and suspended in the center of the trap. Polypropylene rope (4-8 mm diameter) as well as standard longline rope (4 mm diameter) was used in conjunction with surface buoys and marker flags. Single traps were deployed, with double anchors (scrap iron or cement) and sand anchors to reduce dragging.

[1]R. B. Moffitt and F. A. Parrish. Comparison of submersible observations of shrimp densities with trap catches for *Heterocarpus laevigatus* in Hawaii. Manuscr. in prep.

[2]The family Geryonidae has recently been revised by Manning and Holthuis (1989) to include two new genera, one of which, *Chaceon*, includes the Palauan species *C. granulatus*.

[3]W. B. Saunders, L. C. Hastie, and T. Paulis. 1989. Deep-water shrimp survey and feasibility study, Republic of Palau, Western Caroline Islands. Pac. Fish. Develop. Found., Honolulu, Final Rep., Proj. 63A, 120 p.

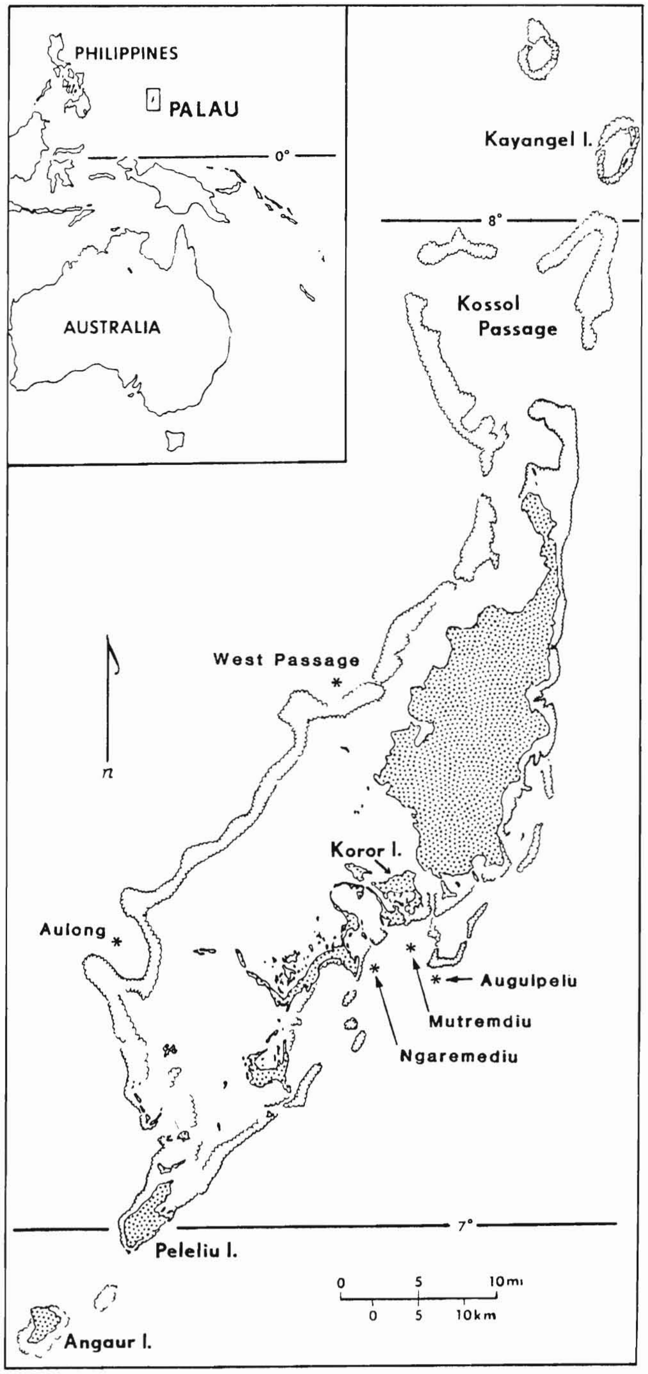


Figure 1.—The deep-water trapping and remote camera sites around Palau, Western Caroline Islands.

Water temperature profiles were obtained with a HUGRUN[4] Seamon Immersible Temperature Recorder, programmed to record temperature at specific time intervals while lowered slowly to the bottom.

The survey vessel was a diesel 10 m Yanmar equipped with a gasoline pot hauler. The catches were sorted in the laboratory according to species and whether ovigerous and measured for body weight and carapace length. These also were sexed, and tail weight, body weight, and egg color were noted.

Remote Camera Photosequences

Photosequence records show several aspects of shrimp behavior and distribution that are relevant to fisheries considerations. This study focused on the two caridean species *Heterocarpus laevigatus* and *H. ensifer* which, because of their greater abundance or size, are the two forms that have commercial potential in Palau (and, in general, at other Pacific localities; King, 1986). The use of a remote, deep-water camera to obtain time-lapse photosequences at baited bottom sites followed approaches developed to study *Nautilus* in Palau (Saunders, 1984, 1985).

The camera unit consists of a standard, motor-driven 35 mm camera coupled to an integrated electronic timing circuit that permits preselection of exposure interval. The light source (a xenon strobe) and timing circuit are powered by 12 v DC (2.4 amp) nicad batteries. The camera and strobe fit into tubular aluminum housings with Plexiglas[4] ports that will withstand hydrostatic pressures equivalent to 1,000 m depth. The camera is attached to a welded rebar frame, providing an obliquely illuminated field of view about 2 m by 1.5 m, focused on a baited trap about 1.5 m away (Fig. 3). The camera is lowered to the bottom, attached to a surface buoy, and tended for the duration of the photosequence. Exposure intervals of 15 and 30 min, respectively, provide 9 and 18 h photoseqences from a 36-exposure roll of film (Kodachrome 64 or Ektachrome 100). A total of 27 photosequences was obtained; of these, numbers 1-22 were taken off Mutremdiu, in conjunction with *Nautilus* studies (see Saunders, 1984), and numbers 23-27 were taken in West Passage in 1988.

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

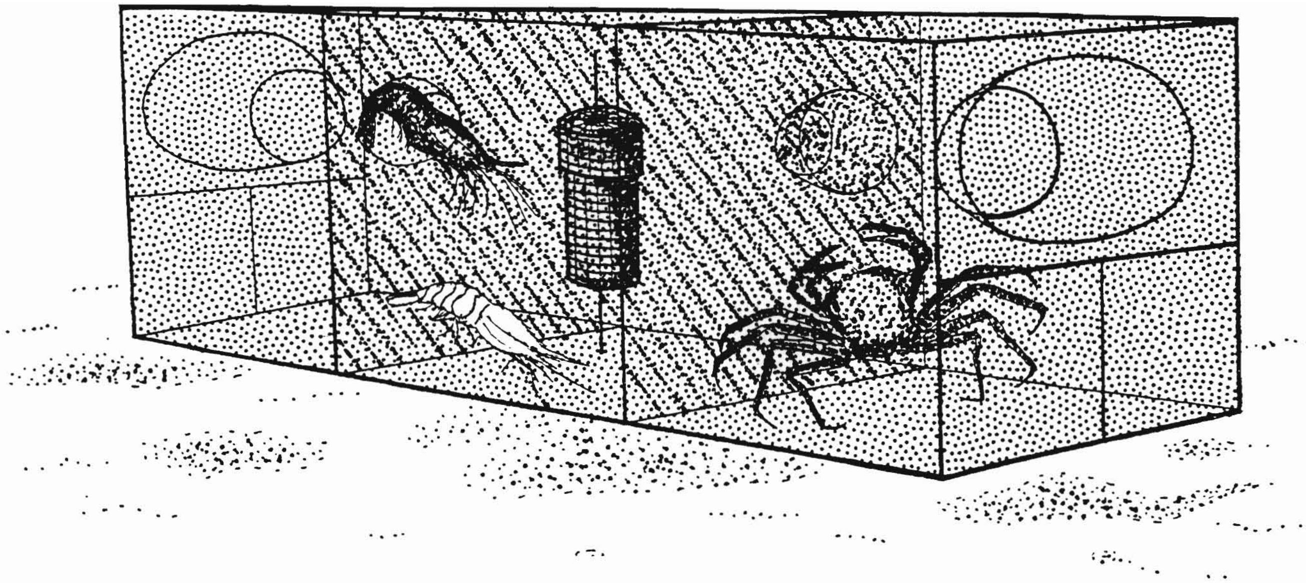


Figure 2.—Three-chambered box-trap for combined shrimp/crab trapping. Crabs (*Chaceon granulatus*) accumulate in the two outer chambers; shrimps are able to enter the central bait chamber, but their escape is impeded by the smaller funnels.

Analysis of the photosequences involved study of each transparency using a stereomicroscope with transmitted light. The identity and number of each organism and any activity within the field of view were tabulated against actual time or elapsed bottom time.

Results

Trapping

Traps were set 103 times at 170-900 m depth, at Mutremdiu Bay (38 sets), Augulpelu Reef (7 sets), Ngaremediu Reef (19 sets), Aulong Bay (7 sets), and Toagel Mlungui (West Passage; 32 sets; Fig. 1). A total of 98 retrieved traps (five were lost) yielded 1,550 shrimps (15 species, 55.08 kg) and 232 geryonid crabs (*Chaceon granulatus*, 268 kg; Table 1).

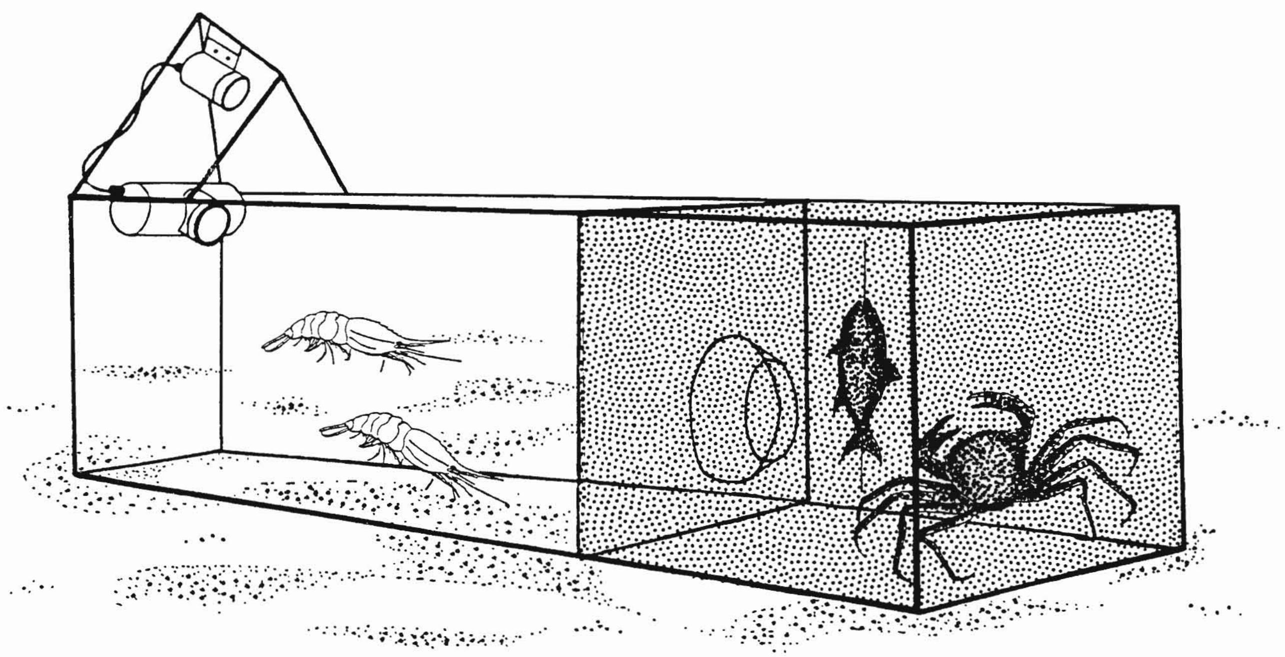


Figure 3.—Remote 35-mm still camera, strobe, frame, and trap used to obtain photosequences. The unit is attached to a rope harness, lowered to the bottom, and tethered to a surface buoy for the duration of the photosequence (trap width 1 m).

The best results were produced from the combined standard trap (Fig. 2). Crabs were caught in the outer chambers of this trap, while shrimps were concentrated in the central bait chamber, from which the smaller funnels impeded egress. Using soak times of 48-72 h, this design produced a per-trap average of 1.45 kg of shrimp and 5.09 kg (~6 individuals) of the large crab *Chaceon*. By contrast, the other trap designs, set for shorter soak times (~24 h) averaged 0.84 kg of shrimps and 2.54 kg of crabs (Table 2).

The shrimp catch was dominated by *Heterocarpus laevigatus* which comprised 92% (51 kg) of the total yield by weight. The smaller species, *H. ensifer*, dominated the shallower (170-400 m) catches, but these catches were generally poor; thus, this species composed only 3% of the total yield by weight (1.52 kg). Shrimp yields >1 kg per trap-night were obtained at each site surveyed, generally between 500 and 800 m, with corresponding water temperatures 6-8°C.

A complete data set was obtained for 693 specimens of *H. laevigatus*, 163 specimens of *H. ensifer*, 150 specimens belonging to four other shrimp taxa, and for 184 specimens of *Chaceon granulatus*. By-catches included 83 eels (10 *Conger* sp., remainder *Synaphobranchus affinis*), 52 *Nautilus belauensis* (<500 m), 21 unidentified crabs (belonging to three noncommercial species), 7 sharks (including *Squalus* sp.), 3 red snappers (*Etelis carbunculus*) and 16 other unidentified teleosts; one *Octopus* sp., and one ophiuroid.

Individual wet weights for *Heterocarpus laevigatus* varied from 2-106 g ($\bar{X}$ = 41 g; Table 1, Fig. 4a). In 675 specimens in which sex could be determined, females slightly outnumbered males (363:312), with a male:female ratio of 1:1.16 (Fig. 5a), and 245 (67.5%) females were ovigerous. Carapace length ranged from 17.2 to 63 mm ($\bar{X}$ = 44.1 mm), and females averaged slightly larger than males ($\bar{X}$ = 47.3 vs. 41.6 mm). Female *H. laevigatus* appear to become ovigerous at ~40 mm carapace length, and at 50 mm most of the females collected were ovigerous (Fig. 5b).

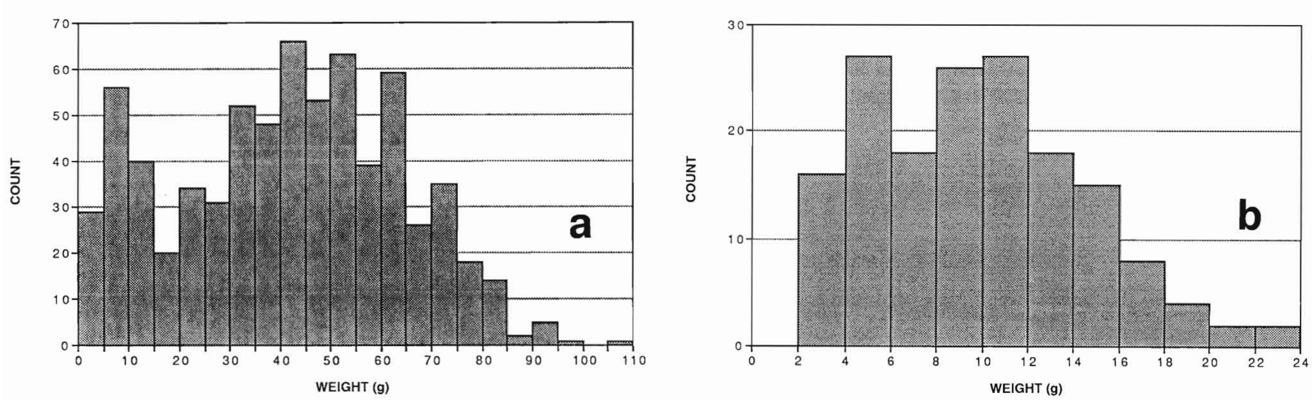
The smaller species, *H. ensifer*, ranged from 2 to 22 g ($\bar{X}$ = 8.8 g; Table 1, Fig. 4b). Females outnumbered males 91:51 (1:1.78), and 47 (51.6%) of the 91 females were ovigerous. Cara-

Table 1.—Summary data on depth-range, number of specimens, carapace size, and wet weight for shrimps H. (*Heterocarpus*), P. (*Plesionika*), Pl. (*Plesiopenaeus*) and for *Chaceon*. Other species obtained in small numbers include *Plesionika martia* (308 m), *P. longirostris* (448 m), *P. rosticresentis* (380-704 m), and *Plesionika* sp. (520-850 m).

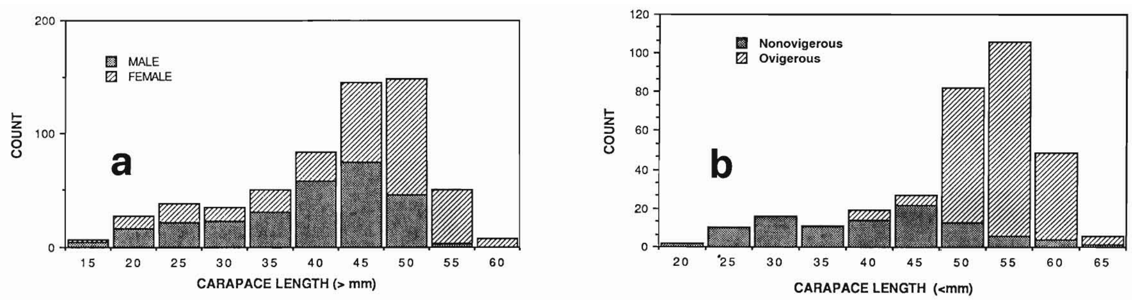
Species	Depth range (m)	No. of specimens	Carapace (mm) Mean	Carapace (mm) (Range)	Weight (g) Mean	Weight (g) (Range)
H. laevigatus	320-850	693	44.1	(17.2-63.0)	41	(2-106)
H. ensifer	170-480	163	25.3	(6.5-35.9)	8.8	(2-22)
H. gibbosus	208-380	15	38.9	(33.6-44.9)	34	(24-42)
H. dorsalis	560-850	24	25.6	(16.0-43.6)	10	(2-32)
P. ensis	200-480	67	18.2	(11.7-23.7)	4	(2-8)
Pl. edwardsianus	320-900	44	27.2	(15.0-81.2)	16	(2-118)
C. granulatus	300-900	184	150.4	(114-179)	1,115	(500-2,020)

Table 2.—Summary comparison of shrimp and crab yields for different types of traps used. Abbreviations are as follows: kg/tp. = kilograms per trap; kg/tp.nt. = kilograms per trap night. Data include all shrimp species but mainly comprise *H. laevigatus*; the crab data are for *Chaceon granulatus*. Trap abbreviations: COMB, combined shrimp/crab trap, three-chambered STD; STD, standard box trap (2x1x1 m); PYM, pyramidal, top entry (1x2 m²); BOX, covered box (1.5x5x5 m); PAL, traditional Palauan fish-trap (1.5x1x1 m); CAA (1x1x1 m) trap on remote camera frame (1988 only); FLT, flat collapsible trap (60x40x20 cm).

Trap	Depth (m)	No. pulls	Shrimp Total	Shrimp kg/tp.	Shrimp kg/tp.nt	Crab Total	Crab kg/tp.	Crab kg/tp.nt.
COMB	480-800	13	18.89	1.45	0.79	66.21	5.09	2.76
STD	170-900	60	31.53	0.53	0.44	160.14	2.67	2.26
PYM	475-790	5	0.81	0.16	0.16	27.86	5.57	5.57
BOX	256-640	2	0.16	0.08	0.08			
FLT	300-580	3	0.41	0.10	0.08	9.81	2.45	1.96
PAL	352-800	9	1.24	0.18	0.14	2.68	0.38	0.30
CAA	464-704	6	2.00	0.33	0.50			



Figures 4a,b.—Frequency distributions showing (a) wet weights of *Heterocarpus laevigatus* (n=694, range 2-106 g, mean 41 g), and (b) *Heterocarpus ensifer* (n=163, range 2-22 g, mean 9 g).



Figures 5a,b.—Frequency distributions showing (a) proportions of male/female *H. laevigatus* according to carapace length, and (b) ovigerous/nonovigerous females according to carapace length in *H. laevigatus*.

pace length for the entire sample ranged from 6.5 to 35.9 mm ($\bar{X}$ 25.3 mm), and the two sexes were essentially the same size ($\bar{X}$ males 26.5 mm, and females 26.8 mm). Other shrimp species occasionally caught in substantial numbers included *Heterocarpus gibbosus* (24 to 42 g, ($\bar{X}$ = 34 g), *Plesionika ensis* (2-8 g, ($\bar{X}$ = 4 g), and *Plesiopenaeus edwardsianus* (2-118 g, ($\bar{X}$ = 16 g; Table 1).

The overall weight range for 184 individuals of *Chaceon granulatus* was 500-2,020 g ($\bar{X}$ = 1,115 g; Fig. 6), and maximum carapace width ranged from 114 to 179 mm ($\bar{X}$ = 150.4 mm). Males were substantially larger than females (male $\bar{X}$ = 1,219 g vs. female $\bar{X}$ = 976.9 g, and male carapace width $\bar{X}$ = 153.2 mm vs. female $\bar{X}$ = 146.7 mm). Males outnumbered females 107 to 80 (1:0.75). However, the proportion of females increased with depth, and the nine deepest traps (900 m) contained all females. Only 11 (13.8%) of the 80 females were ovigerous.

Photosequences

Perhaps the greatest advantage of a time-lapse photosequence sampling technique is that it provides a chronological record of bait site activity, including numbers and types of animals both in and around the trap, rather than just a record of what remains in the trap when it reaches the surface (Fig. 7, 8).

A total of 27 photosequences was obtained, including 22 in Mutremdiu Bay (Fig. 1), taken between 1979 and 1982 (additional details are provided by Saunders 1984), and five additional sequences were obtained in West Passage, in 1988. The 27 photosequences obtained spanned periods of 3.5-17 h, at depths of 73-700 m. *Heterocarpus ensifer* was present in 14 photosequences, *H. laevigatus* was present in seven, *H. laevigatus* and *H. ensifer* together were recorded in six, and *H. laevigatus* alone was recorded in one (Table 3).

Behavior and Activity

First appearance of the shrimps at baited camera sites (bait discovery

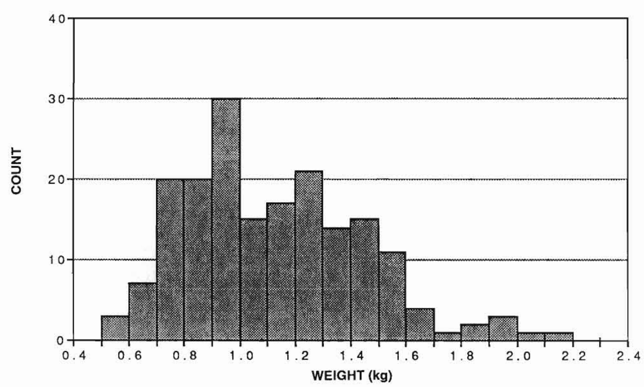


Figure 6.—Frequency distribution showing wet weights of *Chaceon granulatus* (n=184, range 0.5-2.02 kg, mean 1.11 kg).

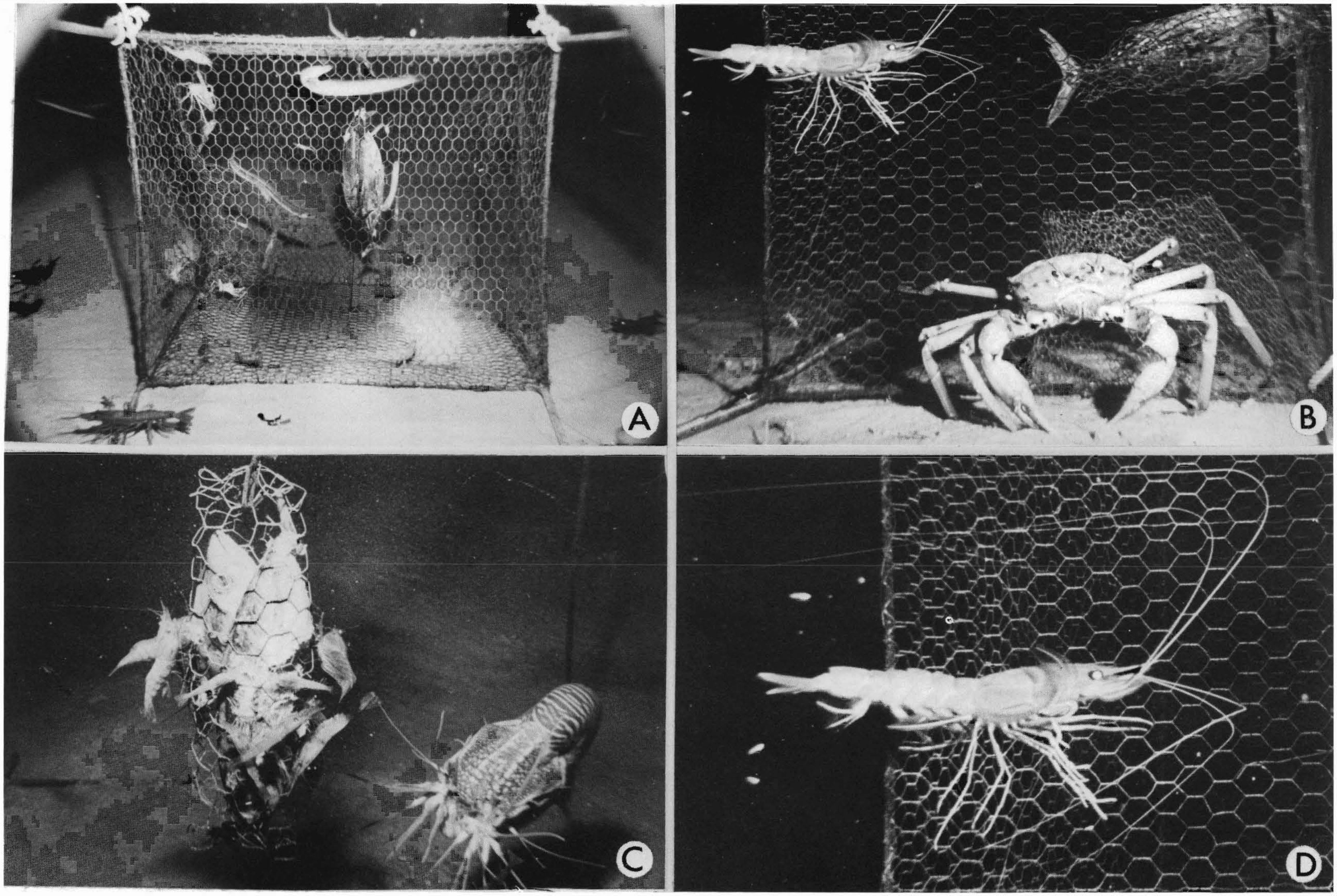


Figure 7.—Selected remote camera photographs taken at baited trap sites around Palau: A) *Heterocarpus laevigatus*, *Plesiopenaeus edwardsianus* and deep-water eels, 469 m, day set (seq. 18); B, D) *Chaceon granulatus* and *Plesiopenaeus edwardsianus*, 700 m, night set (seq. 27); and C) *Heterocarpus ensifer* and *Nautilus belauensis*, night set, 217 m (seq. 21). For scale, trap is 1 m across, mesh is 2.5 cm.

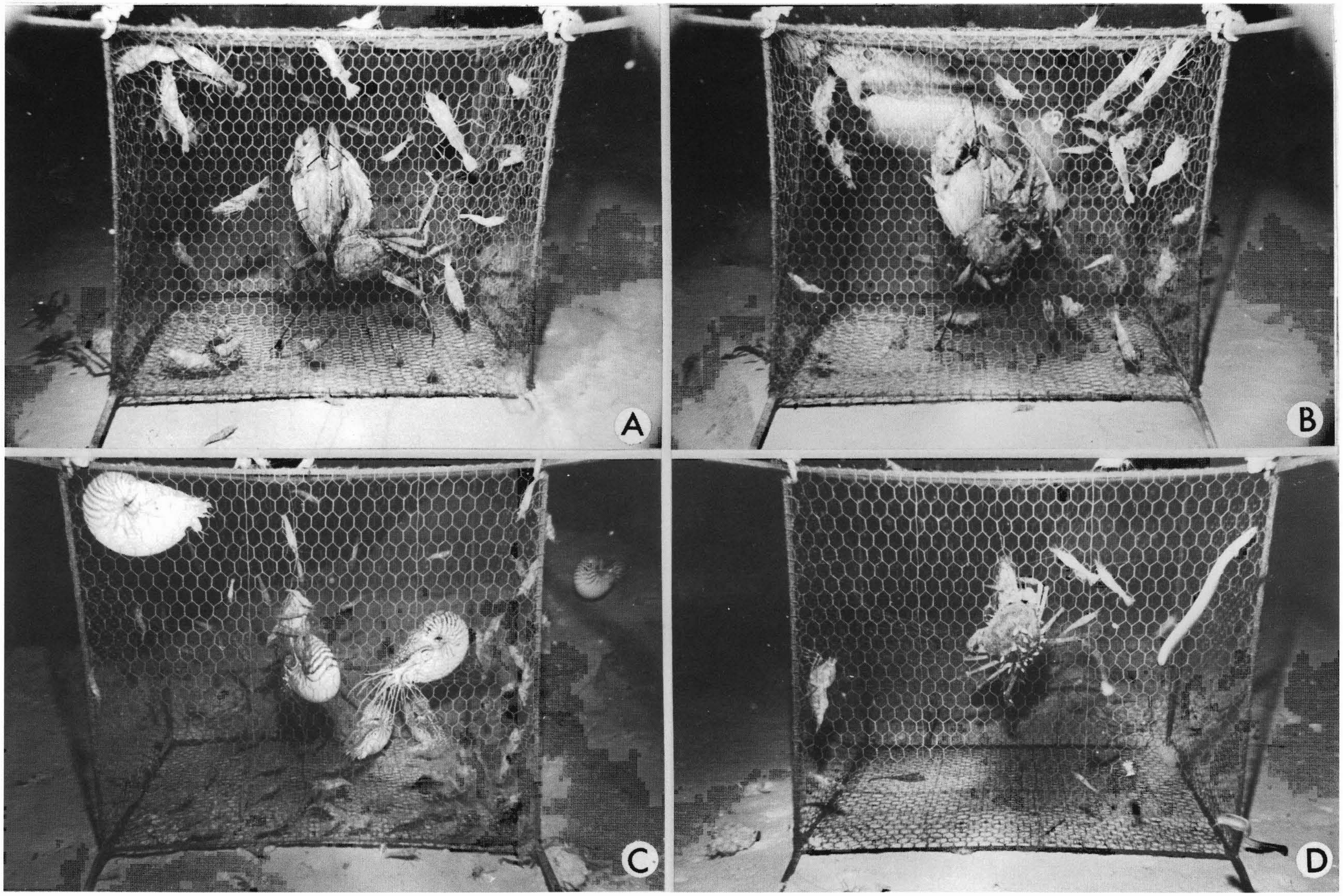


Figure 8.—Additional remote camera photographs from Palau: A) *Heterocarpus laevigatus, Plesiopenaeus edwardsianus, Chaceon granulatus,* and (in B) *Hexanchus griseus* (bluntnosed six-gill shark), 528 m, day set (seq. 20); C) *Nautilus belauensis* and swarm of *Heterocarpus ensifer*, day set, 284 m (seq. 7); D) *Heterocarpus laevigatus, H. ensifer*, and deep-water eels, 479 m, day set (seq. 6). Same scale as Figure 7.

Table 3.—Summary data for remote deep-water photosequences (arranged by increasing depth). Maximum number of *Heterocarpus laevigatus* (*H. laev.*) or *H. ensifer* (*H. ensif.*) observed in a single frame; B.T.=botom time in hours or span of photosequence on the bottom; N/D=whether primarily daylight or darkness; B.D.T.=bait discovery time or elapsed time in hours before first arrival of *H. laevigatus* or *H. ensifer*. Sequences 1-22 taken off Mutremdiu Point, Augulpelu Reef; sequences 23-27 taken off West Passage.

Sequence		Depth (m)	H. laev.	H. ensif.	B.T (h)	N/D	B.D.T (h)
1	14	73	0	0	1100-1620	D	
2.	10	95	0	0	900-1815	D	
3.	11	107	0	0	2015-0530	N	
4.	9	110	0	0	0915-1645	D	
5.	3	146	0	20	1500-0700	N	1.5
6.	13	146	0	0	0930-1730	D	
7.	12	146	0	0	1145-1530	D	
8.	22	191	0	28	1800-0300	N	0.75
9.	1	192	0	27	1830-1030	N	0[1]
10.	21	217	0	12	1745-0230	N	1.25
11	15	238	0	100	2030-0630	N	0[1]
12.	2	238	0	0	0900-1700	D	
13.	4	274	0	4	1000-1630	D	3.5
14.	5	278	0	50	0730-1545	D	0[1]
15.	7	284	0	50	0800-1530	D	0[1]
16.	17	357	0	150	0930-1530	D	0[1]
17.	19	449	12	3	1830-0315	N	0[1]
18.	18	469	6	21	0930-1615	D	0[1]
19.	6	479	6	15	0930-1630	D	0[1]
20.	16	504	20	8	0900-1715	D	0.25
21	20	528	26	14	0945-1630	D	0[1]
22.	8	538	29	0	1830-0430	N	0[1]
23.	23	512	4	0	1130-1300	D	0[1]
24.	24	550	6	2	1200-0530	D	0.25
25.	27	560	6	2	1700-0800	N	0.5
26.	25[2]	590	8	3	1630-1900	N	1.5
27	26[2]	700	9	0	1630-2430	N	1.0

[1]Bait discovery times (BDT) of 0 indicate that shrimps were present in the first frame taken.
[2]Camera malfunction caused irregular photograph interval.

time) is essentially instantaneous, as shown by their presence in the first frame of almost every sequence taken at depths below 270 m (Table 3). Comparison of a series of individual photosequences provides evidence that the two species behave differently. The larger species, *H. laevigatus*, is drawn to the bait in slow but steadily increasing numbers, as shown in plots of the maximum number of shrimp recorded in a single photographic frame, against elapsed time (Fig. 9, 10). By contrast, *H. ensifer* behaves in a much more erratic fashion, with specimen counts fluctuating as much as 100% between successive photosequence frames (e.g., Fig. 10b). The records suggest that *H. ensifer* is gregarious, and possibly follows scent trails in swarms. Traps are observed containing well over 100 specimens of *H. ensifer* in several photosequences, but the shrimps seem to have no difficulty in moving in and out of the trap. By contrast, *Heterocarpus laevigatus* appears in fewer numbers and tends to be solitary. This species also seems less active, in that individuals are often seen to remain motionless for as long as several hours at a time—either on the sea bottom or, more often, on the sides of the trap.

Diurnal/Nocturnal Variations

Detailed analysis of data from Palau provides evidence of crepuscular influence on *Heterocarpus ensifer*, as follows:

1) In two shallower photosequences (146 m depth), no shrimps are recorded during daylight, but as many as 20/frame are present at night, appearing at about sunset, leaving the bait site as dawn approaches (Fig 11a).

2) In three sequences at 191-217 m depths, *Heterocarpus ensifer* appears en masse during the evening crepuscular period (1830-1900 h).

3) In two 238 m sequences, no shrimps are recorded during daytime sets, whereas more than 100/frame are present at this depth during a night sequence (Fig. 11a).

4) These crepuscular fluctuations in *H. ensifer* do not occur below about 270 m, and the deeper species, *H. laevigatus* (whose upper range is ~350 m), is not sensitive to crepuscular photic changes. Two daytime sets at 274 and 278 m show *H. ensifer* in the first frames at 0730 and 0930 h, and such

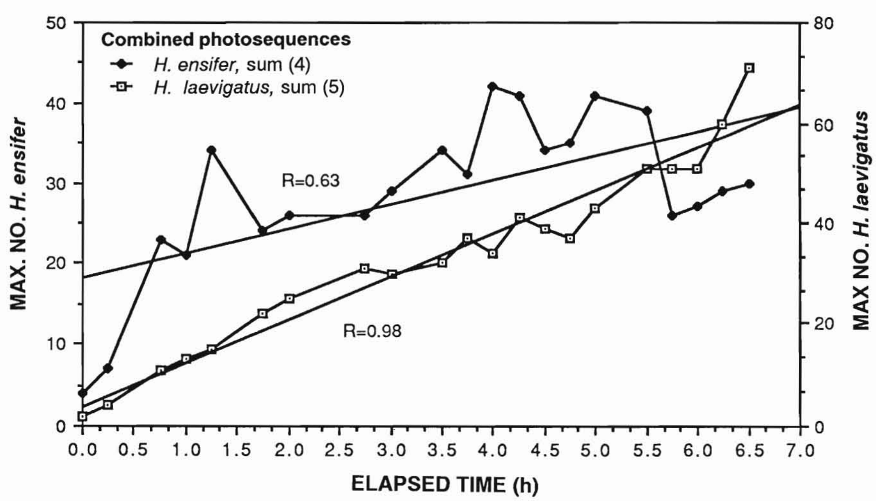


Figure 9.—Combined record of five photosequences showing the number of *Heterocarpus laevigatus* and four sequences showing *H. ensifer* visible in each photosequence frame, plotted against elapsed time (beginning with camera touchdown; see Table 3 for clock times). Note that the numbers of *H. laevigatus* in the field of view tend to gradually increase with time. By contrast, *H. ensifer* numbers may fluctuate widely, reflecting their tendency for erratic swarming behavior and for crepuscular migrations.

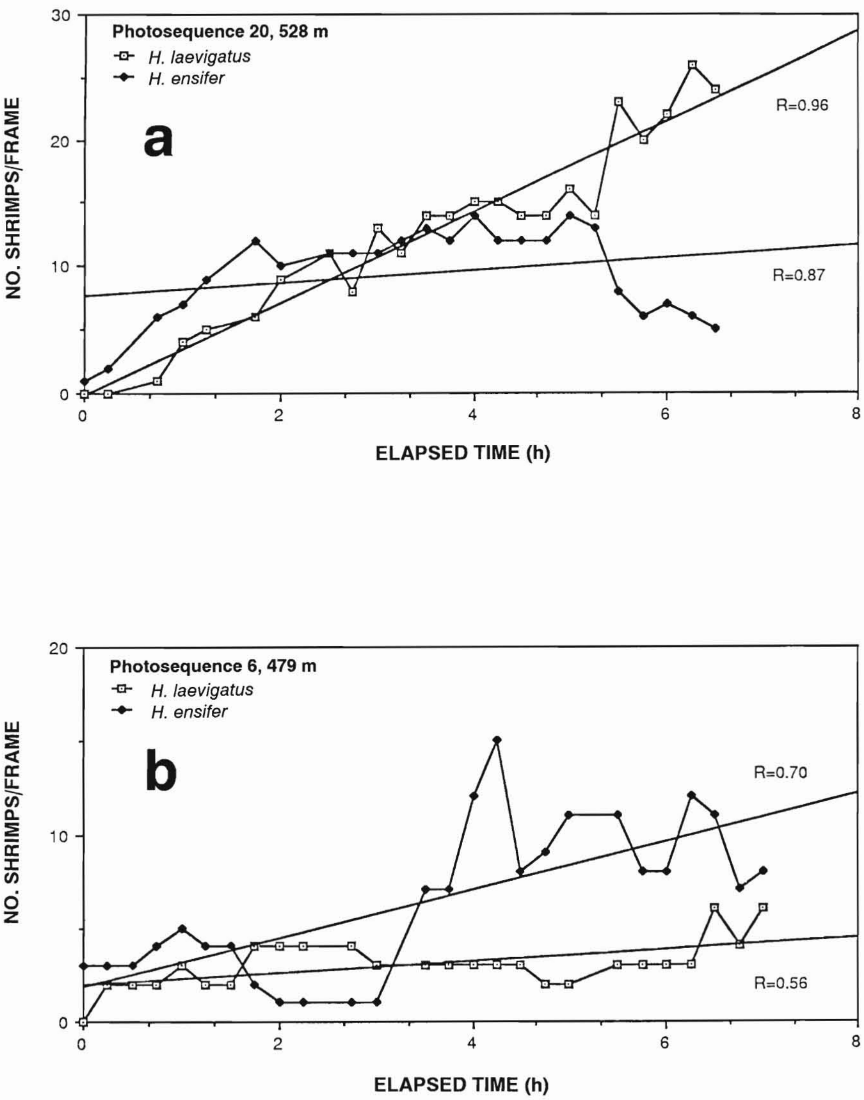


Figure 10a,b.—Individual photosequence records showing numbers of *Heterocarpus laevigatus* and *H. ensifer* visible in each photosequence frame, plotted against elapsed time (beginning with camera touchdown; see Table 3 for clock times). Note differences in behavior of the two species, reflected by difference in linear slopes, and fluctuations in numbers of individuals with time.

"on-arrival" appearances characterize all daytime sequences below 300 m (e.g., Fig. 11b, Table 3).

5) In all photosequences below 270 m, there appears to be no correlation between time of day and shrimp activity or numbers; there is, however, a good positive correlation between elapsed time and numbers of shrimps present.

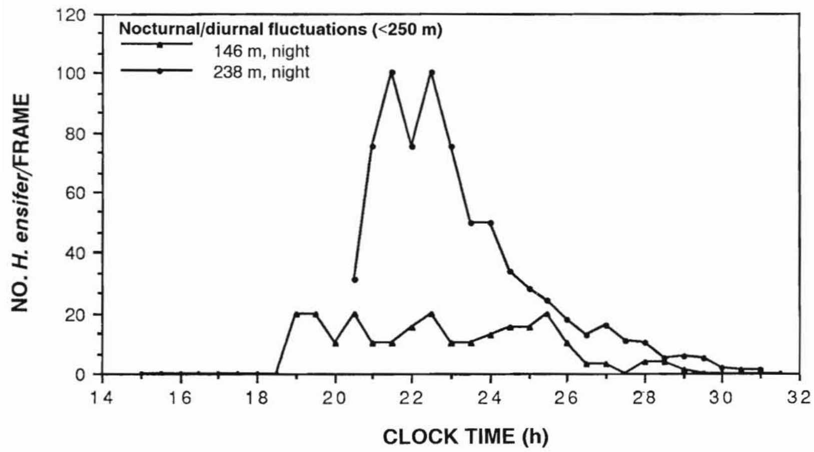
Discussion

The combination three-chambered trap, with extended soak times of 48-72 h, consistently produced higher yields than more conventional designs such as are successfully used elsewhere (King, 1980, 1982, 1984; Struhsaker and Aasted, 1974; Gooding, 1984; Tagami and Barrows, 1988).

Of the 15 shrimp species caught during the Palau survey, only *H. laevigatus* (maximum weight = 106 g) was caught in sufficient quantities to qualify as a potential fishery resource. The same sex ratio was reported for this species in Hawaii by Dailey and Ralston (1986) who also recorded seasonal fluctuations in the proportion of ovigerous females. However, Moffitt and Polovina (1987) suggested that the depth of sampling effort may greatly influence the observed overall sex ratio. The size at maturity of female *H. laevigatus* (~40 mm carapace length) observed in Palau is similar to that reported for this species elsewhere (Dailey and Ralston, 1986; Moffitt and Polovina, 1987).

The smaller species, *H. ensifer*, was caught in low numbers and inconsistently. Substantially higher yields of the larger species were also recorded by Moffitt and Polovina (1987) in the Marianas. Of the other species recorded in Palau, *H. gibbosus, H. dorsalis*, and the penaeid species *Plesiopenaeus edwardsianus*, attained large sizes (maximum weights of 42 g, 32 g, and 118 g, respectively) although numbers were generally low. For marketing purposes, these species could be combined with *H. laevigatus*, but the other species obtained were too few or too small to be regarded as a marketable by-catch. King (1986) mentioned that *Nautilus* shells may represent a valuable by-catch for the tourist market in the Pacific islands. However, in Palau, *Nautilus* is protected, and is the type locality and only known occurrence of *N. belauensis* (Saunders, 1984).

Although the depth ranges of *Heterocarpus ensifer* and *H. laevigatus* overlap in Palau, they do not occur together in great numbers as reported elsewhere (e.g. King, 1986; Moffitt and Polovina, 1987). The Palau photosequences record *H. ensifer* between ~150 and 550 m, but it should be noted that the shallower occurrences (<250 m) are all nocturnal. Trap yields indicate a slightly narrower range for *H. ensifer*, ~200-350 m. *Heterocarpus laevigatus* is generally a deeper ranging species; the upper range in photosequences is 449 m (and this is not subject to diurnal fluctuations), but moderate trap yields were obtained as shallow as 375-400 m. Trapping results show that this species ranges as deep as 850 m, but the lower limit in Palau is not known. The combined evidence indicates the overlapping depth range of the two species is about 300-550 m.



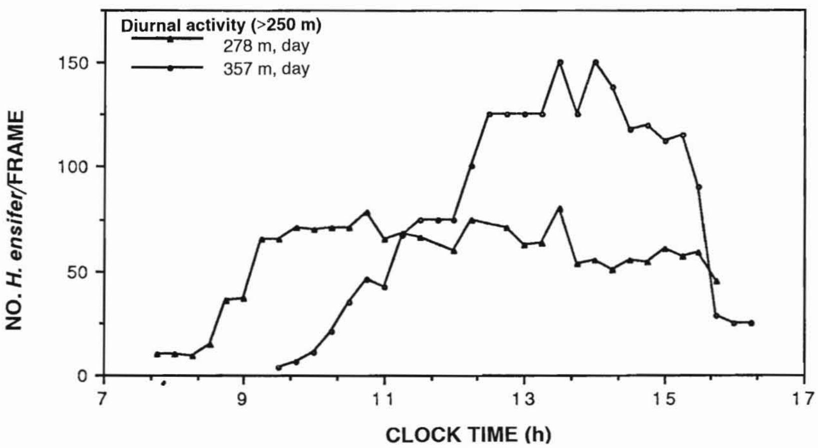


Figure 11a,b.—Records of four photosequences showing number of *Heterocarpus ensifer* per photosequence frame, plotted against clock time. Above 250 m (a), *H. ensifer* is present only during hours of darkness, arriving and departing during evening and morning crepuscular periods, respectively. Below ~250 m (b), *H. ensifer* is present and active during daylight as well as darkness, often occurring in swarms, with more than 150 individuals visible in a single frame.

The preferred depth ranges appear to be ~200-400 m for *H. ensifer*, and ~400-800 m for *H. laevigatus*.

Time-lapse remote camera photosequence records permit monitoring different species and even different individuals over a prolonged period. The counts of individuals observed in a single frame are probably underestimates of the numbers of individuals actually present in the field of view, because the bait or larger animals may obscure some smaller specimens. But the general consistency of specimen counts from one frame to the next suggests that this is an equitable estimate of what is present around the bait site.

The instantaneous appearance of shrimps at bait sites may mean that they can detect the scent trails of descending baited traps. This ability has previously been observed in the planktonic shrimp *Acetes* (Hamner and Hamner, 1977). As the records show, *Heterocarpus ensifer* tends to occur in erratic swarms, moving actively in and out of traps, whereas *H. laevigatus* tends to be more of a solitary animal, drawn in gradually increasing numbers to the bait over a longer period of time. Like *Nautilus* (Saunders, 1984), *H. ensifer* in its upper depth range seems to be affected by diurnal photic fluctuations; between depths of 150 and 270 m, it appears in large numbers during the evening crepuscular period and disappears at dawn. Essentially identical patterns of crepuscular movement have recently been reported in photosequences taken at 147-372 m depths off Manus, Papua New Guinea, with morning arrivals and evening crepuscular disappearances recorded in every sequence (Saunders, 1990). These fluctuations apparently reflect movement up and down the reef slope, for below 270 m this species is present at all times. The larger shrimp, *H. laevigatus*, and the geryonid *Chaceon granulatus* do not seem to be affected by nocturnal/diurnal photic fluctuations.

The photosequences indicate that the key to attracting shrimps and retaining them is scent. As long as bait is present, even if it is inaccessible (e.g., if enclosed in fine wire mesh bags), shrimps will linger in the vicinity whether or not they are actually feeding on bait. However, once the bait has been consumed (in many cases this is accelerated by copepods), the animals move about the trap until egress is attained. Trapping strategists would do well to keep these behavior modes in mind; not only is it necessary to attract the animal using scent sources, it is also necessary to maintain a scent presence to discourage escape. It may be that preventing or discouraging egress is a more important factor in trapping yields than attracting large numbers of animals to the bait. From this standpoint, spring-loaded door closure triggered by soluble magnesium links, timed to scent dimunition, might be a productive direction for future research efforts.

At present, little information is available regarding the life history and fishery potential of *Chaceon granulatus*, and only recently have data become available on geryonid crab fisheries in general (Melville-Smith, 1988; Lindberg and Wenner, 1990). A few details are now available concerning *C. fenneri* and *C. quinquedens* off the eastern United States and in the Gulf of Mexico (Wigley, et al., 1975;

Wenner, 1990; Lindberg, et al., 1990; Kendall, 1990; Armstrong, 1990; Hinsch, 1990) and considerably more information is available for *C. maritae* off southwest Africa (Melville-Smith, 1988; 1990). These sources indicate that observations reported here on *C. granulatus* in Palau are also generally true for other species of *Chaceon*, including sexual dimorphism, unequal sex ratios, and sex segregation by depth.

The present study indicates that there is potential for combined deepwater trapping of *Heterocarpus laevigatus* and *Chaceon granulatus*. This requires using large, three-chambered traps set for extended soak times (48-72 h), at depths of ~400-800 m. The forereef slopes of most western Pacific islands have only a limited number of sites with low-slope bottom conditions favorable for setting traps, but each of these could accomodate a few traps over an extended period, with replenishment of stocks generated from the extensive adjacent reef slopes that are too steep to trap. This is envisaged as a secondary undertaking by individual fishermen, to supplement ongoing fishing efforts. The economic feasibility of such an operation, based on the local infrastructure of Palau, is discussed in greater detail by Saunders et al. (1989). Similar small-scale deepwater trapping efforts should also be feasible in other oceanic archipelagoes in the Indo-Pacific. If properly managed, they could provide a supplementary source of income for local fishermen that should sustain itself indefinitely.

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