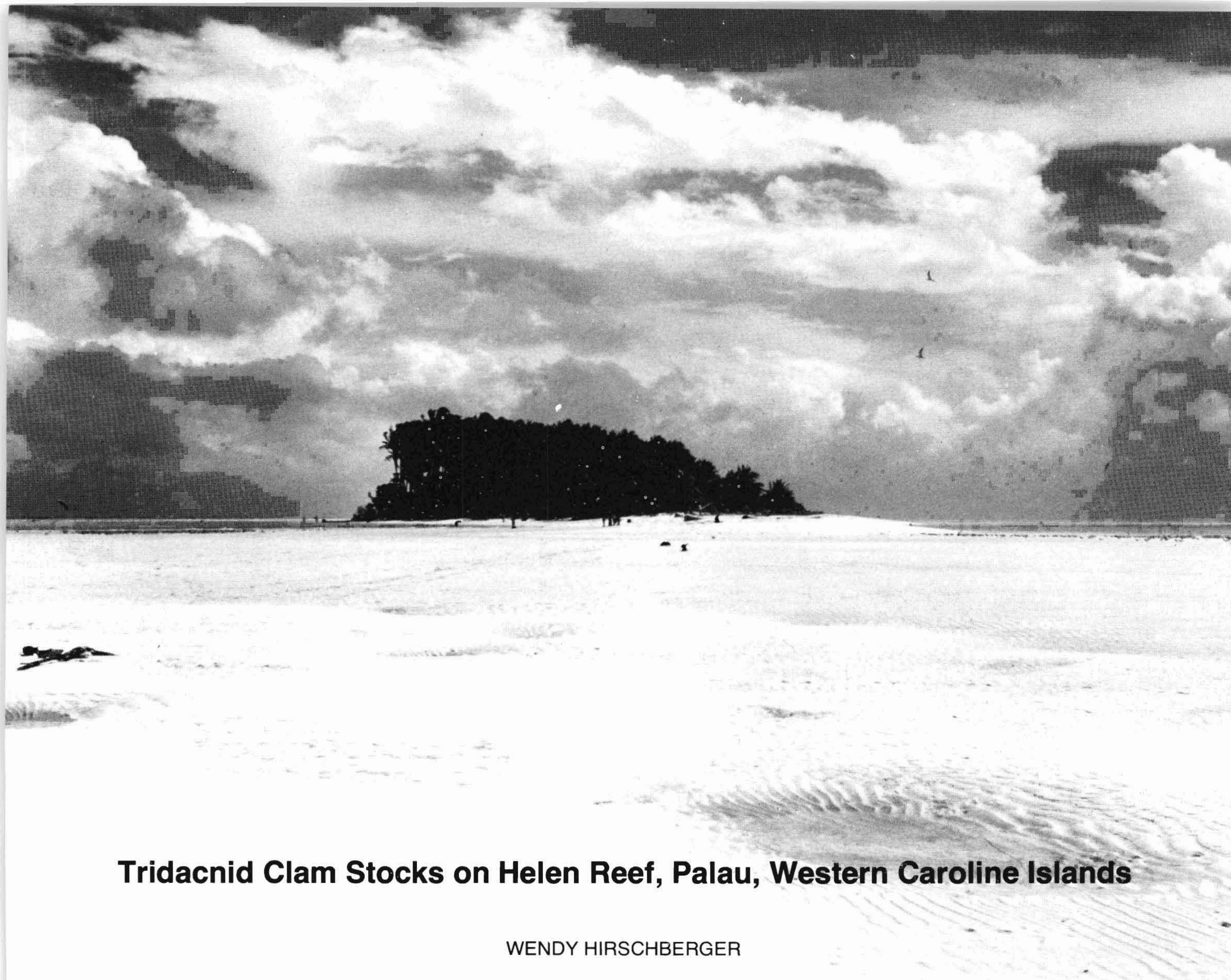

Tridacnid Clam Stocks on Helen Reef, Palau, Western Caroline Islands

WENDY HIRSCHBERGER

Figure 1.—Helen Island at Helen Reef atoll, in Palau's southwest islands.

Introduction

Overexploitation of tridacnid clam populations appears to be a current problem in many areas of the Indo-Pacific. One area where some of the effects of harvesting have been studied is Helen Reef, a small atoll in the south Palau District, Western Caroline Islands, Trust Territory of the Pacific Islands. The submerged reef and lagoon, lying at approximately lat. 3°N and long. 131°E (Fig. 1, 2), occupy about 216 km^2 with a small island (Helen Island) located at the northern end. Depths inside the lagoon exceed 60 m; outside, the bottom slopes steeply. This remote area is uninhabited and receives only occasional visits from U.S. Trust Territory outer island support ships and foreign fishing vessels.

In May 1971, the NOAA research vessel *Townsend Cromwell*, operated by the National Marine Fisheries Ser-

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ABSTRACT–A survey of Palau District's Helen Reef was conducted in May 1976 to continue monitoring changes in tridacnid clam abundances. The densities of the four largest tridacnid species were slightly higher than observed in 1975; however, ratios of live individuals to empty shells continued to remain very low. Only Hippopus hippopus *showed a substantial decrease in the percentage dead. This is in contrast to* Tridacna maxima *which is subject to relatively no fishing mortality and showed less than 5 percent dead. These smaller species may possibly be used as natural population indicators at Helen Reef.* Tridacna squamosa *is still rare, probably owing to poor environmental conditions for this species.*

vice, NOAA, conducted a survey of the Trust Territory's marine resources. Only a stop was made at Helen Reef at this time, and the ship returned in March 1972 to survey the tridacnid clam populations. In their report, Hester and Jones (1974) concluded that the tridacnid populations at Helen Reef were large and that *Tridacna gigas* and *T. derasa* could possibly withstand a moderate, controlled fishery.

A resurvey effort was undertaken in April 1975 by a team of biologists supported by the Palau District Marine Resources Office, a division of the Trust Territory Department of Marine Resources, in response to increasing reports of foreign fishing vessels in the Helen Reef area. They found that tridacnid clam populations had apparently been reduced since 1972 (Bryan and McConnell, 1976).

In 1976 the Palau Marine Resources Office requested another resurvey in response to continued reports of unauthorized fishing vessels in the Helen Reef area. There was concern that continued fishing in this area could lead to severe stock depletions, with small chances of recovery. This report gives a description of the 1976 resurvey effort, monitoring changes in the abundance of tridacnid clams on Helen Reef, and provides population densities of the area with comparison to earlier surveys.

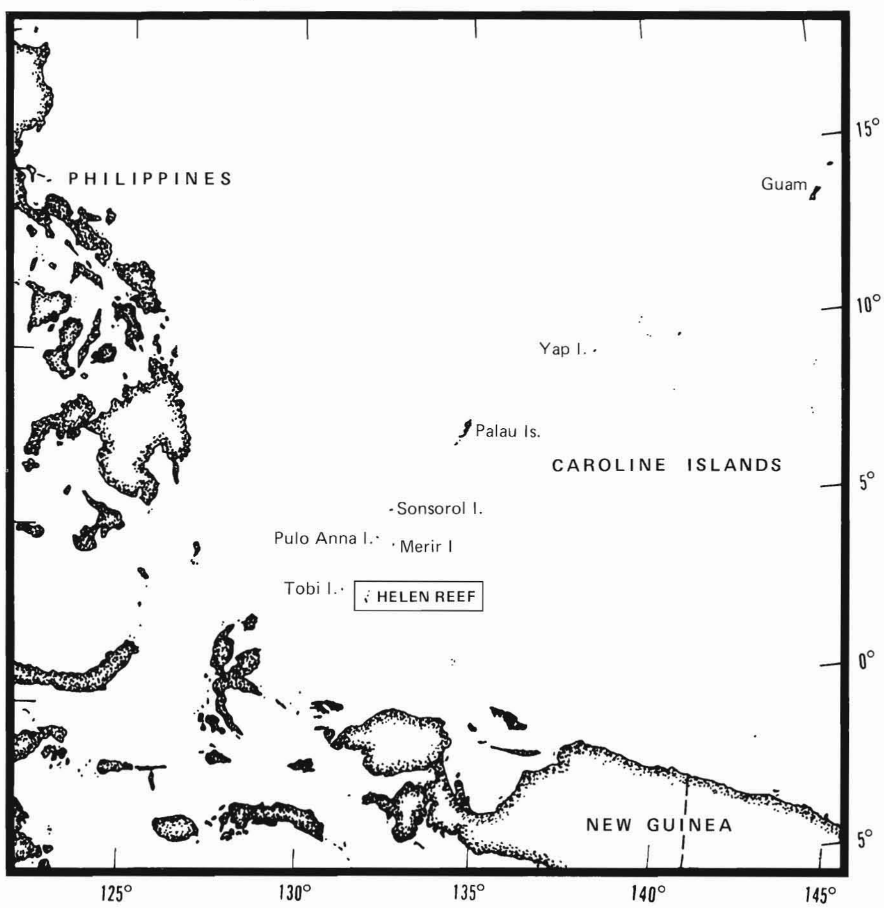
Natural History

Because of its isolation, Helen Reef at one time supported large tridacnid clam populations. In one instance, Motoda (1938) reported observing approximately 38-46 *T. gigas* within 100 m^2. Although populations have been greatly reduced over the years, all six species of the Tridacnidae family still occur on Helen Reef: *T. gigas* (Linné), *T. derasa* (Röding), *T. squamosa* Lamarck, *T. maxima* (Röding), *T. crocea* Lamarck, and *Hippopus hippopus (Linné)*. These beautiful and sometimes colossal bivalves are found only in the Indo-Pacific faunal region (Fig. 3).

The two largest *Tridacna* species are *T. gigas* (Fig. 4a) and *T. derasa*. *Tridacna gigas* is the species usually referred to as the "giant clam," as old individuals may attain lengths of up to 135 cm (about 4½ feet). They usually occur on sandy areas of the reef or in areas of coral rubble and reef degeneration, within intertidal regions to approximate depths of 20 m. Although *T. gigas* exhibits a small byssus orifice, the adults remain unattached to any substrate. The dorsal margin and ribs exhibit deep undulation. *Tridacna derasa*, also a species capable of reaching large sizes, reportedly attain lengths of 50 cm (20 inches). These clams often live towards the outer edge of coral reefs and are usually unattached, although very young individuals (<10 cm length) develop weak byssal anchors. *Tridacna derasa* appear to prefer the more shallow reef areas (approximate depth range, 4-10 m).

There are two slightly smaller tridacnids of commercial importance. *Tridacna squamosa* usually occurs on coral reef surfaces in depths less than 15 m, most often in protected environments such as reef canyons and fissures, sheltered lagoons, and marine lakes. These tridacnids are often referred to as "fluted clams" because of their characteristic broad, plate-like projections. In size, they can range up to 45 cm (over 17 inches). Although they are never imbedded, *T. squamosa* are often found nestled among coral and anchored with a weak but abundant byssus. *Hippopus hippopus* grow to 40 cm (close to 16 inches) in size and usually occur in sandy areas of the reef never more than 6 m in depth. Young *H. hippopus* attach by a weak, sparse byssus which disappears with age. These clams have heavy triangular shells and an undulating dorsal margin with very sharp, triangular, interdigitating processes.

Figure 2.—Palau District's southwest islands.



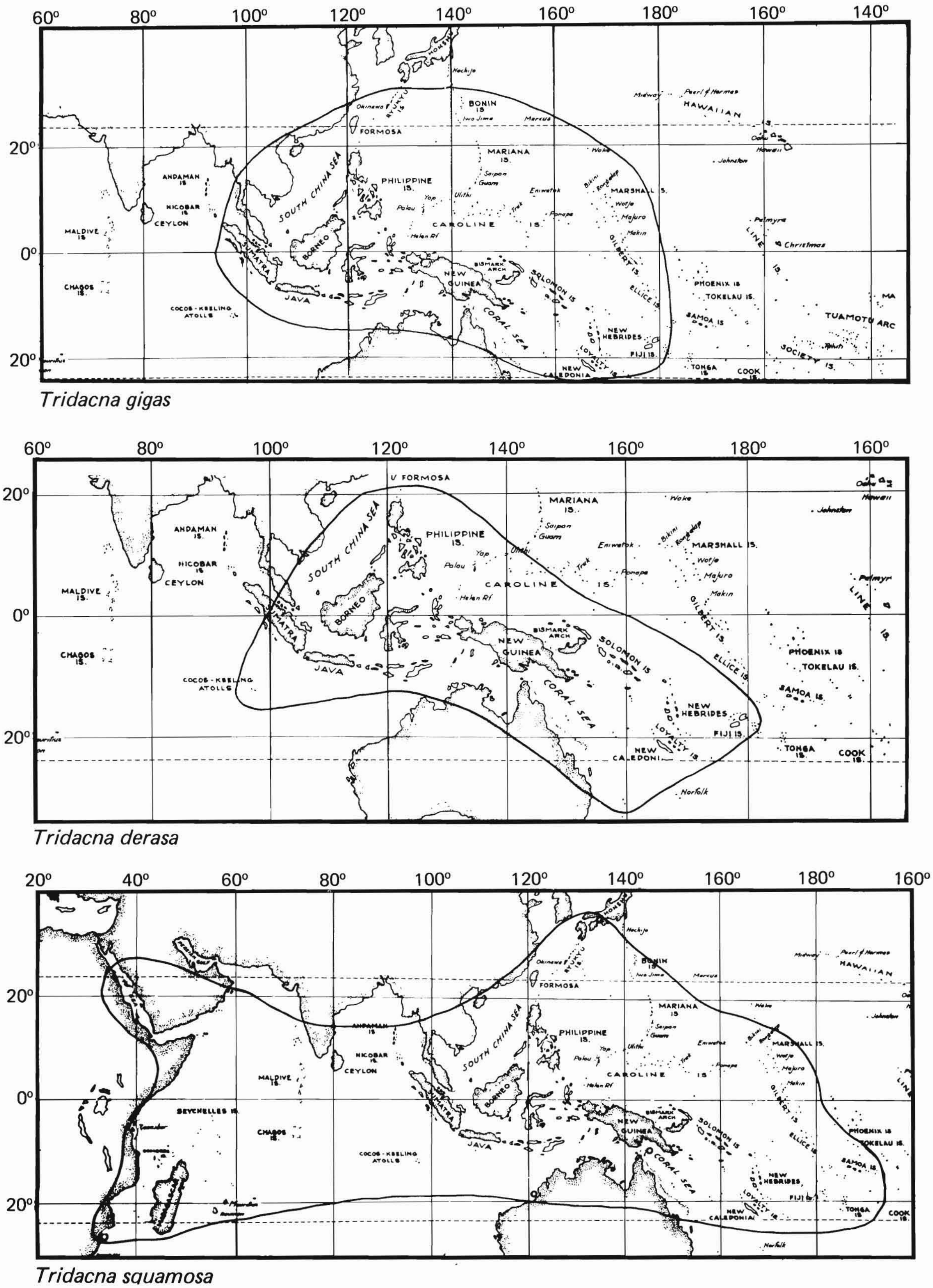
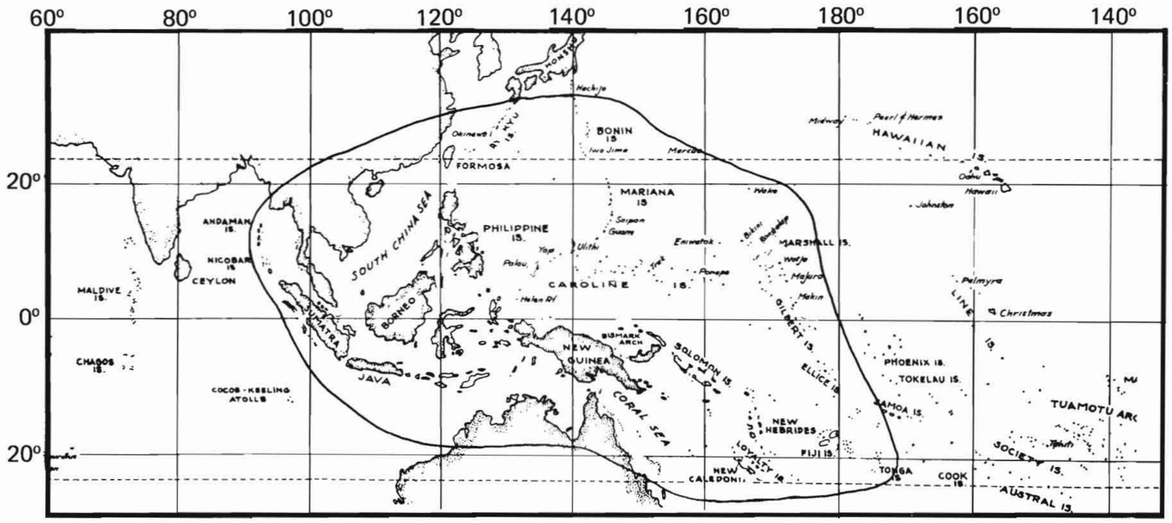
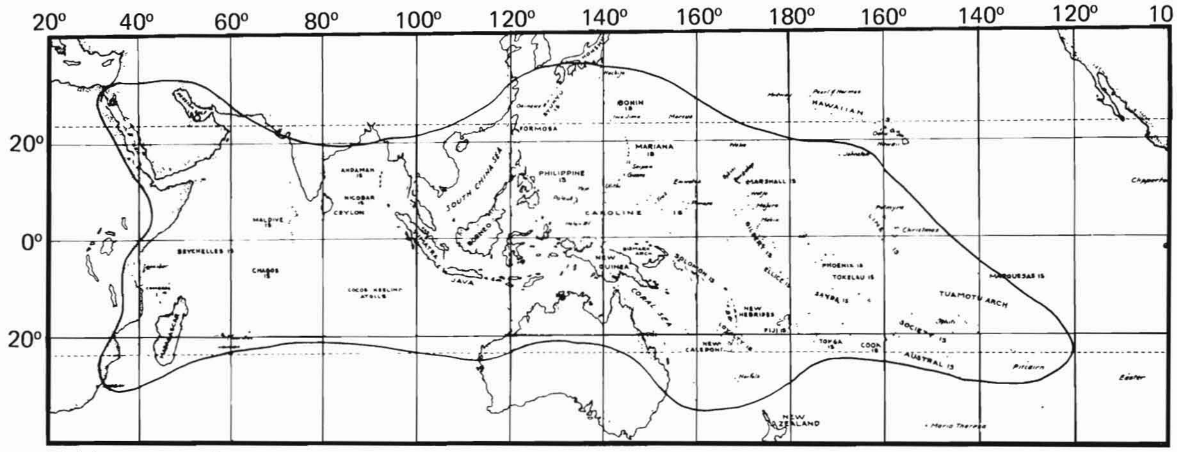


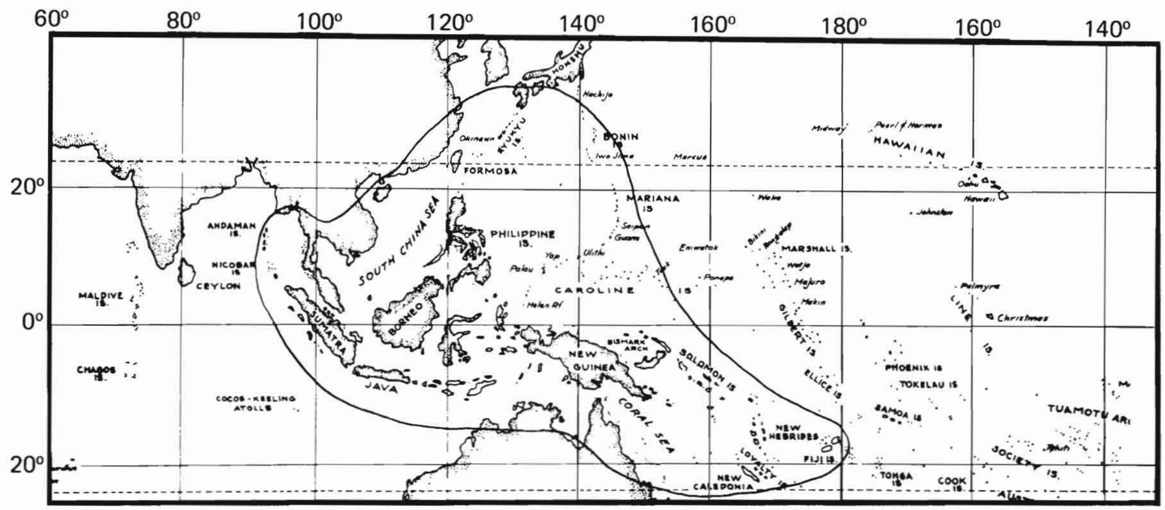
Figure 3.—Geographical ranges of tridacnid clams (from Rosewater, 1965).



Hippopus hippopus



Tridacna maxima



Tridacna crocea

Figure 3. — Continued.

Figure 4a.—*Tridacna gigas*, about 3 feet in length, on the reef at low tide.

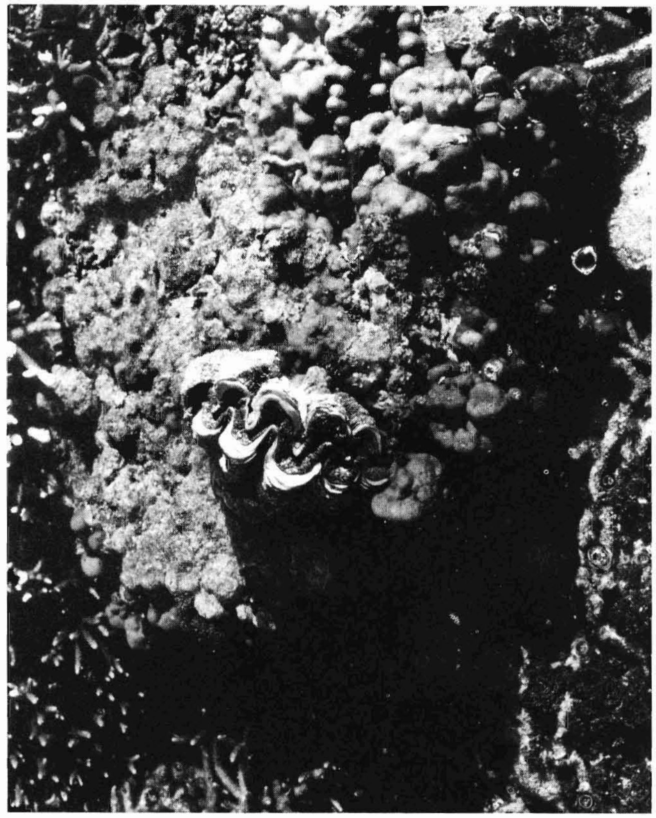


Figure 4b.—*Tridacna maxima* partially embedded in coral.

The larger *Tridacna* species are the clams which are most often utilized by Palauans and foreign fishermen. The mantle and the adductor muscle tissues are highly favored food items, the larger clams producing a higher yield per expended fishing effort. Except for a small trade as a tourist item, shells are discarded.

The two smallest species, *T. maxima* (Fig. 4b) and *T. crocea*, are not usually harvested by foreign fishermen and are minimally used for food by Palauans. *Tridacna maxima* can grow to 35 cm (close to 14 inches). It can often be confused with *T. crocea*, but *T. maxima* is distinguished by its more triangular shape; its byssus keeps it firmly anchored halfway embedded in coral and coral heads. *Tridacna crocea* is the smallest species, approximately 15 cm (6 inches maximum) and is found completely embedded in coral heads on the reef flats and reef edge, remaining firmly anchored by a byssus.

Survey Methods

Attempts were made during the May 1976 survey to duplicate, as closely as possible, sampling locations and field methods used during the 1975 survey (Bryan and McConnell, 1976). Transect lengths were determined from the U.S. Navy Hydrographic Office Chart of Helen Reef, No. 6072. The same transects as reported by Bryan and McConnell (1976) were resurveyed. The bottom depths along transects varied from approximately 6 m on the ends, to a minimum of 1 m along the midsection. Two observers were pulled slowly behind a boat while all occurrences of live or dead tridacnid clams within a 2 m wide path below the boat were recorded on plastic writing tablets. Each biologist was responsible for counting two or three assigned clam species.

Total population sizes (N_j) for Helen Reef atoll were estimated by the equation (Cochran, 1963):

$$N_j = \left[\frac{\sum_{i=1}^{n} y_{ij}}{\sum_{i=1}^{n} l_i} \right] \frac{A}{w}$$

where Y_{ij} is the number of individuals of tridacnid clam species j observed along transect i, l_i is the length of transect i, w is the transect path width (= 2 m), and A is the total reef area (= 5.34×10^7 m^2; Hester and Jones, 1974), for n total transects.

Survey Results and Discussion

During the resurvey, we were able to repeat eight transects from the 1975 survey (Fig. 5). Summary data collected from the transects are presented

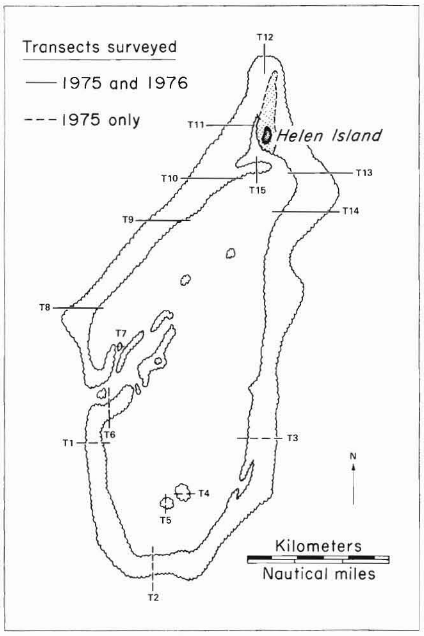


Figure 5.—Locations of sampling transects made on Helen Reef atoll, May 1976.

Table 1.—Summary of results from the 1976 survey of Helen Reef, Western Caroline Islands.

Transect	Location and direction of transect	Length of transect (m)	Area surveyed (m^2)	No. of live individuals counted	1976 Density of clams/100 m^2	[1]1975 Density of clams/100 m^2
T_8	lat. 2°54′42″N	970	1,940	3 *Hippopus hippopus*	0.20	0.10
	long. 131°45′14″E			61 *Tridacna maxima*	3.10	3.10
	270° true			— *T. derasa*	—	0.10
T_9	lat. 2°56′20″N	·970	1,940	2 *H. hippopus*	0.10	—
	long. 131°46′53″E			1 *T. gigas*	0.05	—
	270° true			2 *T. derasa*	0.10	0.10
				34 *T. maxima*	1.80	2.00
				1 *T. squamosa*	0.10	0.10
T_{10}	lat. 2°58′00″N	1,130	2,260	5 *H. hippopus*	0.20	—
	long. 131°48′16″E			47 *T. maxima*	2.10	2.00
	270° true					
T_{11}	lat. 2°59′05″N	800	1,600	7 *H. hippopus*	0.40	0.20
	long. 131°48′30″E			1 *T. gigas*	0.10	—
	270° true			1 *T. squamosa*	0.10	—
				11 *T. maxima*	0.70	2.7
T_{12}	lat. 3°00′30″N	645	1,290	26 *H. hippopus*	2.00	—
	long. 131°48′55″E			4 *T. maxima*	0.30	0.20
	0° true					
T_{13}	lat. 2°58′06″N	1,610	3,220	18 *H. hippopus*	0.60	0.30
	long. 131°49′24″E			2 *T. gigas*	0.10	—
	90° true			4 *T. derasa*	0.10	0.03
				1 *T. squamosa*	0.03	—
				106 *T. maxima*	3.30	4.30
T_{14}	lat. 2°56′30″N	1,130	2,260	1 *H. hippopus*	0.04	0.30
	long. 131°49′51″E			1 *T. derasa*	0.04	—
	90° true			11 *T. maxima*	0.50	0.20
T_{15}	lat. 2°58′00″N	480	960	1 *H. hippopus*	0.10	—
	long. 131°49′00″E			38 *T. maxima*	4.00	5.70
	180° true					

[1]Data from Bryan and McConnell (1976).

Table 2.—Stock estimates for tridacnids on Helen Reef, Western Caroline Islands.

Species	1972 Est. of standing stock[1]	1975 Est. of standing stock [2]	1975 Est. of standing stock from $T_8, \ldots, T_{15}$[3]	1976 Est. of standing stock[4]
Tridacna gigas	49.8×10^3	8.6×10^3	None observed	13.8×10^3 (4.7×10^3 – 22.9×10^3)
Tridacna derasa	32.8×10^3	12.9×10^3	14.1×10^3	24.2×10^3 (8.1×10^3 – 40.3×10^3)
Tridacna squamosa	1.2×10^3	4.3×10^3	3.5×10^3	10.4×10^3 (3.8×10^3 – 17.0×10^3)
Hippopus hippopus	44.6×10^3	47.4×10^3	70.5×10^3	217.5×10^3 (89.1×10^3 – 345.9×10^3)
Tridacna maxima	1.7×10^6	1.4×10^6	1.3×10^6	1.1×10^6 (0.7×10^6 – 1.4×10^6)
Tridacna crocea	3.7×10^6	Ubiquitous	Ubiquitous	Ubiquitous

[1]Data from Hester and Jones (1974).
[2]Data from Bryan and McConnell (1976), computed from all transects.
[3]Data from Bryan and McConnell (1976), computed from only the eight transects resurveyed in 1976.
[4]80 percent confidence limits in parentheses.

in Table 1; also included for comparison are the 1975 estimates for tridacnid population densities. In many instances, the 1975 and 1976 estimates were quite close. For each survey, the mean observed densities were expanded to provide estimates of the total populations on Helen Reef (Table 2). Because of the reduced survey size in 1976, estimates of standing stocks for 1975 were recalculated using only the eight northern transects that were resurveyed in 1976. This was done to allow a more direct comparison between the two survey results.

The 1972 estimates for the larger clams, *T. gigas* and *T. derasa*, were high compared with 1975 and 1976 estimates. These species showed a large reduction in apparent population sizes between 1972 and 1975. The apparent differences in the most recent stock estimates for *T. derasa* were relatively small and should be attributed to survey variation. Some transect variation is inevitable despite attempts to duplicate 1975 methods, which may help explain the observance of *T. gigas* in the northern transects during the 1976 survey and the absence of observation in 1975. Recruitment can also be a consideration when observing population fluctuations but the extent that apparent increases were caused by recruitment remains unknown. Table 3 presents a comparison of the ratios of live and dead individuals for the two most recent surveys. In 1976, both species still showed large numbers of dead individuals, although the proportions of dead individuals were slightly less than 1975, especially for *T. derasa*. All empty shells of *T. gigas* and *T. derasa* observed were heavily encrusted with marine organisms, displaying little evidence of recent harvesting.

Tridacna squamosa has been reported at low densities during all previous surveys. In 1972, Hester and Jones (1974) observed only one *T. squamosa*; in 1975, Bryan and McConnell (1976) counted only two individuals. These earlier investigators indicated that this tridacnid species is either very rare or not easily distinguished from *T. maxima* in this particular environment. During the 1976 survey, however, the two species were readily distinguished. Although three individuals of *T. squamosa* were identified, their densities were still low compared with all other species. *Tridacna squamosa* appears to prefer relatively protected areas, so wave exposure may be a limiting factor for *T. squamosa* at Helen Reef. Although their relatively large size would make them desirable for harvesting, since only one dead individual was observed in 1975, their population was apparently not strongly affected by this activity.

The 1976 survey showed a substantial increase in the apparent abundance of *H. hippopus*, compared with the 1972 and 1975 surveys, but the ratio of dead individuals to empty shells was still high. This species is characteristically very angular in appearance with dusky, sandy mantle tones. Their cryptic coloration makes them one of the more difficult tridacnids to count in the field, perhaps contributing to an underestimation of abundance by earlier investigators.

The most curious condition observed during the 1976 survey was the absence of large numbers of empty shells reported by Bryan and McConnell (1976). Foreign fishing boats had been observed in the area between the 1975 and 1976 surveys, possibly taking shells for the tourist market. Alternatively, heavy seas and rough weather could have broken up old shells and swept them off the reefs.

The two smallest tridacnid species have shown little variation in apparent population densities over the years. The small *T. maxima* have shown low variance in stock size, with very little variation in apparent densities from 1972 through 1976. The ubiquitous *T. crocea* was not surveyed in 1975 and 1976 because of the small size of individuals and high population densities. Large coral heads can be embedded with many *T. crocea*, and it would take much time and a more detailed sampling effort to survey this species reliably. Therefore, its presence in large numbers was only noted during the 1975 and 1976 surveys. Lack of fishing pressure may allow these smallest tridacnids to maintain a more constant population size.

Table 3.—Comparison of the number of live and dead tridacnid clams observed during the 1975 and 1976 surveys, Helen Reef, Western Caroline Islands.

	1975[1]		1976	
Species	Ratio of live: dead individuals	Percent dead	Ratio of live: dead individuals	Percent dead
Tridacna gigas	4:206	98.1	4:47	91.5
Tridacna derasa	6:168	96.6	7:24	70.8
Tridacna squamosa	2:1	33.3	3:0	0
Hippopus hippopus	22:458	95.4	63:39	38.1
Tridacna maxima	629:23	3.5	312:5	1.6
Tridacna crocea	Ubiquitous	—	Ubiquitous	—

[1]Data from Bryan and McConnell (1976).

Table 4.—Comparison of the number of live tridacnids counted in 1975 along transects in north (transects 8 to 15) and south (transects 1 to 7) regions of Helen Reef, Western Caroline Islands (from Bryan and McConnell, 1976).

Species	Live individuals counted in north reef transects	Live individuals counted in south reef transects	Percent located in north reef transects
Tridacna gigas	0	4	0
Tridacna derasa	4	2	66.7
Tridacna squamosa	1	1	50.0
Hippopus hippopus	20	2	90.9
Tridacna maxima	367	262	58.3
Tridacna crocea	Ubiquitous	Ubiquitous	—

In Table 4 a comparison was made between the numbers of live tridacnids found in north and south areas of the reef in 1975 to examine the influences of large-scale distribution on population estimates. The reef was sampled by transects 8-15 in the north and by transects 1-7 in the south. Transects 8-15 in the north correspond to the areas that were resurveyed in 1976. The percentage of clams located in the northern eight transects in 1975 was calculated for each species. There appeared to be differences among some of the tridacnids in location preference. In 1975, *T. gigas* was observed only in the south, while almost 91 percent of *H. hippopus* were found in the north. Since *T. gigas* is usually quite visible, the apparent skewed distribution may only be a product of sampling variability since only small numbers of this species were observed. It is possible that a preference for the south reef area may exist but it is impossible to verify from this survey. This apparent preference for the north reef region by *H. hippopus* would contribute to a population overestimation in the 1976 survey. Other species appeared to be relatively evenly represented in both north and south regions.

Excluding *T. maxima* and *T. crocea* because of their lack of value to foreign fishermen, less than half (43.6 percent) the tridacnid clams observed on Helen Reef in 1975 were alive. In 1976, the conditions were much the same with only 40.1 percent of the clams surveyed alive. In natural reef environments, it is unusual to see so many empty shells unless fishing pressures have been high. Large percentages of empty shells have been observed following concentrated fishing activities (Motoda, 1938; Bryan and McConnell, 1976). Because of the lack of fishing pressure on the smaller species, perhaps *T. maxima*, and maybe *T. crocea*, indicate the normal ratios of live to dead individuals representative of tridacnid populations subject only to natural sources of mortality.

In May 1976, the effects of recent harvests were evident at Helen Reef with tridacnid populations reduced from much higher levels of abundance (Motoda, 1938; Hester and Jones, 1974). The conditions of the clam resources observed in 1976 emphasized the need to prevent their further uncontrolled harvesting, especially since most of the clams observed in 1976 appeared smaller than the mean sizes reported in 1972 (Hester and Jones, 1974). Because the recruitment of tridacnid clams appears to be slow and irregular, large population depletions could have serious long-term effects. Wada (1952, 1954) suggested that because of the nature of spawning behavior in tridacnid clams, self-fertilization rarely occurs. Other observations have also shown no normal larval development after attempts at self-fertilization. If this is the case, then there may be some minimum threshold density from which reduced populations would be unable to recover.

Harvests of tridacnid clams from Helen Reef should continue to be restricted until increases in stock abundances have been observed and documented. Additional research is needed to determine allowable clam harvest levels, threshold densities, and stock recovery rates.

Acknowledgments

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