On the Distribution and Fishery Potential of the Japanese Red Crab *Chaceon granulatus* in the Palauan Archipelago, Western Caroline Islands

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Introduction

As the world demand for crustacean meat of all kinds continues to rise, interest has grown in the potential for commercial exploitation of deep-water geryonid crabs. These animals are widely distributed in the world's oceans, commonly occurring on continental slopes at depths of 100-2,000 m (Manning, 1990). Several members of the genus *Chaceon* (formerly *Geryon*[1]), typically medium to large crabs with high quality flesh, are considered marketable.

Presently, there are two major geryonid fisheries in the Atlantic. Off the northeastern United States is an established fishery for the red crab, *Chaceon quinquedens*, which has operated since the early 1970's (Armstrong, 1990). A similar species from west African waters, *C. maritae*, has also been significantly exploited (Melville-Smith, 1988). On information from FAO (1986) and Melville-Smith (1988), it can be estimated that the total world geryonid catch exceeded 12,000 t in 1981. Interest in these fisheries has resulted in exploratory surveys for several Atlantic species, including *C. affinis* (Shelton, 1979), *C. fenneri* (Wenner et al., 1987; Kendall, 1990; Lindberg et al., 1990; Wenner, 1990), *C. notialis* (Barea and Defeo, 1985; Defeo et al., 1991), and, in other areas, *C. quinquedens* (McElman and Elner, 1982) and *C. maritae* (Cayre et al., 1979).

There is an apparently similar, wide distribution of geryonid crabs in the tropical and subtropical Pacific (Sakai,1978; Cayre et al., 1979; King, 1984; Saunders, 1984; Hayasaka, 1985; Manning and Holthuis, 1989). Extensive exploratory deep-water trapping surveys have been undertaken in this region and are well documented (Struhsaker and Aasted, 1974; King, 1981, 1986; Gooding, 1984; Moffit and Polovina, 1987). However, these have tended to concentrate on the two caridean shrimp species, *Heterocarpus ensifer* and *H. laevigatus*.

A recent study of this nature by Saunders et al., (1989) revealed a population of the Japanese red crab, *Chaceon granulatus*, on the deep forereef slopes around Palau, Western Caroline Islands. Preliminary evidence suggests that it may be of sufficient density to support a local fishery. It is possible that similar populations of geryonids exist on the slopes of several Indo-Pacific archipelagoes. This paper is largely based on observations of *C. granulatus* made during red crab explorations in Palau. A brief review of the present status, distribution, and fishery potential of Pacific geryonids in general is included.

Procedures

A total of 103 traps was set between 170 m and 900 m depth at five stations around Palau (Fig. 1), between 1987 and 1988. Several trap designs were initially tested (Saunders et al., 1989). Quantitative samples were obtained by using a large box trap (2x1x1 m) with 25 cm diameter funnels at each end. About 1 kg of bait, usually frozen skipjack tuna, *Katsuwonus pelamis*, was wrapped in chicken wire and suspended in the cen-

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ABSTRACT—A deep-water trapping survey in the Palauan archipelago, Western Caroline Islands, has revealed an abundance of the Japanese red crab, Chaceon granulatus. *The recorded depth range (250-900 m) is similar to that of other geryonids, but the large numbers of females caught below 700 m is atypical. Mean yields in excess of 5 kg crabs plus 1 kg shrimp,* Heterocarpus laevigatus, *by-catch per trap-night were attainable at optimum depths.* Chaceon granulatus *is apparently a very large geryonid, with maximum weights of 2.02 kg and 1.51 kg recorded for male and female specimens, respectively. A range of body colors was observed: Orange-red shades appear to dominate the deeper waters (below 500 m) while yellow-tan colors are more abundant in the upper reaches.*

Preliminary evidence suggests that Chaceon granulatus *is highly marketable, and the infrastructure in Palau is such that crabs could either be marketed fresh locally or airfreighted to Japan as a quick-frozen product. The high post-trapping survival rates observed indicate that maintaining crabs in live-holding tanks may be a feasible option. The large catches and quality of deep-water crabs taken suggests that the Palauan population of* Chaceon granulatus *may be able to support a small-scale fishery. It is not yet known whether this population is unusually large or whether these findings typify the deep fore-reef fauna of the region.*

[1]The family geryonidae was revised by Manning and Holthuis (1989) to include three genera: *Geryon* (2 species), *Chaceon* (21 species), and *Zariquieyon* (1 species).

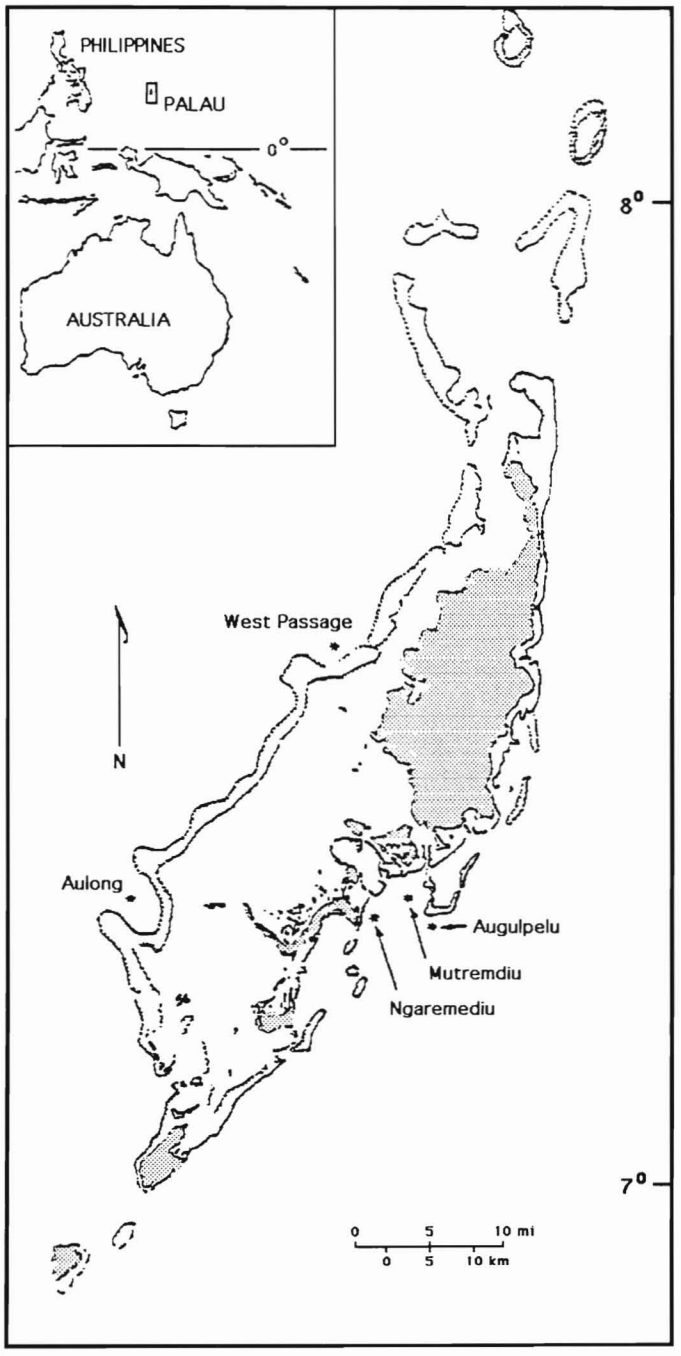

Figure 1.—Map showing deep-water trapping stations around Palau, Western Caroline Islands. Traps were set 103 times at 170-900 m, at 1) Mutremdiu Bay (38 sets), 2) Augulpelu Reef (7 sets), 3) Ngaremediu Reef (19 sets), 4) Aulong Bay (7 sets), and 5) Toagel Mlungui (West Passage) (32 sets).

ter of the trap; mesh baffles were included to impede egress (this design is referred to as the standard trap henceforth). Polypropylene rope (4-8 mm diameter) was used in conjunction with surface buoys and marker flags. Scrap-iron weights and anchors were attached to reduce trap dragging. Set traps were usually soaked overnight for 15-25 hours and pulled the following day.

The survey vessel was the MRD *Mesekiu*, a diesel 10 m Yanmar[2], equipped with a gasoline pot hauler. An Echotec CV950 VDU fathometer was available for depth determination. Catches, stored in a large ice cooler onboard, were later sorted in the laboratory. The crabs were sexed, weighed, and measured, and the shrimp by-catch data (species, number, weight) were also collected. All data were logged into a Macintosh Plus microcomputer using Cricket Statworks software.

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

Results

Distribution and Catch Rates

A total of 98 retrieved traps (5 were lost) yielded 238 red crabs (*C. granulatus*, 268 kg) and 1,550 shrimps (15 species, 55 kg). *Chaceon* was found over a considerable depth range (250-900 m, with corresponding water temperatures of 5-10°C (Fig. 2; Saunders et al., 1989)); the lower limit of the depth range was not established. Figure 3 shows the relative numbers of crabs caught at 50 m intervals. There is a marked increase below 650 m. The sex ratio recorded overall was 1.329:1 in favor of males, which were caught more frequently over most of their range (350-850 m). However, female crabs were more abundant in the deeper sets and tended to dominate catches from below 700 m. A few females were also caught in the shallowest sets (ca. 250 m), resulting in a greater depth range than that recorded for males. All the berried females were caught between 650 m and 770 m depth (Table 1).

In terms of catch per unit effort (CPUE), high yields (>5 kg per trap-night) were attained below 500 m (Fig. 2). Mean shrimp by-catches of around 1 kg per trap-night were also obtained between 600 and 700 m. These were dominated by the caridean *Heterocarpus laevigatus*, which composed 92% (51 kg) of the total shrimp yield by weight. A smaller species, *H. ensifer,* dominated the shallower catches of shrimp (170-400 m), but catch rates were generally poor (Fig. 2). Large numbers of the deep-water eel, *Synaphobranchus affinis*, were also taken, below 400 m.

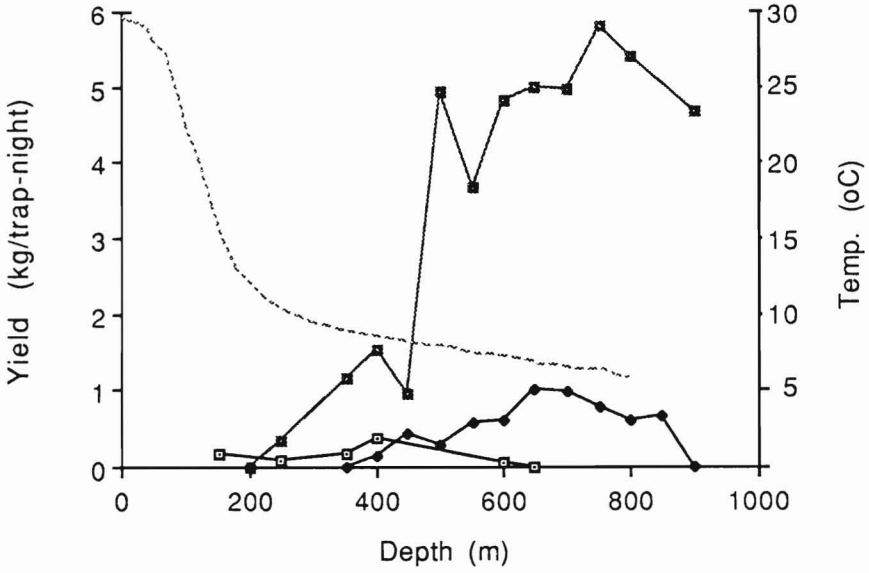

Figure 2.—CPUE values obtained for *Chaceon granulatus* (black squares) between 170 and 900 m depth. Shrimp by-catch values for *Heterocarpus laevigatus* (diamonds) and *H. ensifer* (white squares) are included. Based on standard trap data. The broken line represents a water temperature profile for Palau (May-October 1987), based on average readings from four trap sites (Saunders et al., 1989).

Physical Characteristics

Figure 4 shows the relative wet weights of male and nonovigerous female crabs examined. On average, males are larger and heavier than females (Table 1). Significant differences ($P<0.01$) in size and body weight were detectable (Student's t test). The relationships between carapace width and body weight were also tested, showing significant correlations ($P<0.01$) in both sexes (Fig. 5).

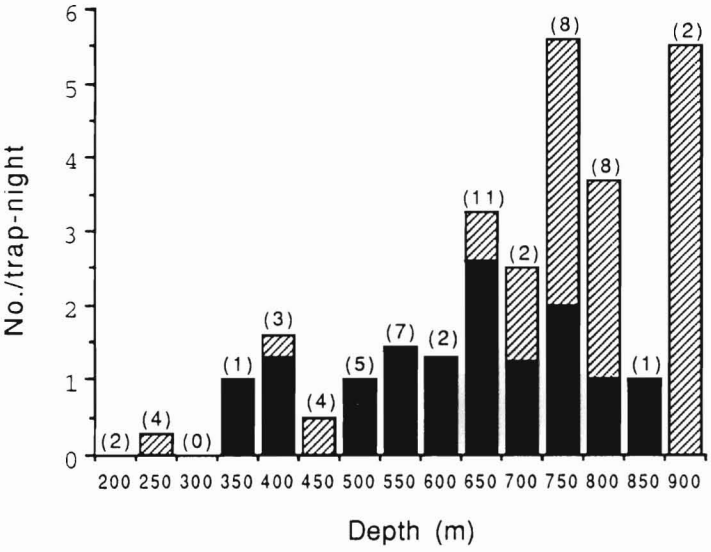

Figure 3.—Numbers of *Chaceon granulatus* caught at 50 m depth intervals, based on standard trap data. Male and female crabs are represented by black and hatched columns respectively. Effort (trap-nights) is shown in parentheses.

Observed body colors ranged from light yellow to deep red. Differences between sexes were not detected (Table 2). However, orange-red shades appear to dominate the deep waters (below 500 m), while yellow-tan colored animals are more abundant in the upper reaches (Table 3). Most individuals were uniformly colored, although a few dark red specimens had black patches on the carapace, claws, and legs. Darker crabs also tended to have harder, worn shells and frequently exhibited heavy barnacle settlement.

Marketability

Yields of quality white meat were easily extracted from the claws, legs, and bodies of a number of fresh crabs which had been steam-cooked. This was found to be palatable and similar in texture and flavor to that of lobster, *Homarus* sp. Some brown meat, also found in the bodies, was of poor quality.

A high percentage of crabs appeared to survive trapping operations. A sample of 43 hauled crabs were examined after 30 minutes on ice, and recorded as dead or alive, depending on any signs of movement in the claws, legs and oral region; only 7 remained moribund after 1 hour, representing a rapid revival rate of 84%. Two healthy animals were later maintained in refrigerated seawater (4°C) for 1 week.

Discussion

Chaceon granulatus has previously been recorded in the Western Pacific, as far south as Japan (Sakai, 1978). There it is considered to be quite rare and thus unsuitable for commercial exploitation (Tomiyama, 1983). The catches taken in Palauan waters are

Table 1.—Summarized size and weight data recorded for *Chaceon granulatus* specimens.

		Carapace width (mm)			Weight (kg)		
Sex	No.	Mean	S.D.	Range	Mean	S.D.	Range
Male	105	153.2	12.401	124-179	1.219	0.329	0.58-2.02
Female[1]	68	146.6	11.472	114-174	0.963	0.224	0.50-1.51
Female[2]	11	147.6	10.782	134-170	1.061	0.208	0.73-1.46

[1]Nonovigerous.
[2]Ovigerous.

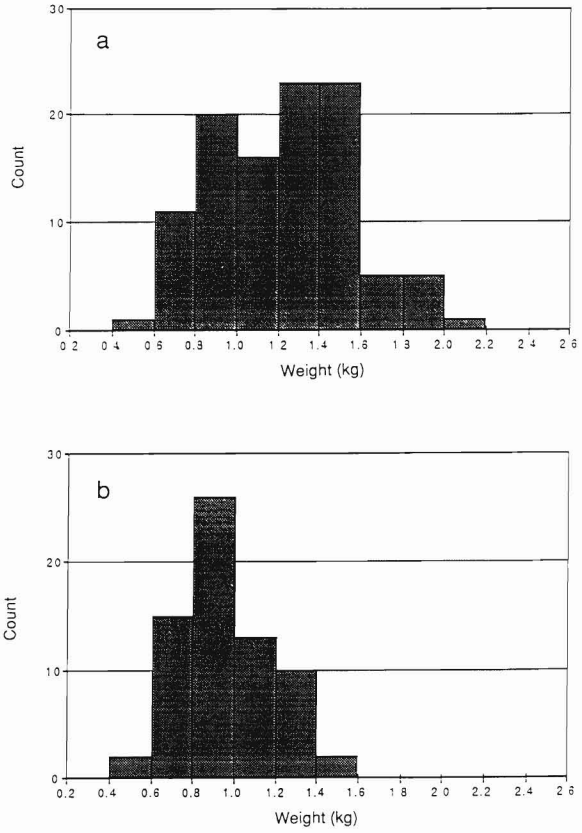

Figure 4.—Histograms of wet weights recorded for a) male and b) nonovigerous female crabs captured during the survey.

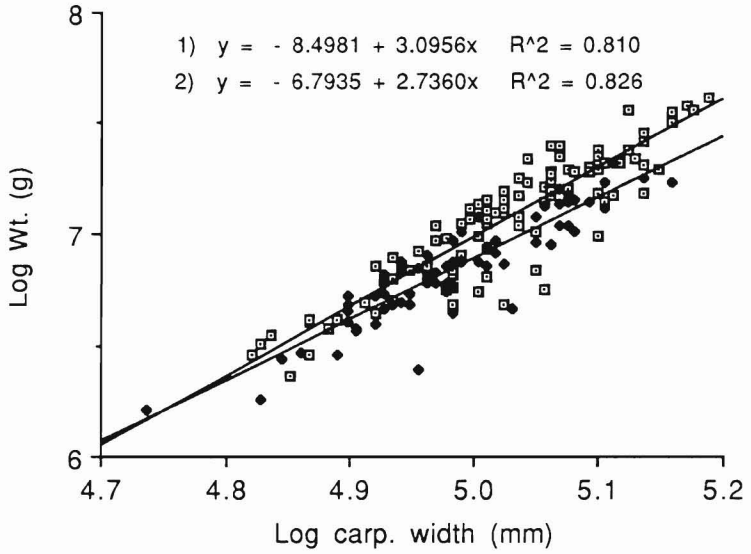

Figure 5.—Bivariate size (carapace width)-weight scatterplots for 1) male and 2) nonovigerous female crabs. Corresponding regression lines and correlation coefficients are displayed.

Table 2.—Observed body colors (carapace, claws, legs) of 51 *Chaceon granulatus* specimens caught at stations 4 and 5.

Color	No.	% of Males	% of Females
Orange-red	31	60% (24)	64% (7)
Dark red	9	18% (7)	18% (2)
Yellow-tan	10	20% (8)	18% (2)
Brown	1	2% (1)	0% (0)

similar to those reported for *C. quinquedens* (Gray,1970; Meade and Gray, 1973; Haefner and Musick, 1974; McElman and Elner, 1982) and *C. maritae* (Cayre et al, 1979; Melville-Smith, 1986), as well as other species under economic consideration in certain areas (Wenner et al., 1987; Defeo et al., 1991).

Although the lower depth limit was not established, the observed depth range of *Chaceon granulatus* (240-900 m) appears to be geryonid-typical. Sexual zonation has been frequently reported for geryonids (Haefner and Musick,1974; Wigley et al., 1975; Cayre et al., 1979; Beyers and Wilke, 1980; McElman and Elner, 1982; Barea and Defeo, 1985; Melville-Smith, 1988), with most workers concluding that females are typically more abundant at shallower depths. However, our findings suggest that, within the population of *Chaceon granulatus* around Palau, the reverse may be the case. A few *C. fenneri* females trapped by Wenner et al. (1987) in the South Atlantic Bight were deeper than most of the males, suggesting that sexual zonation may depend on several factors, such as species, water temperatures, seasonal effects, and spawning migrations.

Overall sex ratios in favor of males have been reported in trapping surveys for *C. quinquedens* (Gray, 1970; Haefner and Musick, 1974; McElman and Elner, 1982), *C. maritae* (Melville-Smith, 1988), *C. fenneri* (Wenner et al., 1987), and *C. notialis* (Defeo et al., 1991). To an extent, trapping may

Table 3.—Percent of observed body colors (pooled sexes) of *Chaceon granulatus* recorded at different depth intervals.

		<500 m		500-700 m		>700 m	
Color	No.	%	No.	%	No.	%	No.
Orange-red	31	25%	(2)	60%	(18)	85%	(11)
Dark red	9	25%	(2)	17%	(5)	15%	(2)
Yellow-tan	10	50%	(4)	20%	(6)	0%	(0)
Brown	1	0%	(0)	3%	(1)	0%	(0)

be sex-selective, in that female crabs carrying ripe eggs may not be attracted to bait; the possible exclusion of larger males due to funnel diameter restrictions should also be considered. Haefner and Musick (1974) observed a predominance of female *C. quinquedens* in trawls at shallower depths, while Melville-Smith (1988) has reported that *C. maritae* females are sometimes more abundant at certain depths and localities. The larger number of male crabs caught during this survey may have been influenced by the trapping effort, which was concentrated between 500 m and 750 m depth (Fig. 3).

According to records (Shroeder, 1959; McRae, 1961; Kjennerud, 1967; Mason and Davidson, 1969; Haefner and Musick, 1974; Sakai, 1978; Cayre et al., 1979; McElman and Elner, 1982; Barea and Defeo, 1985; Wenner et al., 1987; Manning and Holthuis, 1989), *C. granulatus* appears to be similar in size and weight to *C. affinis*, *C. bicolor,* and *C. fenneri*, and considerably larger than *C. quinquedens, C. maritae*, and *C. notialis*. Larger attainable sizes of male geryonids have previously been reported for all the aforementioned species (Schroeder, 1959; McRae, 1961; Sakai, 1978; Cayre et al., 1979; Shelton, 1979; McElman and Elner, 1982; Barea and Defeo, 1985; Wenner et al., 1987), and so *C. granulatus* appears typical in this respect.

Presently, there is debate as to whether body coloration is useful in distinguishing geryonid species (Manning and Holthuis, 1989; Manning, 1990), or whether it is too variable within certain species to be used as a taxonomic character (Hines, 1990). Our findings support the latter view, at least for *C. granulatus*. Manning (1990) has noted that red geryonid species are often found in deeper water than tan ones; this tendency has now been recorded intraspecifically for *C. granulatus*.

Preliminary evidence suggests that *C. granulatus* is highly marketable. Handling and processing techniques for geryonids are well documented (McRae, 1961; Haefner and Musick, 1974; Meade and Gray, 1973; Cayre et al., 1979; Melville-Smith, 1988). The present infrastructure in Palau is such that crabs could either be marketed fresh locally or as a quick-frozen product airfreighted to Japan (Y. Akiba, Nippa Fishing Corporation, Tokyo, personal commun.). The caridean shrimp by-catches are also valuable and could be marketed similarly. These options could be assessed in an economic feasibility study, based on extensive CPUE data. Given the high post-trapping survival rates observed, a further option might be to maintain crabs in live-holding tanks.

The catches and quality of deep-water crabs taken indicate that the Palauan population of *C. granulatus* may be able to support a small-scale fishery. It is not known, presently, whether this population is unusually large or whether these findings typify the deep fore-reef fauna of the region. Certainly, this species and its close congener, *C. bicolor* have been recorded in several Pacific localities (Fig. 6; Sakai, 1978; Cayre et al., 1979; King, 1984; Hayasaka, 1985; Manning and Holthuis, 1989).

Geryonid crabs are typically slow growing (Lux et al., 1982; Van Heukelem et al., 1983; Melville-Smith, 1989), and major recruitment events are thought to occur very rarely (Hines, 1990). Deep-water communities in general are particularly vulnerable to overfishing (Ralston, 1986), and the protection of these resources by strict management regimes will be crucial, particularly in Palau and other similar Indo-Pacific archipelagoes. Although these deep-water crab stocks are likely to be small and restricted in comparison to those on the continental slopes, they should be easier to define and hence manage effectively. Biomass estimates of several geryonid stocks have been calculated by various techniques, including trapping (Cayre et al., 1979; Defeo et al., 1991), trawling (Beyers and Wilke, 1980), effective area fished (EFA) (McElman and Elner, 1982; Melville-Smith, 1986; Defeo et al., 1991), and photography (Wigley et al., 1975; Melville-Smith, 1983, 1985). Individual archipelagoes in the Western Pacific possess relatively small areas at suitable depths for geryonid exploitation. Collectively, however, this area must be considerable.

Acknowledgments

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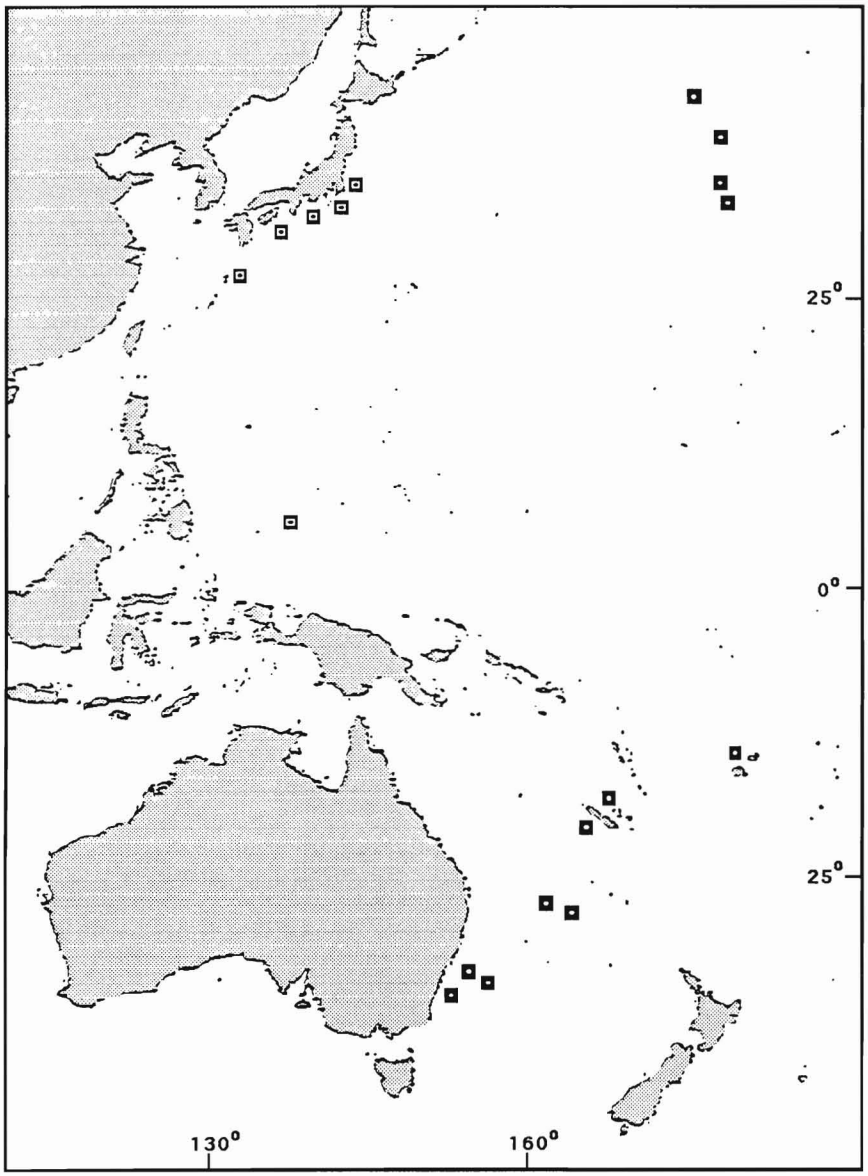

Figure 6.—Distribution of *Chaceon granulatus* (white squares) and *C. bicolor* (black squares) in the Western Pacific Ocean, based on the records of Sakai (1978), Cayre et al. (1979), Hayasaka (1985), Manning and Holthuis (1989), and Saunders et al. (1989).

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