

Assessment of the trochus resources of Pohnpei Island in June 2008 and recommendations for management

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1. Introduction

1.1 General Overview

Pohnpei is the capital state of Federated States of Micronesia (FSM), located in the Micronesian region between Marshall Islands and Palau. FSM is divided into four separate states: Chuuk, Yap, Kosrae and Pohnpei. Formerly part of the United Nations Trust Territory of the Pacific Islands, FSM adopted a constitution in 1979. Independence was achieved in 1986 under a Compact of Free Association with the United States. The financial terms of the new, 20-year compact (2004–2023) aim to encourage sustainable development. Present population stands at about 108,000 people, mainly Micronesians. Chuuk is the most populous state with 48.8% of total population, while Pohnpei has 24.2% of the population, Kosrae 6.2% and Yap 5.2%. Each of the four states is seen as a separate island country, with different cultural and ethnic characteristics due to their vast separation by ocean.

The state of Pohnpei consists of the main island of Pohnpei and eight outer atolls: Mwoakiloa, Ngatik, Nukuoro, Oroluk, Pingelap, Kapingamarngi, Sapwuafik and Ant. These outer atolls form six municipalities in Pohnpei State in addition to the other six in Pohnpei proper: Sokehs, Nett, U, Kitt, Madolenihm and Kolonia (<http://en.wikipedia.org/wiki/Pohnpei>). Pohnpei proper is the largest island in Micronesia. It is mountainous with an annual rainfall >194 inches, making it one of the wettest places on earth. The island's rugged topography and limited lowlands areas limit any medium- to large-scale agricultural activities. Pohnpei State hosts both FSM's main urban centre, Kolonia and the capital city, Palikir. At the 2000 census, the total population of Pohnpei State was estimated to be 34,486 people, 93% of whom live in Pohnpei proper. Residents from the other states and immigrants workers also live and work in Pohnpei (<http://www.fsmgov.org/info/people.html>).

Agriculture and fishing are the principal economic activities on Pohnpei proper providing 84% of employment in 2000. Produce such as breadfruit, banana and taro are common. Kava is grown and eaten in Pohnpei; and kava juice or *sakau* drinking is a growing industry amongst the locals. The influx of larger amounts of American aid money under the Compact of Free Association has seen increasing amounts of imported foods. Locally grown foods account for only 27% of the average indigenous diets, the rest of the demand is satisfied by imported processed foods. About 30,000 FSM nationals live abroad in the US mainland and in Hawaii, Guam and Saipan; these nationals contribute remittances to the local economy but information on this is not well documented.

Fishing is an important activity for the people of Pohnpei. Over 120 reef fish species inhabiting the waters of Pohnpei are edible. Fishing within the lagoon areas is done at day and night using a variety of fishing techniques including nets, spears, hooks and lines (<http://www.everyculture.com/Oceania/Pohnpei-Economy.html>). Mid-water longlining for yellowfin tuna is practised off the northeast barrier reef at an upwelling zone. Surplus catch is sold at Kolonia market, while the rest supplies subsistence needs.

Invertebrate fisheries include trochus, giant clams, sea cucumbers and cockle shells. Trochus and sea cucumber are exclusively commercial fisheries and trochus is important in Pohnpei, Moakiloa and Sapwoafik islands, where the species were introduced. Pohnpei Island produces much of the State's trochus catch from its large

reef area. Fishing is tightly controlled by the state government and when the season is open, trochus fishing provides the communities with a rare, one-off opportunity to earn cash income (Dave Mathias, pers. comm. 2008).

1.2 Trochus fisheries in Pohnpei

Trochus introduction

The commercial mother-of-pearl topshell (*Trochus niloticus*) does not naturally occur in most islands in FSM except the main island of Yap (**Figure 1**). Historically, trochus was introduced to FSM when shells were introduced to Chuuk Lagoon from Palau in 1931 (Asano 1991). However, the Japanese administration introduced trochus shells to Chuuk earlier than 1927. According to Mr Benito Nero, Mayor of Piis-Panewu (pers. comm. 2006), some of the shells from Rabaol Province in PNG (perhaps stolen there) were transported to Chuuk by cargo ship, earning it the name *Rabaol Moat* meaning *Rabaol shell* in the Chuuk language. The main introductions to Chuuk were from Palau. Trochus successfully spread over Chuuk lagoon reefs and developed into a fishery. Chuuk later supported major introductions to Pohnpei in 1939, along with Palau and Yap.

The introduction of trochus to Pohnpei was first attempted sometime before 1927, but was unsuccessful (McGowan 1957). In 1930, trochus from Palau and Yap were introduced to several sites in the Caroline Islands, including Pohnpei's outer islands of Ngatik, Mwoakiloa, Kapingamarangi and Nukuoro. Another attempt made in 1938 with stock from Chuuk lagoon successfully established in Sapwuafik and Mwoakiloa Atolls (McGowan 1957). Then, in 1939, two shipments of 6700 shells from Chuuk lagoon were released on the south and west barrier reefs of Pohnpei Island by the Japanese administration (Asano 1991). Perhaps this same 1939 shipment to Pohnpei was recorded by McGowan (1958) to be from Palau. In 1959, trochus from Pohnpei were transplanted to Kosrae, Pingalap and again to Nukuoro and Kapingamarangi (Gawel 1982).

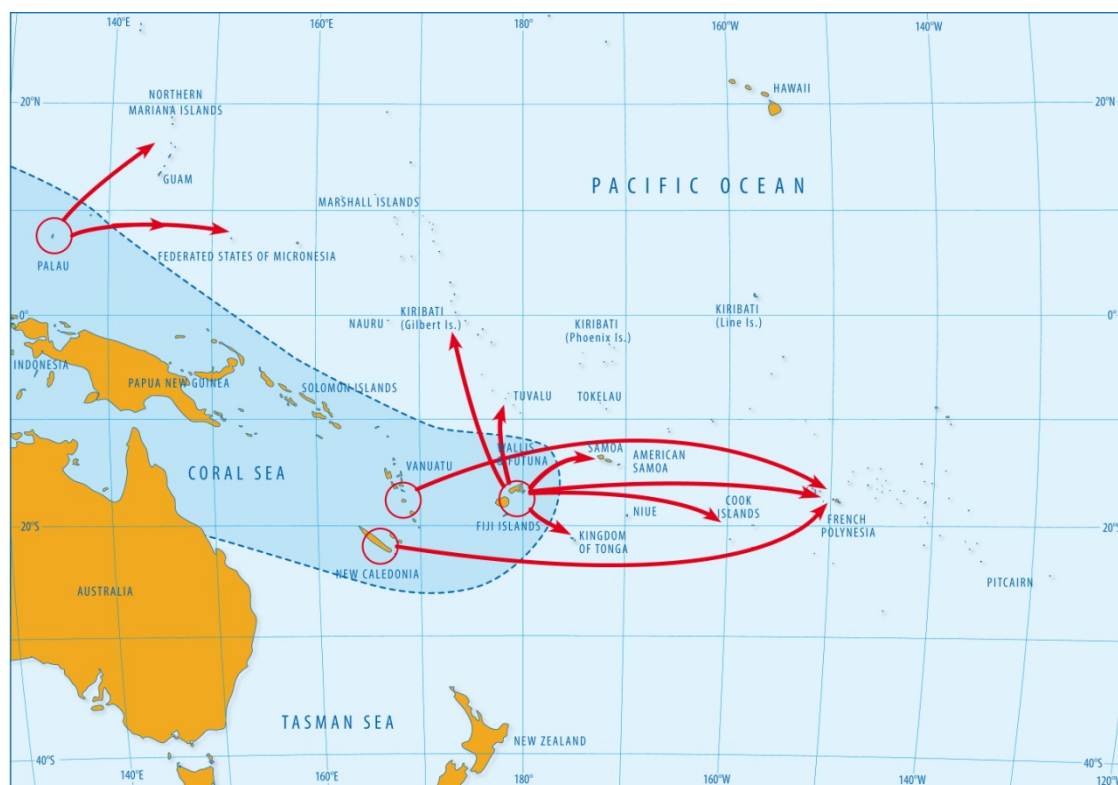


Figure 1 : Natural distribution of *Trochus niloticus* in the Pacific Ocean (dark blue) and main introduction (red arrows)

Biology and ecology of trochus

The average life span of trochus is 15–20 years. Most animals reach reproductive maturity by 2 years of age in the wild and 12 months in captivity. The size at which trochus become sexually mature has been found to be 5–6.5 cm in diameter. Lacombe (1993) found growth rates for animals 10–14 cm in size to vary between locations, with a general trend for smaller shells to be found on southern reefs. Trochus are dioecious (separate male and female) broadcast spawners and fertilisation takes place in the water column. Spawning is initiated by the males, and females spawn in response to the presence of sperm in the water. Females generally spawn for 5–10 minutes, with individuals releasing more than one million eggs (Nash 1985).

Spawning often occurs in synchrony with lunar or tidal conditions, generally occurring at night and within one or two nights of either full or new moon (Nash 1985). Spawning occurs throughout the year in low latitudes and only during the warmer months in high latitudes (Nash 1985). In the central Great Barrier Reef region, spawning occurs throughout the year. After they have been fertilised, the eggs hatch into trochophore larvae (planktonic phase) after approximately 12 hours. The larval phase lasts approximately 3–5 days and the veligers then settle onto the reef substrate and begin grazing on fine filamentous algae and microorganisms (Nash 1985). Trochus adults are largely non-selective herbivores, grazing the epibenthos of a wide variety of biotic and abiotic materials, including algae, foraminifera, molluscs and crustaceans. Small-to-medium size shells are cryptic, while larger specimens are less cryptic and visible on the reef.

Trochus fishery in Pohnpei

The trochus fishery became active at different time periods in FSM and may have begun much earlier in Yap than in the other states of FSM. From 1985 to 1994 FSM production was high on average, with 206 metric tonnes (mt) per year. FSM then became the fifth most important trochus-producing country in the Pacific Islands region, among the larger Melanesian islands (World Bank 1997). Export of unprocessed shell remains the preferred option in these remote islands, where processing factories are not an option. Information on recent production is lacking but it is likely to have fallen below the 80s and the 90s level.

In Pohnpei, the fishery began in 1948, when the first open season was made (9 years after the first recorded successful introduction). A total of 84 mt of trochus was produced in the first harvest. From 1948 to 1956 an average of 87 mt of trochus was produced annually, with the first highest production of 170 mt (McGowen 1958; Asano 1991). The fishery may have been closed for 11 years from 1957 to 1968. From 1969 up to 2005, a total of 19 annual open seasons were made, producing an average of 94.6 mt/year of trochus, ranging from 27 mt in 1976 to 192 mt in 1988. The overall average production from 1948 to 2005 was 93.3 mt/year (**Figure 2**). Existing records did not indicate productions from outer islands except for in 2001 and 2005; thus it is likely that outer island catch data may have been lumped together with Pohnpei Island data.

Trochus fishing anywhere in FSM waters is open to all FSM nationals, meaning that other nationals from other States living in Pohnpei can fish for trochus during an open season (Dave Mathias pers. comm. 2008). Prior to harvest, a resource survey is conducted by the Division of Marine Resources, from which an allowable quota is determined. The quota normally allocated for fishing is calculated as 50% of the existing stock, which is determined by a resource survey (Donald David pers. comm. 2008). Several interested buyers would place their bid to buy the shells with the Head of the Division of Marine Resources. A committee comprising members from Fisheries Department, Environment Department, and Attorney General's Office would meet to endorse an open season and, in the process, select the best bidder to purchase shells during harvest.

The best bidder normally gets the licence to buy and export the shells (Dave Mathias pers. Comm. 2008). Local shell price is the main part of the bidding package. The highest price sought was ~ \$3–4/kg in 1992. The price paid in 2004 was lower at \$2.87/kg (\$1.30/lb) in Pohnpei and in 2005 was at \$3.64/kg (1.65/lb) for shells from Sapwuafik Atoll. Shells from Sapwuafik fetch more because they are of superior quality to those from Pohnpei proper. These prices (\$2.87–3.64/kg) are roughly the same as offered currently in other Pacific Island countries.

As in other island countries, attempts in the 1990s to process trochus locally into button blanks were not viable due to high costs and irregular supply (Gillett and Gaudechoux 2001). Raw shell export remains the best option for the islands of FSM but current export prices of shells are not available from exporters.

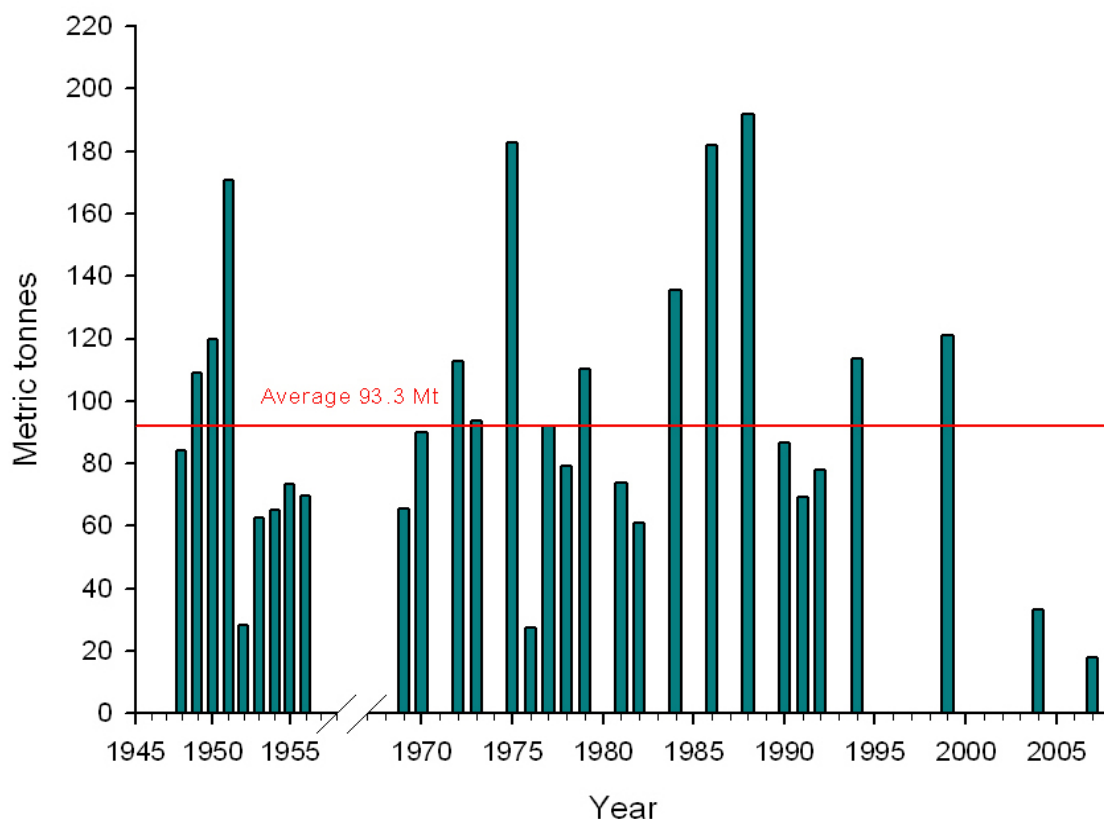


Figure 2 : Historical trochus production for Pohnpei, FSM. (Source: Pohnpei Marine Resource Development Division). (2007 data is from Sapwafik island and unpublished data from Pohnpei proper in 2006 is 200 mt)

Management of the trochus fishery

Coastal fisheries and aquaculture are under the state government's jurisdiction in FSM as oppose to oceanic fisheries, which are under the national government. Traditional ownership and management of reef resources remain strong and are still practised in Yap and, to certain extent, in Chuuk; however, these no longer recognised in Kosrae and Pohnpei (SPREP 1993).

Coastal fisheries management in Pohnpei State is under the jurisdiction of the Marine Resource Division (MRD) of the Department of Resource Management and Development. During this survey, the fisheries management role was in the process of being moved to the Forestry and Conservation Division under the new arrangement. A total of 16 trochus sanctuaries were established on the barrier reef around Pohnpei Island to protect spawning stocks and recruitment (McGowen 1958). However, management of these sanctuaries is proving to be a challenge for the local Fisheries Division. Seven of these trochus sanctuaries were effectively enforced in 1988 and these seven remain active today (Curren 1988). An additional five MPAs were set up in the 1980s to protect fish spawning aggregations; these MPAs also protect trochus stocks.

The length of each open season is decided by a committee. Earlier open seasons were 2–3 weeks long, but have been shortened to 6–9 hours nowadays in response to the increased number of fishers. Increasing mobility of people, both on the land and at sea, has also given fishers access to more fishing grounds than in the past. Monitoring during the open season is part of the MRD role to control fishing activities and legal shell sizes. A prior size limit recommended by Curren (1988) was 3–5 inches or 7.6–12.7 cm. In the existing size regulation, the lower size limit is 3 inches (7.6 cm) and the upper size limit is 4 inches (10.2 cm), a reduction of one inch from Curren's upper size limit recommendation.

Past trochus stock assessments

Before 1985, trochus surveys were done simply through observation by skin divers. Trochus abundance was then quantified visually and described as 'many', 'few' or 'none'. Scuba diving, size measurement and actual trochus counts only began after 1985, using a 100-metre transect. In 1994, the joint project by FSM Government, Pohnpei State, and Overseas Fishery Cooperation Foundation of Japan (The PIReM Project) was implemented, with the aim of developing appropriate management guidelines for the Pohnpei trochus fishery. Assessment surveys from 1994 to 1999 were made in 7 reef zones from back reef to outer reefs of the barrier reef, in passages reefs and in reef patches in the lagoon. Comparison was made between MPAs and trochus sanctuaries, and open-access reefs. Results of these assessments are presented in unpublished project progress reports (Hakamata and Moses 2000). The last assessments from 1999 estimated the total number of trochus at 935,300 specimens in the open reefs and 362,745 specimens in the MPA/trochus sanctuaries; the mean size was 8.8 cm. It was then recommended that total production for Pohnpei Island should not exceed 100 short tons/year (91 mt/year) and harvestable size be 3–4.5 inches (Hakamata and Moses 2000).

Current situation

Trochus fishing is currently closed on Pohnpei proper as well as on the other three islands since the last harvest in 2004 (Donald David pers. com. 2008). Beside these isolated incidences, there is an overall need to assess the trochus resources across the four States of FSM to obtain information on the current status of the resource for management purposes.

2. Purpose of the survey

This assessment survey was officially requested by the national government of Federated States of Micronesia in 2007 to conduct trochus resource assessments and training of local officers in both Pohnpei and Kosrae States. The mission therefore was to conduct a resource survey for trochus to give a post-harvest snapshot of the resource, which can be used to develop management guidelines for the fishery. Secondly, the mission was to train the local team in the two States on the regional standardised surveying protocol for future monitoring activities.

In response, two reef fisheries officers from the PROCFish/C programme were sent to FSM during in June 2008. Fieldwork was completed between 11 and 19 June in Pohnpei. Similar types of surveys had previously been conducted at two sites each in Chuuk and Yap under the PROCFish Project, and information on the invertebrate resources of those sites is now available on the following SPC web page:

(http://www.spc.int/coastfish/sections/reef/PROCFish_Web/Countries/CountryReport.aspx?CountryCode=FM). Similar information from Pohnpei will add to the existing data to present the status level for invertebrate fisheries in FSM.

Importantly, this survey will provide an indication of the current status of resources, since the yearly surveys conducted between 1996 and 1999 by the FSM Government, the Pohnpei State Government and the Overseas Fishery Cooperation Foundation (OFCF).

3. Survey site

Pohnpei Island (**Figure 5**) is surrounded by barrier reefs, lagoons and patch reefs. A well developed reef system comprising mangrove forest, extensive fringing reef and sea grass beds, lagoon and barrier reef exists in Pohnpei. An extensive barrier reef about 3km offshore encircles much of the island with some 15 passage breaks. In the lagoon encircling most of the island are numerous patch reefs. Trochus are found on the barrier reef, mainly at the outer slopes and reefs inside passes where suitable habitat exists. Seaward reef shelves of the barrier reefs are extensive enough (around 100 m) with steep slopes dropping off to abyssal depths commencing at ~10–15 m. The reef flats behind the crests were scattered with large boulders and coral rubble which were exposed during low tides. Limestone substrates covered with crustose coralline algae were prevalent. Spur-and-groove systems were apparent but surface topography was rather simple along the western barrier reef.

4. Survey design and methodologies

The original aim was to survey a relatively large proportion of the trochus habitat around the island of Pohnpei and collect as many records as possible to understand distribution, abundance and density of trochus. Invertebrate resource survey protocols

used by PROCFISH/C were adopted to assess presence, abundance, distribution and size characteristics for trochus. Although trochus was the focus of this assessment, other invertebrate species, including sea cucumbers and giant clams, were recorded. Layout of stations covered both inside and outside the MPAs and trochus sanctuaries to provide contrast and to assess the condition of the protected areas. Four main survey protocols were adopted: timed swim searches along the reef front areas (RFs); shallow-water reef-benthos transects (RBt); mother-of-pearl transects (MOPt) and mother-of-pearl searches (MOPs). These protocols are described in more detail in the following sections;

Reef front search (RFs) or timed swim

Reef-front searches (RFs) or timed swims were performed by snorkeling along the reef front just behind the swells (usually only conducted if swell conditions permit) where trochus (*Trochus niloticus*); green snail (*Turbo marmoratus*) and the surf redfish (*Actinopyga mauritiana*) generally aggregate (Figure 3). Two observers snorkelled side-by-side, separated by 10–15 m and each observer counted and recorded the abundance of conspicuous sedentary species observed on the way (focusing on trochus, surf redfish, clams and other gastropods) during three 5-minute search periods each (6 replicates for a total of 30 minutes search). The start and end positions of each RFS station swim were recorded on a GPS. Using MAP INFO the swim distance can be calculated although it varies among stations, depending on wind, current and wave conditions. Observation from the surface can also vary with depth and visibility, and this technique is used to give only a general indication of resource status, not to give precise density data.

Mother of pearl transects (MOPt)

Mother-of-pearl transects (MOPt) were conducted on SCUBA by two divers along three 40 m transects (of 2 m swathe) parallel to the reef edge in depths not greater than 15 m. In most cases, the depth range was 2–6 m, although depths reached 12 m at some sites where more shallow-water habitat or stocks could not be found. In cases where the reef dropped off steeply, more oblique transect lines were followed. On MOP transects, a hip-mounted chainman® measurement system (thread release) was adopted to measure out 40 m transects. This leaves the diver's hands free and saves time and energy in retrieving the tape in the often dynamic water conditions where *Trochus niloticus* were found. Invertebrates observed within a 2 m swathe were measured and recorded, but particular attention was paid to mother-of-pearl species (Figure 3).



Figure 3 : Pelson Moses measuring a trochus shell on a MOPt station. Note the stringline used to measure the distance of a transect.

Reef-benthos transects (RBt)

Reef-benthos transects were conducted in relatively shallow water areas (0.5–1 m deep), which were representative of the habitat suitable for trochus. Six 40 m transects (1 m swathe) were examined per station by two observers snorkelling either side of the transect line and recording epi-benthic invertebrates within each transect. These included sea stars, sea urchins (as potential indicators of habitat condition), and gastropods, including trochus, sea cucumbers and clams. Transects were randomly positioned, but laid across environmental gradients where possible (usually across reefs and not along reef edges). A single waypoint was recorded for each station (to an accuracy of ≤ 10 m) and habitat recordings were made for each transect. Figure 4 shows the surveys implemented by the PROC-Fish/C programme for all invertebrate species and indicate survey types in different reef zones. The numbers 2, 5, 6, and 7 in Figure 4 denote typical trochus surveys.

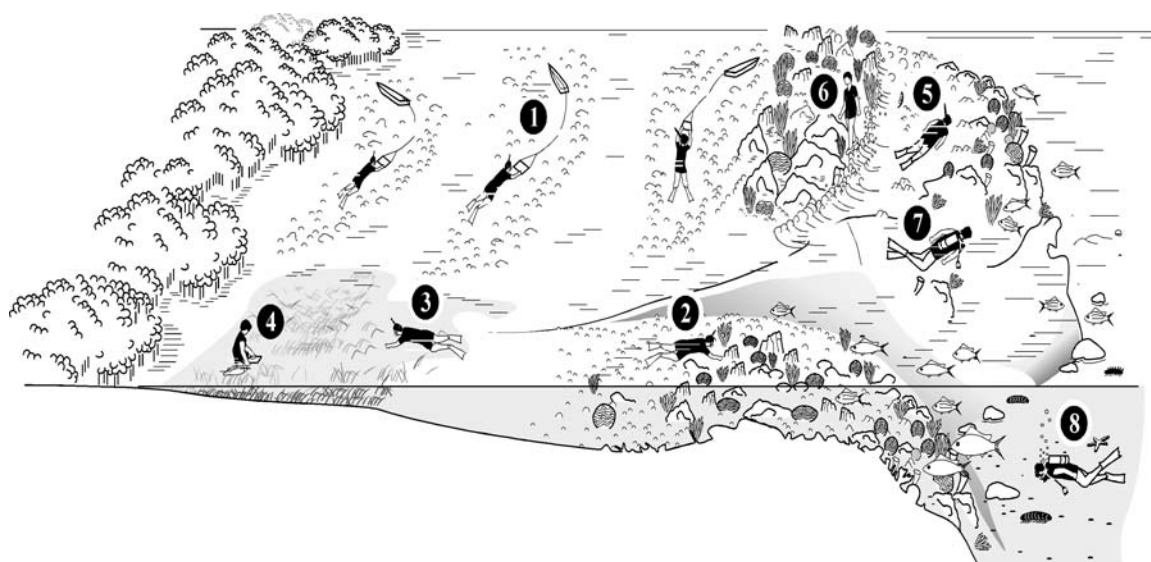


Figure 4 : Invertebrate survey techniques used by PROCFish/C. Surveys specific to trochus resource are: 2 – Reef-benthos transects (RBt); 5 – Reef-front searches (RFs); 6 – Reef-front search walk (RFSw); and 7 – Mother-of-pearl transects (MOPt) and mother-of-pearl searches (MOPs)

Actual position (longitude and latitude) of the sampling stations (one waypoint for an RBt station, and 2 waypoints for a RFs and a MOP station) were logged at 10 m accuracy using GARMIN GPS 72 (GARMIN Corporation 2002). GPS position data are important in estimating coverage areas for timed search stations using MAPINFO and for future monitoring purposes. Records include species counts, sizes, site name, date and environmental parameters, including descriptors such as relief and complexity, depth and substrate composition. Substrate composition is recorded as percentage of coverage type including fleshy algae, crustose coralline algae, sea grass, soft corals and hard corals. Data were recorded on a standard underwater record sheet.

Stock estimation and basic tools for management

The translation of resource assessment results into management advice is always difficult. Estimation of the stock of trochus per area provides a clearer indication on the potential of the fishery and forms a basis for management guidelines. Trochus stock on Pohnpei has been estimated based on data from the 1996–1999 trochus survey (Hakamata *et al.* 2000). This current survey uses the main area zones determined from the 1996–1999 surveys on the outer barrier reef to formulate a comparable stock estimate.

Several rules of thumb have been developed over the years to deal with translating survey results into management advice. Several sustainable levels for trochus have been set, for example McGown (1957) reckoned that a density of 600–800 shells per hectare constitutes a dense population. In Aitutaki in Cook Islands, a harvest season is declared when surveys show that the population exceeds 600 trochus per hectare (Nash *et al.* 1994). Based on these rule-of-thumb figures, a density of 500 shells per hectare is recommended (by PROCFish/C) as a minimum threshold density below which fishing would not be allowed but that would allow sufficient stock to be available to replenish the resource. This threshold density will be used in determining trochus stock level for Pohnpei.

5. Results

5.1 Coverage and general recordings

A fair proportion of the islands barrier reef system of Pohnpei was surveyed. Habitats covered included outer-reef flats, passages and shoal of the outer slope of the barrier reef within and outside MPA/trochus sanctuaries. To estimate the efficiency of MPA/trochus sanctuaries, sampling stations were completed in 6 of the 7 recorded protected areas (The smallest area was not surveyed due to bad weather and sea conditions.). In total, 65 stations of SCUBA transects (MOPt), timed swims (RFs) and belt transects (RBt) were completed as shown on the survey station coverage map; 24 stations were completed inside MPAs/trochus sanctuaries and 41 stations at the open reefs (**Table 1** and **Figure 5**). One RBt station surveyed inside the lagoon (outside the targeted habitat) held no trochus and was therefore excluded from the analysis. The surface area covered in this survey is >128,000 m², which is much larger than the areas covered by the yearly surveys made between 1996 and 1999, which covered 10,000 m² (with 50 transects of 200 m²) (Hakamata and Moses 2000).

Table 1 : Number of sampling stations and reef area coverage at Pohnpei

Site	Survey method	Stations	Replicate measures	Surface covered (m ²)
All Pohnpei	Reef benthos transects	15	90 transects	3600
	Reef benthos transects *	14	84 transects	3360
	MOP Trochus transects	24	144 transects	11520
	Reef front searches	26	156 search periods	112938
Open reef areas only	Reef benthos transects	7	42 transects	1680
	Reef benthos transects *	6	36 transects	1440
	MOP Trochus transects	17	102 transects	8160
	Reef front searches	17	102 search periods	77786
MPA/trochus sanctuaries only	Reef benthos transects	8	48 transects	1920
	MOP Trochus transects	7	42 transects	3360
	Reef front searches	9	54 search periods	35153

*RBt stations made on the same habitat (reef outside the barrier reef or on the side of the passage), excluding the single RBt station made inside the lagoon (back-reef north of Pohnpei).

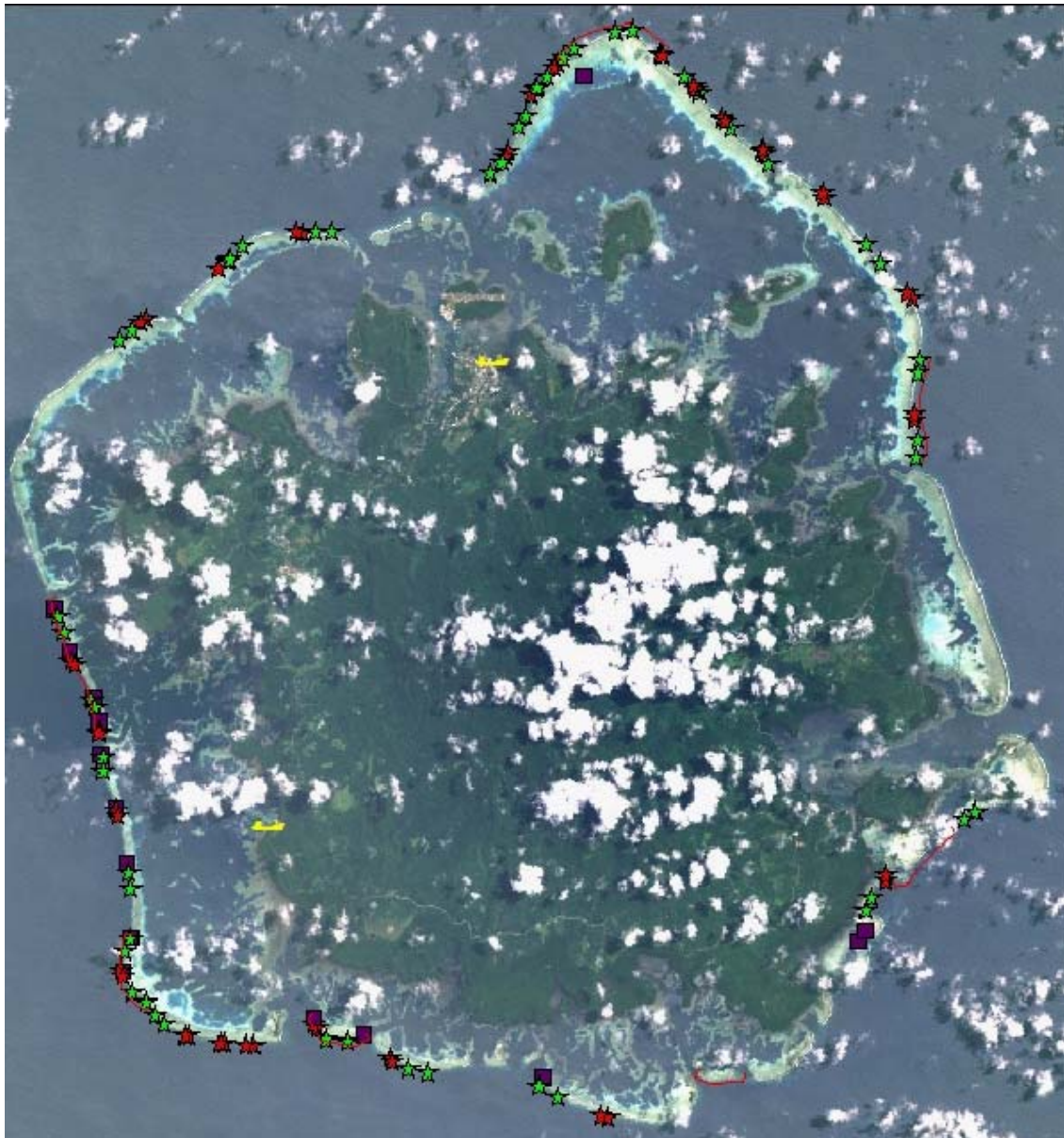


Figure 5 : Survey station coverage at Pohnpei. Green stars: RFS stations (swim); Red stars: MOPT stations (SCUBA); Purple squares: RBt stations (swim); Red line: delineation of trochus sanctuary or MPA; Yellow boats: mooring places.

5.2 Number of invertebrate species recorded

A total of 35 species or species groupings of invertebrate of interest (groups of species within a genus) were recorded in the Pohnpei invertebrate surveys. Among these were: 2 bivalves, 15 gastropods, 9 sea cucumbers, 2 urchins, 5 sea stars, 1 cnidarian, 1 crustacean and one cephalopod. Information on key families and species is detailed in **Appendix 1 to 5**.

5.3 Trochus presence, distribution and density

Trochus were numerous and found at all reef locations around Pohnpei (total $n = 1932$ individuals recorded). In Pohnpei, trochus does not occur in the typical horizontal pattern of distribution usually observed for this species, which usually shows low-density areas between high-density aggregation areas. Here, the species is recorded everywhere along the ocean side of the barrier reefs. Presence of trochus is high with

100% of stations holding trochus. In MPAs, 80%, 81% and 79 % of RBt, RFs and MOPt replicates respectively are holding trochus, while these proportions at open reefs are 86%, 83% and 89%. In the density distribution map (**Figure 8**), more trochus were recorded in the south than in the north of the island. Specifically, high aggregations were found at the whole outer barrier reef of Kitti Municipality, at the southern part of Madolenihmw, the southern barrier reef of Sokehs and the whole barrier reef of Nett Municipality.

The two most important assessment types in this survey are the transect belt stations RBt and MOPt, as they allow precise density calculations unlike time-period stations (RFS) which allow a global understanding of the distribution. Before fishing is recommended, a threshold density of ≥ 500 trochus/ha is required, as explained above.

At open reefs, the average trochus densities recorded in RBt and MOPt assessments were well above this limit with respectively 840.3 ± 180.5 SE and 699.8 ± 112.5 SE trochus/ha. Areas assessed by RFs held a much lower density of 98.4 ± 21.7 trochus/ha. Inside the MPA/trochus sanctuaries, trochus density for RBt stations was high on average, at 911.5 ± 241.6 SE trochus/ha, whereas density for MOPt assessment was lower at 327.4 ± 128.2 SE trochus/ha. Densities for RFs stations were again rather low at 114.1 ± 48.4 trochus/ha on average (**Table 2**).

Table 2: Presence and mean density of trochus (individuals per ha, $\pm$ SE) targeted assessments (Reef benthos transects, reef front searches, MOP transects).

Site	station type	Density	SE	% of stations with species	% of transects or search periods with species
All Pohnpei	RBt	822.2	154.1	14/15 = 93	70/90 = 78
	RBt *	881.0	153.1	14/14 = 100	70/84 = 83
	RFs	103.8	21.4	26/26 = 100	129/158 = 82
	MOPt	591.1	93.5	24/24 = 100	124/144 = 86
Open areas	RBt	720.2	194.1	6/7 = 86	31/42 = 74
	RBt *	840.3	180.5	6/6 = 100	31/36 = 86
	RFs	98.4	21.7	17/17 = 100	86/104 = 83
	MOPt	699.8	112.5	17/17 = 100	91/102 = 89
MPA/trochus sanctuaries	RBt	911.5	241.6	8/8 = 100	39/48 = 81
	RFs	114.1	48.4	9/9 = 100	43/54 = 80
	MOPt	327.4	128.2	7/7 = 100	33/42 = 79

*RBt stations made on the same habitat (reef outside the barrier reef or on the side of the passage), excluding the single RBt station made inside the lagoon (back-reef north of Pohnpei).

Furthermore **Table 3** and **Error! Reference source not found.** show that 14.3% of the MOPt stations and 75.0% of the RBt stations but none of the RFs stations in MPA/trochus sanctuaries were above the threshold density. Densities were surprisingly lower than observed on the open reef areas (**Table 3** and **Figure 7**).

Table 3 : Percentage of stations containing trochus over the threshold density of 500 specimens per ha

Station type	MOP transect with >500 individuals/ha	Reef benthos transect with >500 individuals/ha	Reef front search with >500 individuals/ha
All Pohnpei	11/24 = 45.8	11/14 = 78.6	0/26 = 0
MPA	1/7 = 14.3	6/8 = 75	0/9 = 0
Open areas	10/17 = 58.9	5/6 = 83.3	0/17 = 0

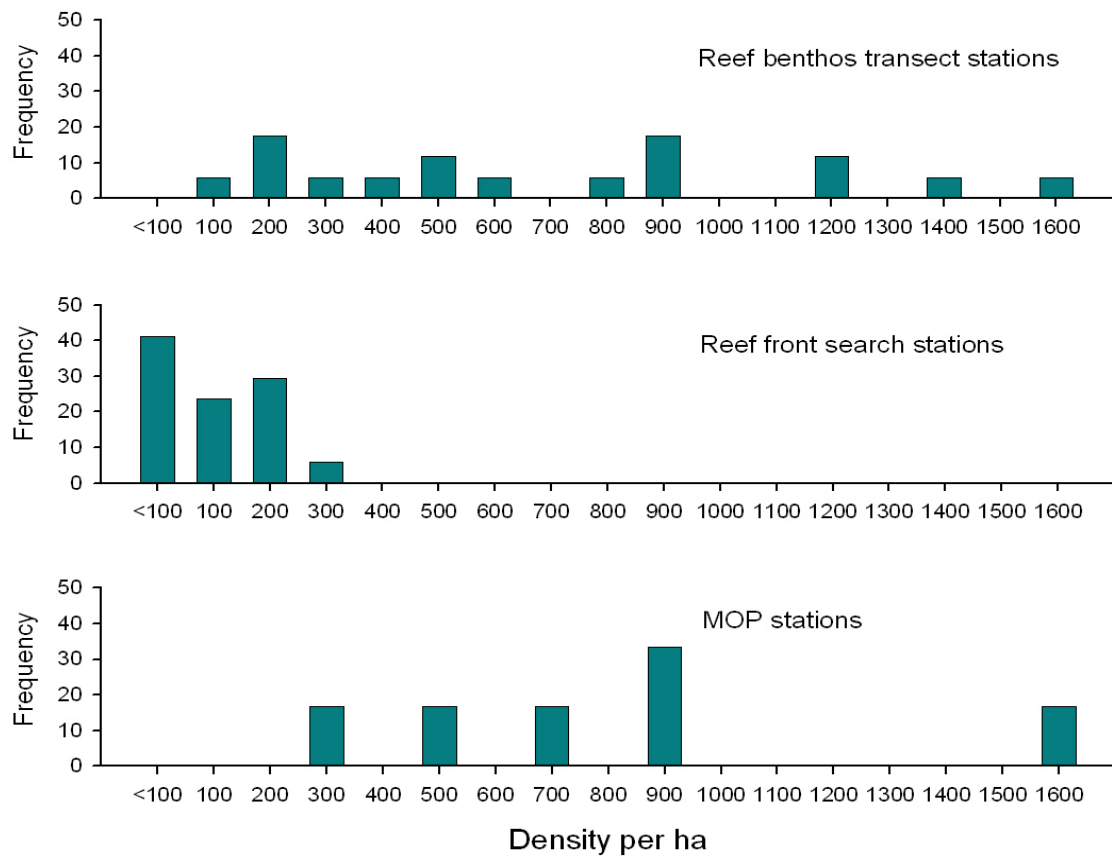


Figure 6: Densities of trochus recorded per survey station at open reefs.

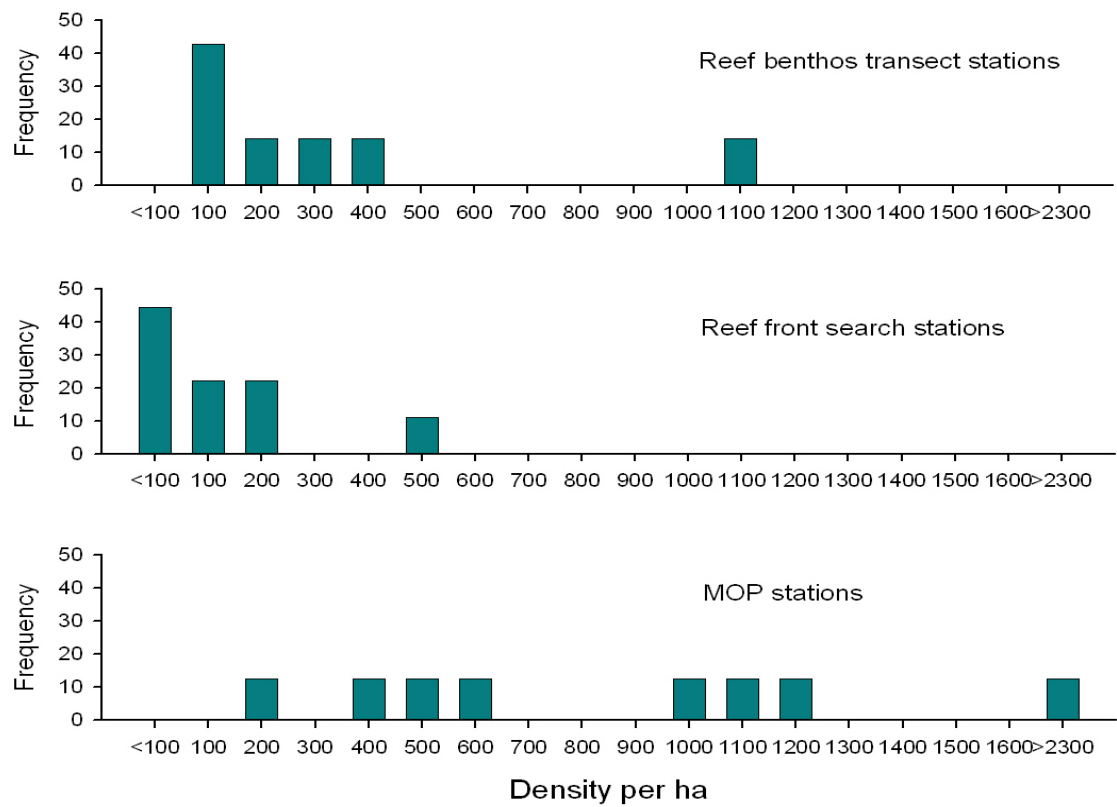


Figure 7: Densities of trochus recorded per survey stations at MPA/trochus sanctuaries.

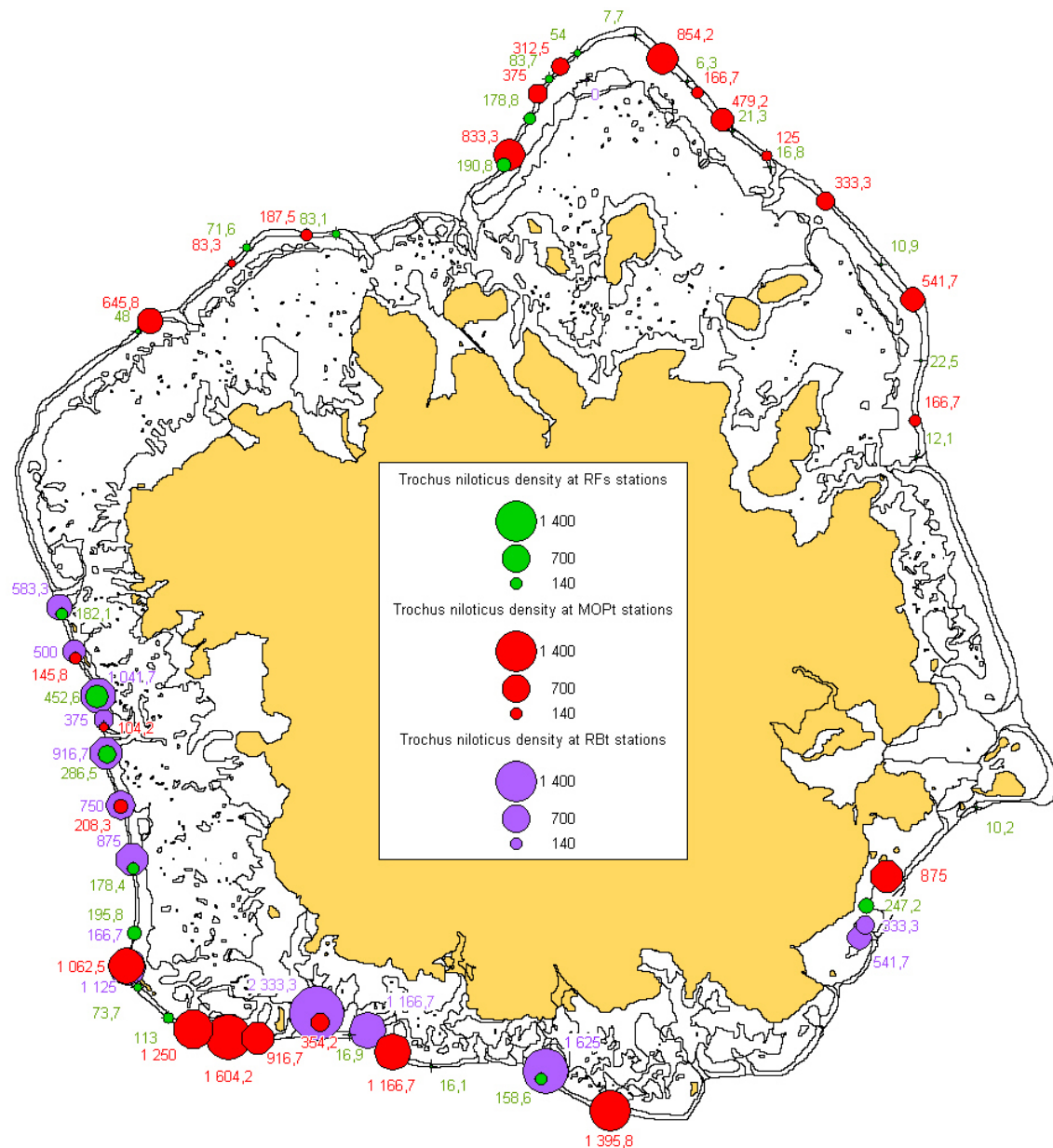


Figure 8: *Trochus niloticus* density (individuals per ha) recorded in all station surveys.

5.4 Trochus size distribution

The shell sizes give important information on the proportion of new recruitment into the fishery (or the lack of recruitment, which has implications for the numbers of trochus entering the capture size classes in the following two years), on the actual portion of the stock that is fishable and on the amount of broodstock available. Overall, 1932 *Trochus niloticus* specimens were noted during the survey, of which 991 (51.1%) were measured.

In the analysis of overall trochus size distribution (**Figure 9**), more large shells were recorded (>10 cm basal diameter) than smaller and younger ones (<10 cm). The mean

size at Pohnpei was 10.2 cm $\pm$ 0.0SE. The minimum size recorded was 2.3 cm and the maximum 13.2 cm. The mean size of trochus recorded on open reefs was 10.1 cm $\pm$ 0.1SE (n = 698) and maximum size was 10.4 cm $\pm$ 0.1SE (n = 293) for those in MPA/trochus sanctuaries.

Of this measured portion of the stock, 34.4% were within harvestable size class (between 3 and 4 inches or 7.6 cm and 10.2 cm), 7.9% were undersize (<7.6cm) and 57.7 % of the stock were over-size (>10.2 cm basal width). In the open areas, the proportion of fishable stock (in numbers) is 36.8% while at MPA/Trochus sanctuaries fishable stock comprises only 28.7% of stock recorded. For oversize stock 55.0% was recorded at open reefs and 64.2 % for MPA/trochus sanctuaries (**Table 4**).

Generally there is an increase in the average size of trochus from the last survey of 1999 with an average size increase of 1.3 cm. In open reefs this difference was 2.2 cm and in MPA/trochus sanctuaries, 1.2 cm. The overall mean size of trochus in 1999 measured on 403 specimens was 8.8 cm, 7.9 cm for open reefs and 9.2 cm for MPA/trochus sanctuaries. Open reefs recorded 46%, 21% and 23% for undersize, legal size and oversize respectively while MPA/trochus sanctuaries recorded 21%, 39% and 40%.

If the proposed alternative harvestable size class of 8 cm to 11cm is considered (as used in several Pacific island fishery regulations), the proportions of the three size classes change dramatically. The proportion of harvestable size class increases to 60.1% (26% more than at the current legal size), while the proportion of oversize stock drops to 31.2 % (27% less than at the current legal size). In the open-access reefs, the proportion of fishable stock (in numbers) increases to 61.9% and 56.0% in the MPA/protected areas (**Table 5**).

Table 4 : Number and percentage of trochus per size class given the current legal size limit

Trochus size classes and percentage	MPA/trochus sanctuaries	Open reefs	All Pohnpei
No. of oversized trochus	188	384	572
Percentage of oversized trochus	64.2	55.0	57.7
No. of trochus at current legal size	84	257	341
Percentage of trochus at current legal size	28.7	36.8	34.4
No. of undersized trochus	21	57	78
Percentage of undersized trochus	7.2	8.2	7.9
Total no. measured, all sizes	293	698	991

Oversized = >10.2 cm; Current legal size = 7.6≤L≤10.2 cm; Undersized = L<7.6 cm.

Number and percentage recorded from survey sample

Table 5 : Number and percentage of trochus per size class given the proposed alternative legal size limit

Trochus size classes and percentage	MPA/trochus sanctuaries	Open reefs	All Pohnpei
No. of oversized trochus	105	204	309
Percentage of oversized trochus	35.8	29.2	31.2
No. of trochus at proposed alternative legal size	164	432	596
Percentage of trochus at proposed alternative legal size	56.0	61.9	60.1
No. of undersized trochus	24	62	86
Percentage of undersized trochus	8.2	8.9	8.7

Total no. measured, all sizes	293	698	991
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Oversized = >11 cm; Proposed alternative legal size = $8 \leq L \leq 11$ cm; Undersized = $L < 8$ cm.
Number and percentage recorded from survey sample

The higher proportion of oversized trochus in MPA/trochus sanctuaries is probably the result of the ban on fishing. The ‘harvestable’ portion of the population (7.6–10.2 cm) is not being depleted by fishing and thus is able to grow to reach the ‘oversize’ size-class (>10.2 cm). These large adults then ‘hold the ground’, leaving little habitat for juveniles to settle (**Figure 11**).

Despite not assessing the back-reef areas, where the typical habitat of juvenile *Trochus niloticus* occurs, the survey was able to detect shells of almost all size classes from 2 cm to 7.5 cm (by 0.5 cm intervals), which indicates that regular spawning and recruitment is occurring over time (First length at capture is 7.6 cm.).

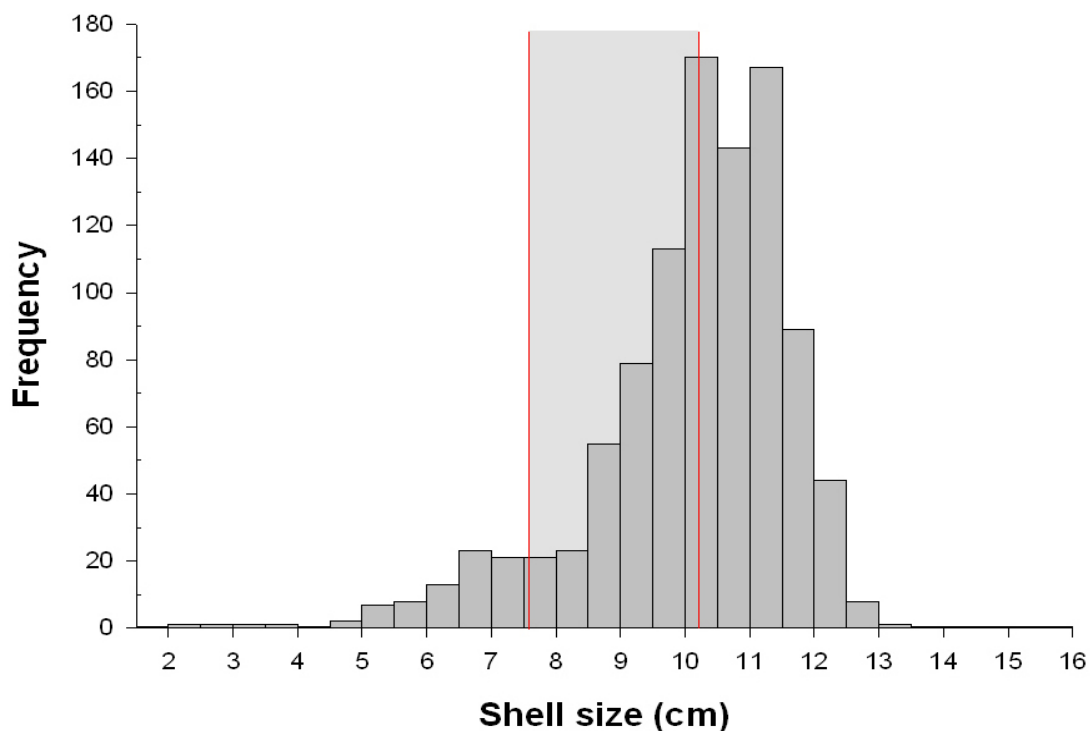


Figure 9: Histogram of trochus (*Trochus niloticus*) shell base diameter for all Pohnpei. Paler grey band denotes current legal shell size classes (7.6–10.2 cm or 3–4 inches).

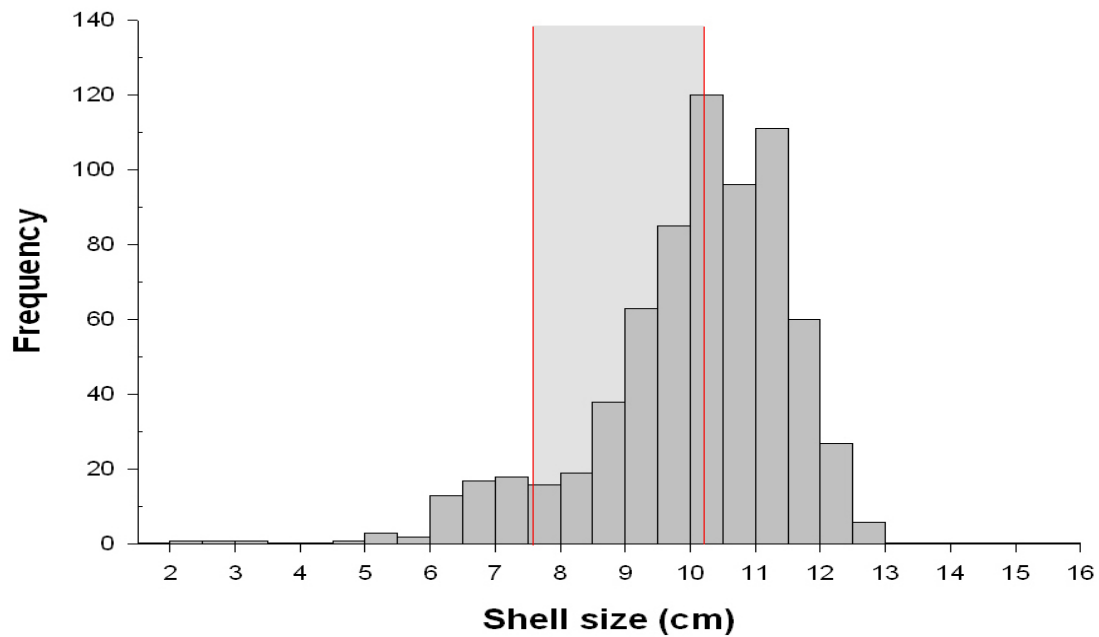


Figure 10 : Histograms of trochus (*Trochus niloticus*) shell base diameter (open reefs only). Paler grey band denotes current legal shell size classes (7.6–10.2 cm or 3–4 inches).

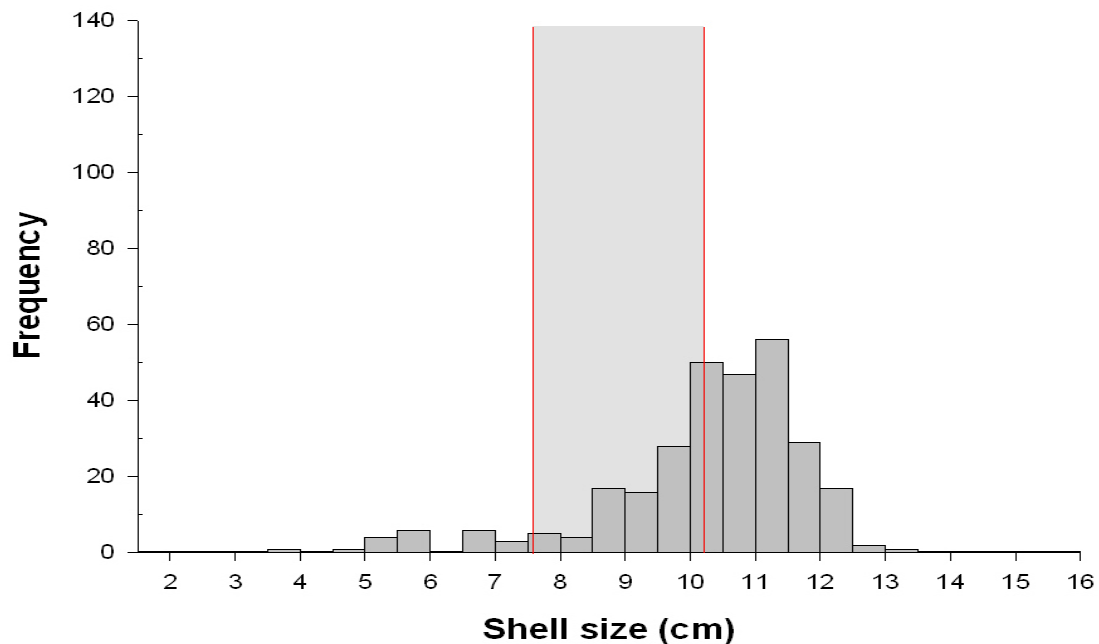


Figure 11: Histogram of trochus (*Trochus niloticus*) shell base diameter (MPA/trochus sanctuary only). Paler grey band denotes current legal shell size classes (7.6–10.2 cm or 3–4 inches).

Further analysis looked into classifying average sizes by depth. Interestingly the distribution of shell sizes by depth reveals good information on the effect of the MPA/trochus sanctuaries. As shown in (Table 6) the average shell size is larger in MPA/trochus sanctuaries than in open access areas. But it is in the shallow areas that this difference is the most important (difference $\Delta=1$ cm). This relative lower size observed in shallow open reefs reflects the fact that the fishers are targeting these easily reachable areas first, and that MPA/trochus sanctuaries have been successful in protecting the resource. If poaching did occur, it was probably marginal and did not impact the population structure.

Table 6 : Average trochus size (cm) by depth and by areas (in mm)

	d <1.5 m			1.5 m < d <5 m			5 m < d <10 m		
Site	mean length (L)	SE	No. shells measured / no. observed	mean length (L)	SE	No. shells measured / no. observed	mean length (L)	SE	No. shells measured / no. observed
Open reefs	93.6	1.9	58/92	101.1	1.0	203/221	102.9	0.7	437/1067
MPA	103.6	2.2	60/78	102.0	1.3	148/174	106.1	1.6	85/300

d = depth; L= length.

5.5 Estimation of stock

Length-weight relationship

From the size profile recorded, we built a weight profile using the length–weight relationships established from the *Trochus niloticus* survey work in Wallis Island (Chauvet 2006) (**Appendix 6.1**):

$$\text{Wet weight: } W = 0.29 \times \emptyset^{3.07} \text{ (R}^2\text{=0.99)}$$

$$\text{Dry weight: } W = 0.31 \times \emptyset^{2.92} \text{ (R}^2\text{=0.99)}$$

Where W= weight, $\emptyset$ = diameter in cm and R^2 = regression coefficient

We used these relationships to estimate the biomasses of trochus in Pohnpei, as they were the closest fit to our small sample of trochus measured for length and weight in Kosrae, the closest island to Pohnpei.

Weight class composition of the trochus survey sample

From the table in **Appendix 6.1**, the proportional weights of undersized trochus, trochus of current legal size, and oversized trochus are calculated, and the results are given in **Table 7**. We can observe that 27.8% of the living stock of trochus (meat plus shell) and 28.3% of the dry product (cleaned shells only) in the fishing areas is within the current legal size class.

Now, if the alternative proposed capture size of 8–11 cm were adopted (in use in several Pacific Island fishery regulations), the percentage weight of the harvestable stock would climb to 55.7% for live trochus and to 56.2% for the dry product.

This indicates that a quite large portion of the stock is just larger than ‘oversize’ (10.2–11 cm) and that any change in the size-limit regulation would have a significant impact on the trochus biomass.

Table 7: Calculated weight and proportion of trochus sampled per size classes (current legal size and proposed alternative legal size)

	Wet trochus *			Dry trochus *		
<i>Trochus niloticus</i>	open reefs	MPA	total	open reefs	MPA	total
Calculated total weight (kg)	266.5	118.5	385.0	199.8	88.6	288.4
kg of trochus at current legal size	74.1	24.2	98.3	56.5	18.4	74.9
% kg of trochus at current legal size	27.8	20.4	25.5	28.3	20.8	26.0
kg of trochus at proposed alternative legal size	148.5	58.6	207.2	112.2	44.2	156.4
% kg of trochus at proposed alternative legal size	55.7	49.5	53.8	56.2	49.9	54.2

*based on the length–weight relationship established by Chauvet (2006) for *Trochus niloticus* from Wallis.

Current legal size = $7.6 \leq L \leq 10.2$ cm; Proposed alternative legal size = $8 \leq L \leq 11$ cm;

Wet trochus = shell plus live animal; Dry trochus = cleaned shell (no meat).

Estimation of trochus stock

During the years 1996–1999, the Office of Marine and Coastal Resource Management and the Overseas Fishery Cooperation Foundation of Japan (OFCF) conducted trochus surveys using similar assessment techniques to those used in the current survey (Hakamata *et al.* 2000). They estimated the stocks of trochus per zones corresponding to depth surfaces. In this analysis we used the same depth zones and organised the data in order to give comparable results. Their original sampling design included 10 surveyed sites: 5 inside the open reefs and 5 in the trochus sanctuaries/MPA. For each station conducted on the open reefs, 7 transects were made at different zones, while in the MPA only 3 zones were assessed. In the current survey, only these 3 main zones were assessed as, according to the local fishery specialists (and the record of their previous assessment), they are by far the most productive and important trochus fishing areas.

These three zones can be roughly described as: the reef-flat zone at the barrier reef (depth 0–<1.5 m), the surf zone (1.5–<5 m) and the terrace zone (5–10 m). For the sake of comparison, the MOPt and RBt stations were reallocated using these zones according to their individual depth, and trochus densities were recalculated (**Table 8**). This gives a slightly different result from those given by station types (**Table 2**), because each station type covers a larger depth range, and because RFs stations are excluded from these calculations as they only give rough estimates of densities.

Table 8 : Average density per areas and per depth (zones) based on transect stations (MOPt and RBt only)

	Zone (depth in metres)	surface area (m ²) surveyed	Number of <i>T. niloticus</i> recorded	Weighted mean density (individ./ha)	Weighted SE	density at lower value of CI	density at higher value of CI
Open reefs	d <1.5	1320	92	697	143.8	404.1	989.9
	1.5 ≤ d <5	3720	221	594.1	80.7	432.0	756.2
	5 ≤ d <10	4800	379	789.6	70.5	648.5	930.7
	subtotal	9840	692	703.3	50.4	603.7	802.9
MPA / Trochus sanctuaries	d <1.5	1240	78	629	119.9	384.1	873.9
	1.5 ≤ d <5	2120	174	820.8	143.6	529.0	1112.6
	5 ≤ d <10	1920	33	171.9	35.2	99.3	244.5
	subtotal	5280	285	539.8	73	394.8	684.8

CI = 95% confidence interval; d = depth in metres.

As all stations do not have the same surface area, it was necessary to weight the average and standard error of the density. The calculation of the weighted standard error is based on the weighted standard deviation (sd_w), as follows:

$$sd_w = \sqrt{\frac{N' \sum_{i=1}^N w_i (x_i - \bar{x}_w)^2}{(N' - 1) \sum_{i=1}^N w_i}}$$

Where w_i is the weight for the weight for the i^{th} observation, N' is the number of non-zero weights, and $\bar{x}_w$ is the weighted mean of the observations.

Here, w_i is the surface at i^{th} station, (x_i) is the mean density of the i^{th} station, $(\bar{x}_w)$ is the weighted mean density of all stations and N and N' are the number of stations.

Standard error is obtained following the formula

$$Se_w = \frac{Sd_w}{\sqrt{N}}$$

Given the densities calculated per zone, and using the areas estimated by zone, we can calculate the estimated number of trochus by zone, with a 95% confidence interval (CI).

We will adopt the areas surfaces calculated previously by the Office of Marine and Coastal Resource Management and the OFCF to calculate the total number of trochus by zone (see **Table 9** **Error! Reference source not found.**).

Table 9: Number of trochus per area and zone

	Zone (depth in metres)	surface (ha)	density (indiv./ha)	weighted SE (sp/ha)	Mean no. of trochus	lower value of CI	higher value of CI
Open reefs	d <1.5	294.3	697	143.8	205127	118923	291331
	1.5≤d<5	279.8	594.1	80.7	166229	120876	211582
	5≤d<10	707	789.6	70.5	558247	458511	657984
	sub total	1281.1	703.3	50.4	900998	773368	1028628
MPA/trochus sanctuaries	d <1.5	126.4	629	119.9	79506	48554	110457
	1.5≤d<5	132.7	820.8	143.6	108920	70194	147646
	5≤d<10	194.7	171.9	35.2	33469	19324	47614
	sub total	453.7	539.8	73	244907	179098	310716
All areas	Total				1145905	952466	1339344

CI = 95% confidence interval; d = depth in metres

The total estimated stock of trochus in the three depth zones in Pohnpei is 95% likely to be 952,466–1,339,344 specimens (average 1,145,905). Of this stock, an average of 900,998 specimens is found in the open-reef areas (CI: 773,368 to 1,028,628) which represents 78.6% of the total average number of specimens for all Pohnpei. Surprisingly, MPA/trochus sanctuaries areas hold a smaller number of trochus, with an estimated average of 244,907 specimens (CI: 179,098 to 310,716) which represent only 21.4% of the total, while their total surface areas represent 26% of the total. Overall, MPA/trochus sanctuaries hold lower trochus densities than do open reefs.

The average numbers of specimens calculated for the same areas during the 1996–1999 survey period were 935,300 specimens in the open reefs and 362,745 specimens in the MPA/trochus sanctuaries. Those values are of the same magnitude as those observed in the 1996–1999 surveys. Nevertheless, the numbers observed during the last survey of 1999 were lower at the open reefs, with 552,730 specimens, but higher at the MPA sanctuaries with 378,882 specimens.

Combined with the size data, information on numbers of individuals shows that the stock has recovered fairly well from the previous harvest, with a larger and more mature population.

5.6 Calculation of the harvestable stock

Using the current legal size set for collecting trochus, the harvestable portion of the stock on open reefs is estimated to be 331,743 specimens (CI: 284,750 to 378,735) for a total estimated average wet weight of 95.7 tonnes (CI: 82.1 to 109.3 mt) which is equivalent to an average of 72.9 mt of mother-of-pearl (CI: 62.6 to 83.3 mt) (**Table 10, Table 12 and Table 14**). (Note: CI = 95% confidence interval.)

If the proposed alternative size limit of 8–11 cm were to be adopted, the harvestable stock in open reefs is estimated to be 557,638 specimens (CI: 478,646 to 636,629) for a total average weight of 191.7 mt wet weight (CI: 164.6 to 218.9), which is equivalent to 144.8 mt of mother-of-pearl. (CI: 124.3 to 165.4 mt) (**Table 11, Table 13 and Table 15**)

Table 10: Estimation of number and percentage of trochus per size class and per area based on the current legal size limit (3–4 inches or 7.6–10.2 cm)

Trochus size (cm)	Number and percentage of trochus per size class								
	Open reefs			MPA/sanctuaries			all Pohnpei		
	Mean	95% confidence interval values (min and max)		Mean	95% confidence interval values (min and max)		Mean	95% confidence interval values (min and max)	
L >10.2	495678	425463	565893	157142	114916	199367	652820	542618	763021
% L >10.2	55.0	55.0	55.0	64.2	64.2	64.2	57.0	57.0	57.0
Current legal size 7.6 ≤ L ≤ 10.2	331743	284750	378735	70212	51346	89079	401955	334101	469809
% 7.6 ≤ L ≤ 10.2	36.8	36.8	36.8	28.7	28.7	28.7	35.1	35.1	35.1
L <7.6	73577	63154	84000	17553	12837	22270	91130	75747	106514
% L <7.6	8.2	8.2	8.2	7.2	7.2	7.2	8.0	8.0	8.0
All sizes	900998	773368	1028628	244907	179098	310716	1145905	952466	1339344

Current legal size limit = 3–4 inches or 7.6–10.2 cm. L = length. The highlighted text denotes trochus at the current legal size at open reefs only.

Table 11: Estimation of number and percentage of trochus per size class and per area based on the proposed alternative size limit (8–11 cm)

Trochus size (cm)	Number and percentage of trochus per size class								
	Open reefs			MPA/sanctuaries			all Pohnpei		
	Mean	95% confidence interval values (min and max)		Mean	95% confidence interval values		Mean	95% confidence interval values (min and max)	
L >11.0	263329	226027	300630	87765	64182	111349	351094	291826	410362
% L >11.0	29.2	29.2	29.2	35.8	35.8	35.8	30.6	30.6	30.6
Proposed alternative legal size 8.0 ≤ L ≤ 11.0	557638	478646	636629	137081	100246	173916	694719	577444	811993
% 8.0 ≤ L ≤ 11.0	61.9	61.9	61.9	56.0	56.0	56.0	60.6	60.6	60.6
L <8.0	80031	68695	91368	20061	14670	25451	100092	83196	116988
% L <8.0	8.9	8.9	8.9	8.2	8.2	8.2	8.7	8.7	8.7
All sizes	900998	773368	1028628	244907	179098	310716	1145905	952466	1339344

Proposed alternative legal size = 8 ≤ L ≤ 11 cm. L = length; the highlighted text denotes trochus at the proposed alternative legal size at open reefs only.

Table 12 : Estimation of total wet weight of trochus per size class based on the current legal-size

Trochus size classes (cm)	Wet weight (metric tonnes) and percentage per size class								
	Open reefs			MPA/sanctuaries			all Pohnpei		
	Mean	95% confidence interval values (min and max)		Mean	95% confidence interval values (min and max)		Mean	95% confidence interval values (min and max)	
Oversize : L>10.2	241.0	206.8	275.1	77.5	56.6	98.3	318.4	263.5	373.4
% L>10.2	70	70	70	78.2	78.2	78.2	71.7	71.5	71.8
Current legal size 7.6≤L≤10.2	95.7	82.1	109.3	20.2	14.8	25.6	115.9	96.9	134.9
% 7.6≤L≤10.2	27.8	27.8	27.8	20.4	20.4	20.4	26.3	26.5	26.2
Undersize L<7.6	7.3	6.3	8.4	1.4	1.0	1.8	8.8	7.3	10.2
% L<7.6	2.1	2.1	2.1	1.4	1.4	1.4	2	2	2
All size	344.0	295.3	392.7	99.1	72.4	125.7	443.1	367.7	518.4

Current legal size limit = 3-4 inches or 7.6–10.2 cm. L = length. The highlighted text denotes trochus at the current legal size at open reefs only. Wet weight = meat plus shell

Table 13 : Estimation of total wet weight of trochus per size class based on the proposed alternative legal-size

Trochus size (cm)	Wet weight (metric tonnes) and percentage per size class								
	Open reefs			MPA/sanctuaries			all Pohnpei		
	Mean	95% confidence interval values (min and max)		Mean	95% confidence interval values (min and max)		Mean	95% confidence interval values (min and max)	
L>11.0	144.0	123.6	164.4	48.3	35.3	61.2	192.2	158.9	225.6
% L>11.0	41.8	41.8	41.8	48.7	48.7	48.7	43.2	43.1	43.3
Proposed alternative legal size 8.0≤L≤11.0	191.7	164.6	218.9	49.0	35.8	62.2	240.7	200.4	281.1
% 8.0≤L≤11.0	55.7	55.7	55.7	49.5	49.5	49.5	54.5	54.6	54.4
Undersize L<8.0	8.3	7.2	9.5	1.8	1.3	2.3	10.1	8.5	11.8
% L<8.0	2.4	2.4	2.4	1.8	1.8	1.8	2.3	2.3	2.3
All size classes	344.0	295.3	392.7	99.1	72.4	125.7	443.1	367.7	518.4

Proposed alternative legal size = 8≤L≤11 cm. L = length; the highlighted text denotes trochus at the proposed alternative legal size at open reefs only. Wet weight = meat plus shell

Table 14 : Estimation of dry weight of trochus based on the current legal-size limit

Trochus size classes (cm)	Dry weight (metric tonnes) and percentage per size class								
	Open reefs			MPA/sanctuaries			all Pohnpei		
	Mean	95% confidence interval values (min and max)		Mean	95% confidence interval values (min and max)		Mean	95% confidence interval values (min and max)	
Oversize : L>10.2	179.1	153.7	204.5	57.5	42.1	73.0	236.6	195.8	277.5
% L>10.2	69.4	69.4	69.4	77.7	77.7	77.7	71.1	70.9	71.2
Current legal size 7.6≤L≤10.2	72.9	62.6	83.3	15.4	11.3	19.5	88.3	73.9	102.8
% 76≤L≤102	28.3	28.3	28.3	20.8	20.8	20.8	26.8	27	26.7
Undersize L<7.6	5.9	5.0	6.7	1.1	0.8	1.4	7.0	5.9	8.2
% L<7.6	2.3	2.3	2.3	1.5	1.5	1.5	2.1	2.2	2.1
All size	257.9	221.4	294.5	74.1	54.2	94.0	332.0	275.6	388.4

Current legal size limit = 3-4 inches or 7.6–10.2 cm. L = length. The highlighted text denotes trochus at the current legal size at open reefs only. Dry weight = cleaned shells only (no meat)

Table 15 : Estimation of dry weight of trochus based on the proposed alternative legal-size

Trochus size (cm)	Dry weight (metric tonnes) and percentage per size class								
	Open reefs			MPA/Sanctuaries			all Pohnpei		
	average	95% confidence interval values		average	95% confidence interval values		average	95% confidence interval values	
L>11.0	106.4	91.4	121.5	35.7	26.1	45.3	142.1	117.4	166.8
% L>11.0	41.3	41.3	41.3	48.2	48.2	48.2	42.7	42.5	42.8
Proposed alternative legal size 8.0≤L≤11.0	144.8	124.3	165.4	37.0	27.0	46.9	181.8	151.3	212.2
% 8.0≤L≤11.0	56.2	56.2	56.2	49.9	49.9	49.9	54.9	55.1	54.8
Undersize L<8.0	6.7	5.7	7.6	1.4	1.1	1.8	8.1	6.8	9.4
% L<8.0	2.6	2.6	2.6	1.9	1.9	1.9	2.5	2.5	2.4
All size classes	257.9	221.4	294.5	74.1	54.2	94.0	332.0	275.6	388.4

Proposed alternative legal size = 8≤L≤11 cm. L = length; the highlighted text denotes trochus at the proposed alternative legal size at open reefs only. Dry weight = cleaned shells only (no meat)

In fishery terms, it is important to maintain older, larger trochus as part of the population, as they provide by far the largest input of gametes for future generations (A 10 cm shell produces ~2 million ova, whereas a 13 cm shell produces 3 times as many, ~6 million ova). However some early researchers, e.g. Asano (1963), suggested that this proportion of the stock must not become ‘too’ dominant, and it was better for the productivity of the fishery to fish the stock periodically, maintaining a number of large shells, but not letting them build up to become the dominant size class of the population.

This is due to the fact that although larger shells are need to be at high density for successful reproduction, they can also dominate the best trochus habitat, using available food sources for the maintenance rather than production of new nacre. That hypothesis seems to be confirmed in the MPA/trochus sanctuaries, where older and

larger shells are predominant, but at an overall lower density than on the open reefs. From a fishery perspective it might be worth switching to the alternative legal size limit of 8.0–11.0 cm, providing double the production for the next harvest, and removing part of this unproductive (in terms of the mother of pearl) old trochus stock.

5.7 Other invertebrate resources

Giant clams

Only the elongate giant clam (*Tridacna maxima*) was recorded in this survey. A total of 27 specimens were recorded at Pohnpei. Density of *T. maxima* was critically low with $29.8 \pm 17.5\text{SE}$, $0.9 \pm 0.4\text{SE}$ and $12.2 \pm 5.7\text{SE}$ specimen per ha respectively for RBt, MOPt and RFs. Such a low density makes resource recovery difficult as sparse distribution negatively affects the success of spawning and fertilisation, and therefore the on-going sustainability of this resource. Nevertheless, these densities, which were found outside the lagoon, cannot be used to predict densities that would be found in the lagoon of Pohnpei; therefore, no conclusion can be made on the stock status of this species.

Sizes class recorded were from 3–19 cm, with an average size of $9.9 \pm 1.1\text{SE}$ cm, which is fairly small. Larger clams, which make up an important part of the spawning biomass (clams are protandrous hermaphrodites and only become female at larger size classes) were mostly absent from these reefs. This is most probably due to high fishing pressure. (**Appendix 2-5**)

Sea cucumbers

The barrier-reef fronts assessed in this survey are the main habitat for a few of the commercial sea cucumbers species. Nine (9) species of commercial sea cucumbers were recorded, of which only *Actinopyga mauritiana* shares typically the same habitat as *Trochus niloticus*. Sea cucumber presence and densities were determined through MOPt, RBt and RFs methods (**Table 16**, **Appendix 2-5**, also see Methods).

The medium-value surf redfish, *Actinopyga mauritiana*, was well distributed all around the island (53% of RBt, 65% of RFs and 50 % of MOPt stations), and recorded at moderate-to-low densities (average of $63.9 \pm 37.9\text{SE}$, $10.6 \pm 2.7\text{SE}$ and $51.2 \pm 22.3\text{SE}$ per ha in RBt, RFs and MOPt stations respectively). In some other locations in the Pacific, this species is recorded at densities above 400–500 specimens per ha.

The high-value species prickly redfish or Pineapplefish (*Thelenota ananas*), were few; only 4 specimens were recorded in both RBt and MOPt stations (none at RFs stations). Again density was low at $5.6 \pm 5.6\text{SE}$ and $1.7 \pm 1.2\text{SE}$ sp. per ha respectively for RBt and MOPt stations.

The medium-value green fish (*Stichopus chloronotus*) was recorded in all assessment types. But it was only commonly distributed at RBt stations, mostly at reefs in the passages (67 % of RBt stations), and at an average density of $327.8 \pm 186.3\text{SE}$ per ha.

The lower-value species of sea cucumbers, lollyfish (*Holothuria atra*) was well distributed at shallow depth (in 73 and 31% of RBt and RFs stations respectively), but was absent from MOPt stations. Density recorded was $294.4 \pm 172.7\text{SE}$ per ha at RBt stations and dropped down to $2.6 \pm 1.0\text{SE}$ per ha at RFs stations. Pinkfish (*Holothuria*

edulis) was recorded only on one RBt station (7% of RBt stations), at an aggregation. At this station, density reached 333.3 specimens per ha, compare to the overall density for all RBt station of $22.2 \pm 22.2\text{SE}$ per ha. Pinkfish was also recorded at 8% of the RFs stations at the low density of $0.6 \pm 0.6\text{SE}$ per ha.

Sea cucumber species usually associated with more sheltered areas of shallow reefs such as the medium commercial value leopardfish (*Bohadschia argus*) and the high-value black teatfish (*Holothuria nobilis*) were present. Leopardfish was present at 27%, 4% and 8% of RBt, RFs and MOPt stations respectively and black teatfish at 20%, 23% and 4% of RBt, RFs and MOPt stations. Both were recorded at moderately low densities. Leopardfish density was recorded, $16.7 \pm 7.9\text{SE}$, $0.1 \pm 0.1\text{SE}$ and $1.7 \pm 1.2\text{SE}$ at RBt, RFs and MOPt stations and black teatfish at $8.3 \pm 4.5\text{SE}$, $0.6 \pm 0.3\text{SE}$ and $0.9 \pm 0.9\text{SE}$ at RBt, RFs and MOPt stations.

Table 16 : Sea cucumber species records from Pohnpei, FSM.

Species	Common name	Commercial Value ⁽⁵⁾	Reef benthos stations n = 15			RFs station n = 26			MOPt stations n = 24		
			D ⁽¹⁾	DwP ⁽²⁾	PP ⁽³⁾	D	DwP	PP	D	DwP	PP
<i>Actinopyga mauritiana</i>	Surf redfish	M/H	63.9	119.8	8/15 = 53%	10.6	16.2	17/26 = 65%	51.2	102.4	12/24 = 50%
<i>Bohadschia argus</i>	Leopardfish	M	16.7	62.5	4/15 = 27%	0.1	2.3	1/26 = 4%	1.7	20.8	2/24 = 8%
<i>Bohadschia graeffei</i>	Flowerfish	L				0.2	5.0	1/26 = 4%	6.1	72.9	2/24 = 8%
<i>Holothuria atra</i>	Lollyfish	L	294.4	401.5	11/15 = 73%	2.6	8.4	8/26 = 31%			
<i>Holothuria coluber</i>	Snakefish	L	2.8	41.7	1/15 = 7%						
<i>Holothuria edulis</i>	Pinkfish	L	22.2	333.3	1/15 = 7%	0.6	8.4	2/26 = 8%			
<i>Holothuria nobilis</i> ⁽⁴⁾	Black teatfish	H	8.3	41.7	3/15 = 20%	0.6	2.7	6/26 = 23%	0.9	20.8	1/24 = 4%
<i>Stichopus chloronotus</i>	Greenfish	H/M	327.8	491.7	10/15 = 67%	1.1	7.2	4/26 = 15%	5.2	31.3	4/24 = 17%
<i>Thelenota ananas</i>	Prickly redfish	H	5.6	83.3	1/15 = 7%				1.7	20.8	2/24 = 8%

⁽¹⁾ D = mean density per hectare; ⁽²⁾ DwP = mean density per hectare for transects or stations where the species was present; ⁽³⁾ PP = percentage presence (units where the species was found);

⁽⁴⁾ There has been a recent variation to sea cucumber taxonomy which has changed the name of the black teatfish in the Pacific to *H. whitmaei*. This should be noted when comparing texts, as in this report the 'original' taxonomic names are used; ⁽⁵⁾ L = Low value; M = Medium value; H = High value.

5.8 Environmental parameters

Coral cover

The survey covers a large part of the reef slopes and passages. Corals are globally very impacted and a large part of the substratum (around 44%) is made of relatively recent dead corals. Live-coral cover recorded in this survey is relatively low (22%) (**Figure 13**). This is the result of predation by an outbreak of crown-of-thorns starfish (*Acanthaster planci*). In some stations the bottom is almost exclusively constituted of large dead coral colonies (**Figure 12**). Although this is a tragedy for the reef, this event seems to benefit trochus and other grazing animals. Corals, like other invertebrates, compete for space and, in some cases, can totally dominate the biome. With the death of the corals, space is freed for other invertebrates to colonise the bottom. In that case, trochus find a lot more niches and a lot more epiphytes growing on the dead corals to graze upon.



Figure 12 : Dead coral field commonly seen in Pohnpei.

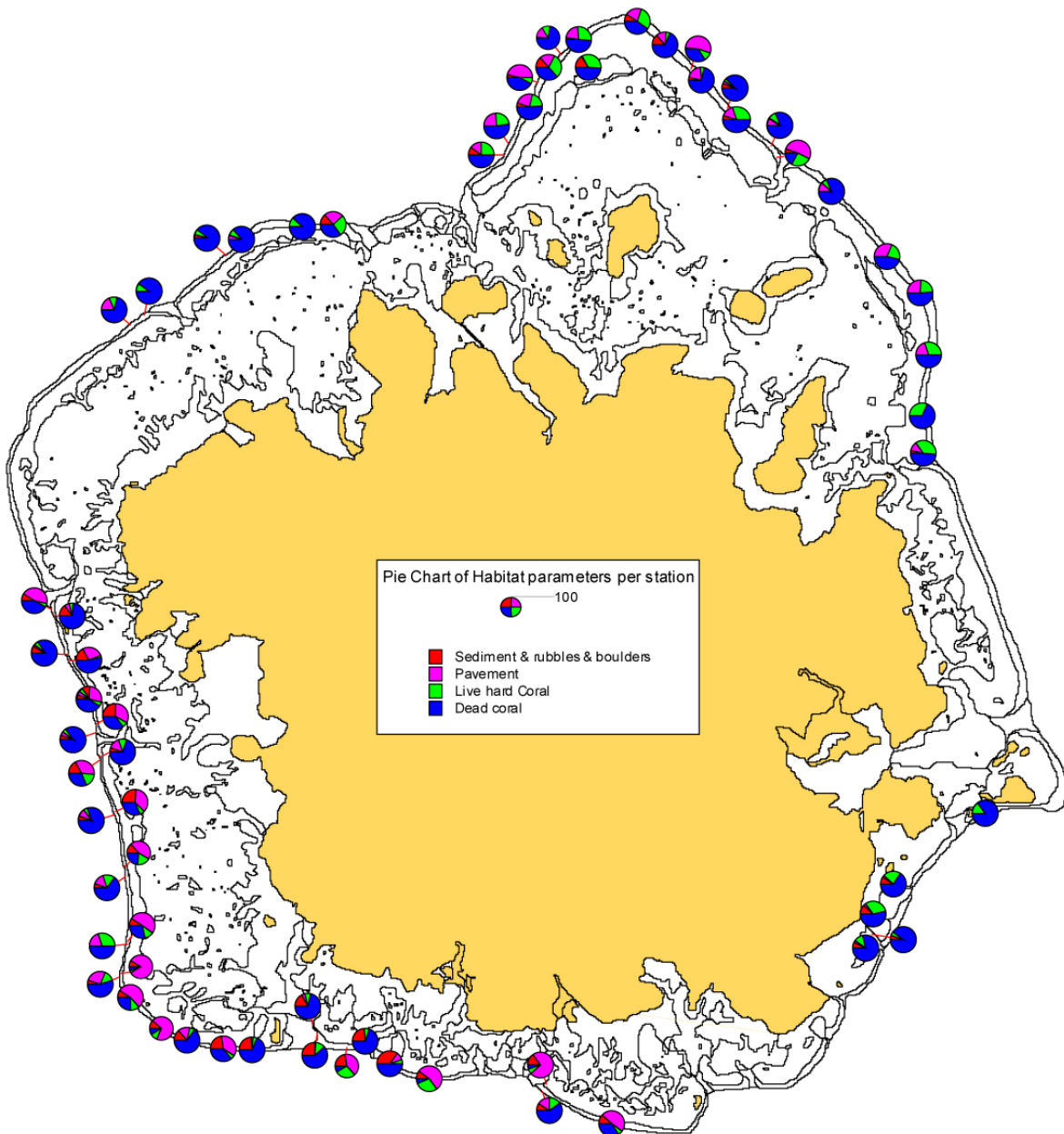


Figure 13 : Habitat composition at Pohnpei survey stations.

Crown-of-thorns starfish (Acanthaster planci)

Crown of thorns starfish (*Acanthaster planci*) have been recorded at a density far above its natural density. A total of 909 specimens was recorded, which makes it the second most recorded invertebrate at Pohnpei after *Trochus niloticus*. Crown-of-thorns starfish has the potential to be very destructive to coral cover if densities become high, as one starfish can devour as much as 2-6 m²/year of coral (**Figure 14**). These starfish begin to eat coral at about six months of age (1 cm) and grow over two years to about 25 cm in diameter. During a severe outbreak, there can be several crown-of-thorns starfish per m² and they can kill most of the living coral in an area of reef, reducing coral cover from the usual 25-40% of the reef surface to less than 1%, which can take up to a decade to recover.

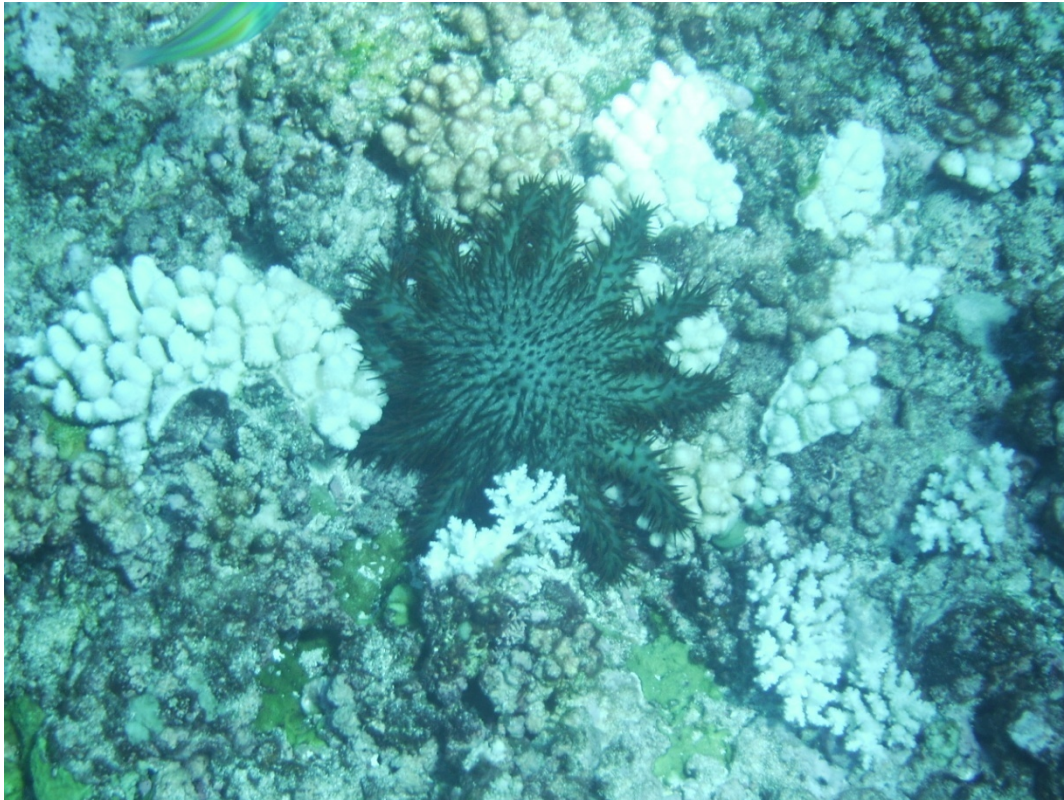


Figure 14 : *Acanthaster planci* feeding on the last remaining corals – a common sight in Pohnpei

Crown-of-thorns starfish (COTS) was recorded at almost all stations around Pohnpei, with the most being recorded on the north western side of the island from the northern tip of the barrier reef all the way down to the Black Coral Island MPA at the south western corner (**Figure 15**). The species was broadly distributed, recorded in 73.3%, 80.8% and 66.7% of RBt, RFs and MOPt stations respectively. Densities recorded per assessment type were $186.1 \pm 64.5\text{SE}$; $70.7 \pm 18.7\text{SE}$; and $93.8 \pm 26.7\text{SE}$ per ha at RBt, RFs and MOPt stations respectively. There are notably lower densities recorded in MPA/trochus sanctuaries than on open reefs (**Table 17**). These densities are indicative of a general active outbreak. On the Great Barrier Reef of Australia, the following system is used for defining outbreaks of crown-of-thorns starfish:

- **Incipient outbreak:** the density at which coral damage is likely. Occurs when there are 0.22 adults recorded per 2-minute manta tow; or >30 adults and subadults per ha using SCUBA diving counts. (Starfish may be mature at 2 years or at a size of 20 cm diameter but, for the definition of an outbreak, an indicator size of >26 cm is used.).
- **Active outbreak:** COTS densities are >1.0 adults per 2-minute manta tow or, if SCUBA diving, at a density of >30 adults only starfish per ha.

The outbreak in Pohnpei probably started a few years ago. We have recorded vast fields of old, dead but still intact coral heads (**Figure 12**), sometimes with very few to no COTS; these bear witness to past predation. Corals along the breakers zone tend to recover better with new recruitment than those in deeper waters (5–10m) but if *A. planci* is present, there is no chance for new coral growths.

Table 17 : Crown of thorns (*Acanthaster planci*) records by area and station type

Area	Station type	Densities		% presence at station
		average	SE	
Open reefs	RBt	214.3	121.5	57.1
	RFs	85.2	26.9	76.5
	MOPt	112.7	35.8	70.6
MPAs	RBt	161.5	66.1	87.5
	RFs	43.2	16.7	88.9
	MOPt	47.6	23.1	57.1
All areas	RBt	186.1	64.5	73.3
	RFs	70.7	18.7	80.8
	MOPt	93.8	26.7	66.7

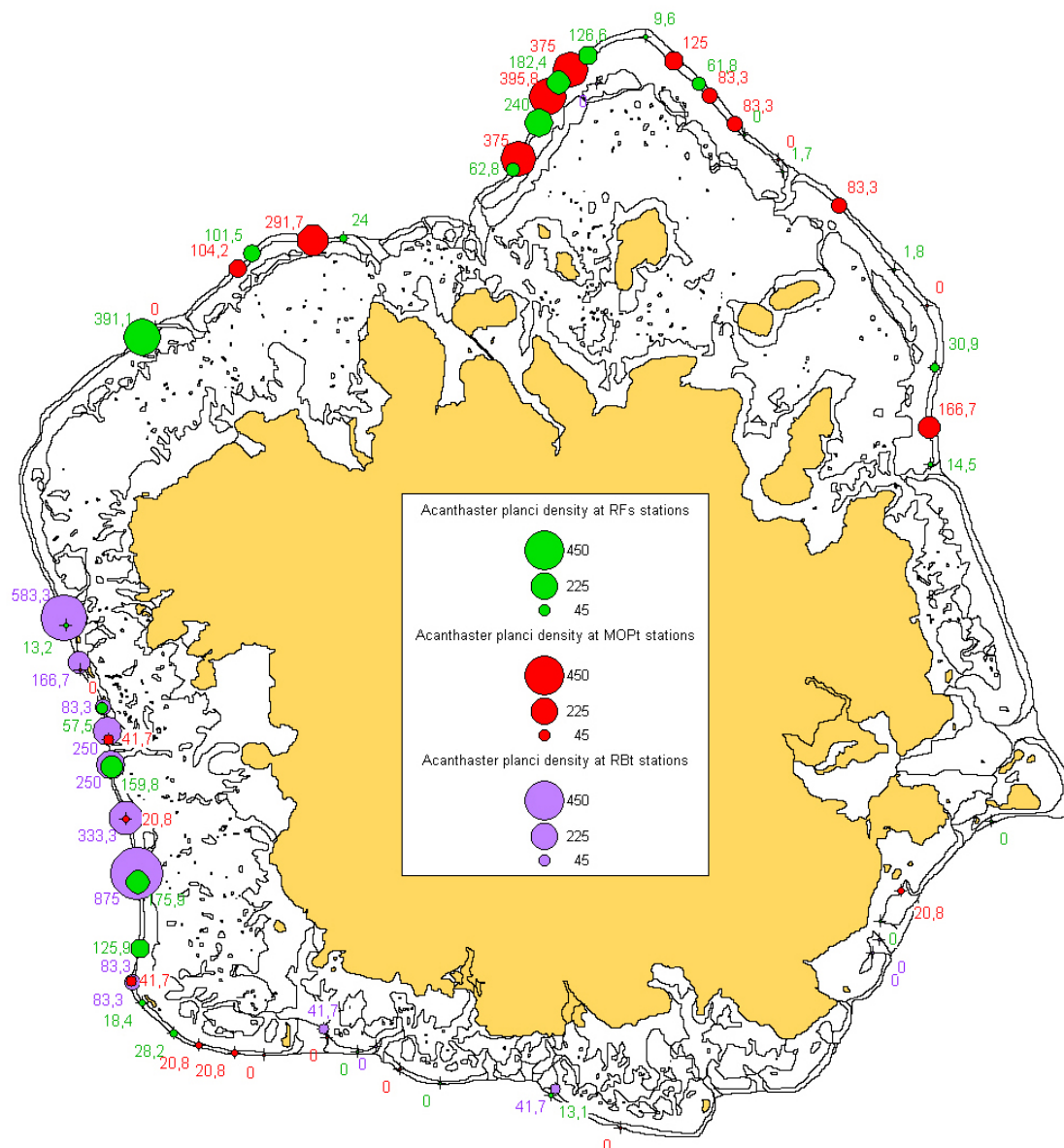


Figure 15 : Crown-of-thorns sea star (*Acanthaster planci*) densities (specimens per ha) at survey stations.

6. Summary of results

6.1 Trochus

- The reef crest and outer reef slope of Pohnpei Island barrier reef constitute an extensive and suitable benthos for *Trochus niloticus* in Pohnpei. The low cover of live coral (22% of total habitat) and large cover of dead coral provide sufficient habitat for grazing invertebrates. As more live corals are lost by COTS predation, more space is made available for grazing invertebrates such as trochus.
- *Trochus niloticus* was common all around Pohnpei (recorded at 100% of stations surveyed) at the outer side of the barrier reefs at many easily accessible shallow-water reefs and reef platform, as well as in deeper areas of the outer slope. This is common in large populations, where aggregations become diffuse as the population increases.
- Trochus density is higher in the southern reefs than in the northern reefs of Pohnpei. Specifically, high aggregations were found at the whole barrier reef of Kitti Municipality, the southern part of Madolenihmw, the southern barrier reef of Sokehs and the whole outer barrier reef of Nett Municipality.
- The trochus mean density at open-access reefs (where fishing would normally occur), was 703 individual per hectare (CI 604 to 803 individuals/ha). Inside the MPA/trochus sanctuaries the average density recorded was lower with 540 individuals/ha (CI 395 to 685 individuals/ha). Trochus density at open-access reefs, therefore, is well above the benchmark of 500 individuals/ha that indicates a healthy trochus stock.
- The healthy condition of the trochus population of Pohnpei is attributed to the relatively good enforcement of the existing management regime (always closed with a pulse open season determined by stock assessment), the active trochus sanctuaries and MPAs and the enforcement of existing size limit (7.6 cm–10.2 cm) regulations. The 4-inch or 10.2-cm upper size limit (the lowest upper size limit in the Pacific Island countries) protects a greater portion of the larger shells, resulting in the exceptionally high stock of larger sizes (>10 cm).
- The population of young shells (<7cm) recorded in this survey was small. This is expected considering this survey did not cover back-reef areas, which would normally have suitable habitat for juveniles, and that juveniles are highly cryptic and therefore very difficult to record. Despite the dominance of oversize shells, the presence of young shells in this survey (>2 cm in size) indicates that recruitment is ongoing, with all representative size classes from 2 cm to 7.5 cm recorded.
- In open-access reefs, mean trochus density in shallow reefs (<1.5 m deep) is slightly lower than in deeper waters and lower than in MPA/trochus sanctuaries. This indicates that fishing is impacting shallow-water stocks, while MPA/trochus sanctuaries are working effectively in protecting and maintaining a breeding population.
- There is a good abundance of commercial size classes at the moment, with more than adequate numbers of ‘broodstock’. In some places, large, old individuals dominate the

stock at both the reef platform and slope. Commercial harvest can be considered and the available biomass of harvestable trochus is 95% likely to be 82.1–109.3 metric tonnes based on the current legal size and 164.6–218.9 metric tonnes based on the proposed alternative harvestable size of 8.0 to 11.0 cm.

- Previous studies in 1999 showed that the extensive lagoon reefs held a significant number of trochus at low density. This is important to keep in mind, as these uncounted trochus (in our present survey) can act as a 'security' broodstock in the case of core stock depletion in the main fishing areas.
- The total average number of specimens calculated in this survey is of the same magnitude as that obtained by Hakamata and Moses between 1996 and 1999 at 935,300 specimens in the open reefs and 362,745 specimens in the MPA/trochus sanctuaries. However, trochus density at the open reefs in the 1999 survey was lower (552,730 specimens) and higher at the MPA sanctuaries (378,882 specimens). Combined with the size data records, this information shows that the stock, even after the 2005 harvest, has recovered fairly well from the 1999 harvest, with a larger and more mature population.
- The impact of the last harvest season is detected by the significantly lower density within shallow waters (<1.5 m depth) at open-access reefs. The reports of overfishing in the previous open season cannot be verified by the results of the current survey, although the relatively low density of trochus at the current legal harvestable size (3–4 inches) compared to the density of larger sized trochus may indicate these sizes have been removed in the last season. Any poaching inside the sanctuaries, which was reported to have possibly happened during the last open season, was undetectable; it may have occurred on a modest scale. Trochus density in shallow waters <1.5 m was higher than on open reefs, indicating the sanctuaries are active in protecting trochus.

6.2 Giant clams

- Size frequency distributions of giant clams revealed that the full range of *Tridacna maxima* size classes were still present at Pohnpei, but larger clams, which make up an important part of the spawning biomass, are absent from easily accessible inshore reef. The stock of *T. maxima* may be seriously depleted in Pohnpei and urgent management intervention is essential at this stage.

6.3 Sea cucumbers

- The large high island of Pohnpei possesses a full range of marine environments with potential to hold a number of commercial sea cucumber species. Protected areas of inshore reef, which normally hold many species, were not assessed in this survey. The predominantly exposed reefs assessed provided suitable habitat for a small number of sea cucumber species.
- In general, the presence and density data collected indicate that the current local population of sea cucumbers is generally not at a high enough density to enable commercial harvest to be recommended.

- The stock of *Stichopus chloronotus* may offer limited potential for commercialisation if short, limited harvests controlled by the fishery department could be interspersed between longer time periods when the fishery remains protected from fishing, to allow stocks to recover from the harvest. This would literally entail just a few days of fishing followed by a period of rest (lasting years rather than months).
- Sea cucumbers play an important role in ‘cleaning’ hard (limestone) and processing soft (sand and mud) benthic substrates. When these species are overfished, there is the potential for detritus to build up, creating conditions that can promote the development of non-palatable algal mats (blue-green algae) or anoxic (oxygen-poor) conditions, unsuitable for life.

6.4 Crown of thorns starfish (*Acanthaster planci*)

Crown of thorns starfish (COTS, *Acanthaster planci*) is the second most important invertebrate recorded in Pohnpei reefs with aggregations far above its natural density. A total of 909 COTS was recorded in almost all stations at Pohnpei. High aggregations were recorded at the northern tip of the barrier reef all the way down to the Black Coral Island MPA at the southwestern corner. The high percentage cover of dead coral and dead but intact coral heads suggest that the outbreak may have started a few years ago. COTS are destructive to live coral (feed on coral polyps) thus urgent action to remove them from the environment is needed.

7. Recommendations

- Any proposed trochus fishing plans may consider the option of increasing the minimum and maximum legal size limit to 8.0 cm and 11.0 cm, which would increase the minimum size by 0.4 cm and increase the maximum size by 0.8 cm. This would firstly free up more fishable shells at least for the first open season in order to reduce the large population of oversized individuals. Reducing the older stocks would revitalise the population by making way for new settlement of young shells to build up the base of the fishery. Raising the minimum size limit would protect young shells in open areas and allow sufficient time for newly recruited shells to reach maturity before entering the fishery (Sexual maturity begins at about 5.0 to 6.0 cm.).
- The present system of opening the harvest season only when a stock assessment survey has determined that a sufficient fishable quantity is available has been effective in controlling the fishery and should continue to be adopted. In addition, the existing practice of surveillance and monitoring during harvest should also be continued as it allows responsible fishing activity and prevent losses through illegal size harvest.
- The existing trochus sanctuaries and MPAs have been effective in preserving trochus breeding stocks and contributing to healthy recruitment. Respect for the regulations controlling these areas should continue to be encouraged. In addition monitoring and surveillance during open season should be strengthened in future.

- Trochus are unevenly distributed around Pohnpei; relatively low densities were recorded in some areas, e.g. reefs west of Sokehs Pass and reefs on the east of Madolenihmw and Uh municipalities. Movement of broodstock to these reefs from the SW reefs, including the MPAs, should be encouraged. This should help thin down the population of older shells and allow recruitment settlement.
- Based on the estimated fishable stock from this survey, any future harvest should be based on 30% of the fishable stock.
- In the case of the pulse fishery, a very easy and accurate way to estimate trochus stock exists. A mark-recapture survey (marking trochus before the harvest and checking the proportion of marked trochus during the harvest) will provide a strong baseline for estimating stocks. It is therefore recommended that, before the next open season, SPC should be contacted in advance to conduct a mark-recapture survey.
- The stock of *T. maxima* at Pohnpei barrier reef is seriously depleted. Giant clam fishing should be stopped; management intervention is considered urgent at this stage if the island wants to preserve its *T. maxima* resource. One of the management options would be to extend the no-take policy in the existing seven trochus sanctuaries to cover giant clams to protect clam stocks within the sanctuaries.
- The three most important commercial sea cucumbers in Pohnpei recorded by Bourgoin and Edward (2005) are *Holothura atra*, *Stichopus chloronatus* and *Actinopyga mauritiana*. In the present survey, only *S. chloronatus* and *A. mauritiana* were recorded in moderate numbers and at sufficient density to support a short pulse commercial fishery. However, the results of this study (which was not a dedicated sea cucumber assessment) should be used together with the results of the work by Bourgoin and Edward (2005) and of any future surveys, to give better analysis of the commercial potential of sea cucumbers in Pohnpei.
- The *Acanthaster planci* population has become chronic and has caused severe damage to the island's live corals. It is an urgent environmental problem for the Pohnpei government. Responsible agencies should coordinate efforts for a cleanup campaign. Reducing the number of COTs would reduce their breeding capacity and the rate of predation on live corals. An eradication programme should start by targeting densely populated areas on the west coast barrier reefs as indicated on the map (Figure 15). Alternative uses of COTs, e.g. for fertiliser or food, should be investigated; Dr Soon-Kil Yi, from Korean Ocean Research & Development Institute in Chuuk, noted that the gonad of COTs is eaten by Chinese people.

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Pohnpei invertebrate survey appendices

1.1 Invertebrate species recorded in different assessments in Pohnpei (all stations)

Group	Species	Reef Front Search	Reef Benthos transect	MOP transect
Bêche-de-mer	<i>Actinopyga mauritiana</i>	+	+	+
Bêche-de-mer	<i>Bohadschia argus</i>	+	+	+
Bêche-de-mer	<i>Bohadschia graeffei</i>	+		+
Bêche-de-mer	<i>Holothuria atra</i>	+	+	
Bêche-de-mer	<i>Holothuria coluber</i>		+	
Bêche-de-mer	<i>Holothuria edulis</i>	+	+	
Bêche-de-mer	<i>Holothuria nobilis</i>	+	+	+
Bêche-de-mer	<i>Stichopus chloronotus</i>	+	+	+
Bêche-de-mer	<i>Thelenota ananas</i>		+	+
Bivalve	<i>Spondylus sp.</i>			+
Bivalve	<i>Tridacna maxima</i>	+		+
Bivalve	<i>Tridacna maxima</i>	+	+	+
Cnidarians	<i>Stichodactyla sp.</i>	+		
Cnidarians	<i>Stichodactyla sp.</i>	+		+
Crustacean	<i>Panulirus penicillatus</i>	+		
Gastropod	<i>Cerithium nodulosum</i>	+		
Gastropod	<i>Charonia tritonis</i>			+
Gastropod	<i>Conus distans</i>	+	+	+
Gastropod	<i>Conus imperialis</i>			+
Gastropod	<i>Conus miles</i>	+		
Gastropod	<i>Conus sp.</i>	+	+	
Gastropod	<i>Cypraea arabica</i>		+	
Gastropod	<i>Cypraea caputserpensis</i>		+	+
Gastropod	<i>Cypraea maculifera</i>		+	+
Gastropod	<i>Cypraea moneta</i>		+	
Gastropod	<i>Cypraea sp.</i>			+
Gastropod	<i>Cypraea tigris</i>		+	
Gastropod	<i>Dendropoma maximum</i>	+	+	+
Gastropod	<i>Lambis crocata</i>		+	
Gastropod	<i>Ovula ovum</i>	+		
Gastropod	<i>Pleuroploca filamentosa</i>	+		
Gastropod	<i>Pleuroploca trapezium</i>			+
Gastropod	<i>Tectus pyramis</i>	+	+	+
Gastropod	<i>Thais armigera</i>	+		+
Gastropod	<i>Thais sp.</i>		+	
Gastropod	<i>Trochus maculata</i>	+	+	+
Gastropod	<i>Trochus niloticus</i>	+	+	+
Gastropod	<i>Trochus sp.</i>		+	+
Gastropod	<i>Turbo argyrostomus</i>	+	+	+
Gastropod	<i>Tutufa bubo</i>		+	+
Gastropod	<i>Vasum ceramicum</i>	+	+	+
Gastropod	<i>Vasum turbinellum</i>			+
Octopus	<i>Octopus sp.</i>	+	+	+
Star	<i>Acanthaster planci</i>	+	+	+
Star	<i>Choriaster granulatus</i>	+	+	+

**1.1 Invertebrate species recorded in different assessments in Pohnpei (all stations)
(continued)**

Group	Species	Reef Front Search	Reef Benthos transect	MOP transect
Star	<i>Culcita novaeguineae</i>	+	+	+
Star	<i>Linckia guildingi</i>	+	+	+
Star	<i>Linckia laevigata</i>	+	+	+
Urchin	<i>Echinometra mathaei</i>	+	+	+
Urchin	<i>Echinothrix diadema</i>	+	+	+

+ = Presence of the species.

2.1 Pohnpei reef-benthos (RBt) assessment data review (all stations)

Station: Six 1 m x 40 m transects, density given in specimen/ha. Qualifier (_P) describes results for only units when the species of interest was present.

Species	Transect			Transect _P			Station			Station _P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Acanthaster planci</i>	186.1	36.1	90	523.4	69.5	32	186.1	64.5	15	253.8	78.9	11
<i>Actinopyga mauritiana</i>	63.9	20.4	90	410.7	85.4	14	63.9	37.9	15	119.8	66.6	8
<i>Bohadschia argus</i>	16.7	7.7	90	300.0	50.0	5	16.7	7.9	15	62.5	12.0	4
<i>Choriaster granulatus</i>	5.6	3.9	90	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
<i>Conus distans</i>	8.3	4.8	90	250.0	0.0	3	8.3	4.5	15	41.7	0.0	3
<i>Conus sp.</i>	55.6	18.4	90	416.7	83.3	12	55.6	21.0	15	119.0	30.7	7
<i>Culcita novaeguineae</i>	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
<i>Cypraea arabica</i>	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
<i>Cypraea caputserpensis</i>	16.7	6.6	90	250.0	0.0	6	16.7	7.9	15	62.5	12.0	4
<i>Cypraea maculifera</i>	5.6	3.9	90	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
<i>Cypraea moneta</i>	27.8	16.5	90	833.3	166.7	3	27.8	27.8	15	416.7		1
<i>Cypraea tigris</i>	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
<i>Dendropoma maximum</i>	422.2	252.9	90	7 600.0	3 460.1	5	422.2	416.3	15	2 111.1	2 069.4	3
<i>Echinometra mathaei</i>	27.8	12.8	90	500.0	79.1	5	27.8	16.1	15	138.9	36.7	3
<i>Echinothrix diadema</i>	116.7	29.4	90	525.0	82.9	20	116.7	38.4	15	175.0	48.0	10
<i>Holothuria atra</i>	294.4	84.8	90	736.1	190.8	36	294.4	172.7	15	401.5	229.4	11
<i>Holothuria coluber</i>	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
<i>Holothuria edulis</i>	22.2	11.6	90	500.0	102.1	4	22.2	22.2	15	333.3		1
<i>Holothuria nobilis</i>	8.3	4.8	90	250.0	0.0	3	8.3	4.5	15	41.7	0.0	3
<i>Lambis crocata</i>	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
<i>Linckia guildingi</i>	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
<i>Linckia laevigata</i>	233.3	46.4	90	656.3	91.7	32	233.3	84.1	15	350.0	109.4	10
<i>Octopus sp.</i>	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
<i>Stichopus chloronotus</i>	327.8	84.8	90	1 017.2	214.2	29	327.8	186.3	15	491.7	268.4	10
<i>Tectus pyramis</i>	38.9	12.4	90	318.2	48.7	11	38.9	13.2	15	83.3	15.7	7
<i>Thais sp.</i>	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1

2.1 Pohnpei reef-benthos (RBt) assessment data review (all stations) (continued)

Species	Transect			Transect_P			Station			Station_P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Thelenota ananas</i>	5.6	3.9	90	250.0	0.0	2	5.6	5.6	15	83.3		1
<i>Tridacna maxima</i>	13.9	7.2	90	312.5	62.5	4	13.9	8.8	15	69.4	27.8	3
<i>Trochus maculata</i>	50.0	17.8	90	409.1	90.9	11	50.0	20.0	15	125.0	30.4	6
<i>Trochus niloticus</i>	822.2	89.4	90	1 057.1	98.3	70	822.2	154.1	15	881.0	153.1	14
<i>Trochus niloticus</i> *	881.0	92.5	84	1 057.1	98.3	70	881.0	153.1	14	881.0	153.1	14
<i>Trochus</i> sp.	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
<i>Turbo argyrostomus</i>	175.0	32.9	90	525.0	60.4	30	175.0	41.3	15	201.9	42.9	13
<i>Tutufa bubo</i>	8.3	6.2	90	375.0	125.0	2	8.3	6.0	15	62.5	20.8	2
<i>Vasum ceramicum</i>	13.9	7.2	90	312.5	62.5	4	13.9	6.6	15	52.1	10.4	4

* Density recorded for RBt made outside the lagoon only (reef crest and edges of passages, excluding the single station made on the reef flat inside the lagoon, which is on a different habitat and held no trochus)

2.2 Pohnpei reef-benthos (RBt) assessment data review on the open reef

Species	Transect			Transect_P			Station			Station_P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Acanthaster planci</i>	214.3	65.2	42	692.3	139.1	13	214.3	121.5	7	375.0	177.6	4
<i>Actinopyga mauritiana</i>	17.9	10.1	42	250.0	0.0	3	17.9	8.4	7	41.7	0.0	3
<i>Bohadschia argus</i>	29.8	15.2	42	312.5	62.5	4	29.8	15.0	7	69.4	13.9	3
<i>Choriaster granulatus</i>	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
<i>Conus distans</i>	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
<i>Conus sp.</i>	83.3	35.8	42	500.0	133.6	7	83.3	40.7	7	145.8	52.4	4
<i>Cypraea caputserpensis</i>	11.9	8.3	42	250.0	0.0	2	11.9	11.9	7	83.3		1
<i>Cypraea maculifera</i>	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
<i>Cypraea tigris</i>	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
<i>Dendropoma maximum</i>	898.8	535.7	42	9 437.5	3 785.1	4	898.8	891.9	7	3 145.8	3 104.2	2
<i>Echinometra mathaei</i>	17.9	13.2	42	375.0	125.0	2	17.9	17.9	7	125.0		1
<i>Echinothrix diadema</i>	65.5	27.0	42	458.3	76.8	6	65.5	30.0	7	114.6	35.6	4
<i>Holothuria atra</i>	470.2	175.5	42	1 161.8	380.4	17	470.2	367.1	7	548.6	424.3	6
<i>Holothuria coluber</i>	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
<i>Holothuria edulis</i>	47.6	24.5	42	500.0	102.1	4	47.6	47.6	7	333.3		1
<i>Holothuria nobilis</i>	11.9	8.3	42	250.0	0.0	2	11.9	7.7	7	41.7	0.0	2
<i>Lambis crocata</i>	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
<i>Linckia guildingi</i>	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
<i>Linckia laevigata</i>	291.7	65.4	42	583.3	95.0	21	291.7	124.7	7	340.3	135.8	6
<i>Octopus sp.</i>	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
<i>Stichopus chloronotus</i>	613.1	170.7	42	1 514.7	314.7	17	613.1	383.6	7	858.3	506.3	5
<i>Tectus pyramis</i>	41.7	22.4	42	437.5	119.7	4	41.7	22.3	7	97.2	27.8	3
<i>Tridacna maxima</i>	29.8	15.2	42	312.5	62.5	4	29.8	17.5	7	69.4	27.8	3
<i>Trochus maculata</i>	59.5	32.8	42	500.0	193.6	5	59.5	35.0	7	138.9	55.6	3
<i>Trochus niloticus</i>	720.2	118.4	42	975.8	132.9	31	720.2	194.1	7	840.3	180.5	6
<i>Trochus niloticus *</i>	840.3	127.6	36	975.8	132.9	31	840.3	180.5	6	840.3	180.5	6
<i>Trochus sp.</i>	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1

* Density recorded for RBt made outside the lagoon only (reef crest and edges of passages, excluding the single station made on the reef flat inside the lagoon, which is on a different habitat and held no trochus)

2.2 Pohnpei reef-benthos (RBt) assessment data review on the open reef (continued)

Species	Transect			Transect_P			Station			Station_P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Turbo argyrostomus</i>	119.0	44.5	42	625.0	125.0	8	119.0	57.1	7	166.7	69.7	5
<i>Tutufa bubo</i>	11.9	11.9	42	500.0		1	11.9	11.9	7	83.3		1
<i>Vasum ceramicum</i>	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1

2.3 Pohnpei reef-benthos (RBt) assessment data review inside MPA/Trochus sanctuary

Station: Six 1 m x 40 m transects, density given in specimen/ha. Qualifier (_P) describes results for only units when the species of interest was present.

Species	Transect			Transect _P			Station			Station _P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Acanthaster planci</i>	161.5	36.8	48	407.9	58.0	19	161.5	66.1	8	184.5	71.5	7
<i>Actinopyga mauritiana</i>	104.2	36.3	48	454.5	105.6	11	104.2	69.5	8	166.7	104.6	5
<i>Bohadschia argus</i>	5.2	5.2	48	250.0		1	5.2	5.2	8	41.7		1
<i>Choriaster granulatus</i>	5.2	5.2	48	250.0		1	5.2	5.2	8	41.7		1
<i>Conus distans</i>	10.4	7.3	48	250.0	0.0	2	10.4	6.8	8	41.7	0.0	2
<i>Conus sp.</i>	31.3	14.2	48	300.0	50.0	5	31.3	15.2	8	83.3	0.0	3
<i>Culcita novaeguineae</i>	5.2	5.2	48	250.0		1	5.2	5.2	8	41.7		1
<i>Cypraea arabica</i>	5.2	5.2	48	250.0		1	5.2	5.2	8	41.7		1
<i>Cypraea caputserpensis</i>	20.8	10.1	48	250.0	0.0	4	20.8	11.1	8	55.6	13.9	3
<i>Cypraea maculifera</i>	5.2	5.2	48	250.0		1	5.2	5.2	8	41.7		1
<i>Cypraea moneta</i>	52.1	30.7	48	833.3	166.7	3	52.1	52.1	8	416.7		1
<i>Dendropoma maximum</i>	5.2	5.2	48	250.0		1	5.2	5.2	8	41.7		1
<i>Echinometra mathaei</i>	36.5	21.0	48	583.3	83.3	3	36.5	26.6	8	145.8	62.5	2
<i>Echinothrix diadema</i>	161.5	49.1	48	553.6	114.8	14	161.5	65.1	8	215.3	74.9	6
<i>Holothuria atra</i>	140.6	30.6	48	355.3	44.1	19	140.6	59.4	8	225.0	71.7	5
<i>Holothuria nobilis</i>	5.2	5.2	48	250.0		1	5.2	5.2	8	41.7		1
<i>Linckia laevigata</i>	182.3	65.2	48	795.5	196.0	11	182.3	118.6	8	364.6	208.6	4
<i>Stichopus chloronotus</i>	78.1	21.3	48	312.5	32.6	12	78.1	27.8	8	125.0	26.4	5
<i>Tectus pyramis</i>	36.5	12.9	48	250.0	0.0	7	36.5	16.6	8	72.9	19.9	4
<i>Thais sp.</i>	5.2	5.2	48	250.0		1	5.2	5.2	8	41.7		1
<i>Thelenota ananas</i>	10.4	7.3	48	250.0	0.0	2	10.4	10.4	8	83.3		1
<i>Trochus maculata</i>	41.7	17.2	48	333.3	52.7	6	41.7	23.6	8	111.1	36.7	3
<i>Trochus niloticus</i>	911.5	131.6	48	1 121.8	141.9	39	911.5	241.6	8	911.5	241.6	8
<i>Turbo argyrostomus</i>	224.0	47.2	48	488.6	68.8	22	224.0	56.7	8	224.0	56.7	8
<i>Tutufa bubo</i>	5.2	5.2	48	250.0		1	5.2	5.2	8	41.7		1
<i>Vasum ceramicum</i>	20.8	12.5	48	333.3	83.3	3	20.8	11.1	8	55.6	13.9	3

3.1 Pohnpei reef-front search (RFs) assessment data review (All stations)

Station: Six 5-min search periods, density given in specimen/ha. Qualifier (_P) describes results for only units when the species of interest was present.

Species	Search period			Search period _P			Station			Station _P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Acanthaster planci</i>	69.9	10.2	158	129.9	16.3	85	70.7	18.7	26	87.5	21.6	21
<i>Actinopyga mauritiana</i>	10.5	1.6	158	29.6	3.1	56	10.6	2.7	26	16.2	3.5	17
<i>Bohadschia argus</i>	0.1	0.1	158	13.6		1	0.1	0.1	26	2.3		1
<i>Bohadschia graeffei</i>	0.2	0.1	158	14.9	0.0	2	0.2	0.2	26	5.0		1
<i>Cerithium nodulosum</i>	0.1	0.1	158	11.2		2	0.1	0.1	26	2.8		1
<i>Choriaster granulatus</i>	0.3	0.2	158	17.6	4.4	3	0.3	0.3	26	8.8		1
<i>Conus distans</i>	2.3	0.8	158	27.6	7.1	13	2.3	1.2	26	8.5	3.4	7
<i>Conus miles</i>	0.1	0.1	158	11.5		1	0.1	0.1	26	1.9		1
<i>Conus sp.</i>	1.7	0.7	158	27.4	7.5	10	1.8	0.9	26	6.5	2.6	7
<i>Culcita novaeguineae</i>	1.5	0.5	158	23.6	4.1	10	1.4	0.6	26	6.3	1.4	6
<i>Dendropoma maximum</i>	32.7	30.0	158	573.8	521.2	9	33.1	30.4	26	122.9	111.5	7
<i>Echinometra mathaei</i>	0.6	0.4	158	32.9	10.2	3	0.6	0.6	26	8.2	6.1	2
<i>Echinothrix diadema</i>	1.6	0.5	158	20.8	3.1	12	1.6	0.6	26	5.1	1.0	8
<i>Holothuria atra</i>	2.5	0.8	158	33.4	6.1	12	2.6	1.0	26	8.4	2.2	8
<i>Holothuria edulis</i>	0.6	0.4	158	33.8	9.3	3	0.6	0.6	26	8.4	5.9	2
<i>Holothuria nobilis</i>	0.6	0.3	158	16.1	3.5	6	0.6	0.3	26	2.7	0.6	6
<i>Linckia guildingi</i>	4.3	0.8	158	23.2	2.4	29	4.3	1.4	26	8.6	2.2	13
<i>Linckia laevigata</i>	11.3	2.6	158	71.2	10.6	25	11.4	5.9	26	33.0	15.0	9
<i>Octopus sp.</i>	0.3	0.3	158	43.1		1	0.3	0.3	26	7.2		1
<i>Ovula ovum</i>	0.2	0.2	158	26.2		1	0.2	0.2	26	4.4		1
<i>Panulirus penicillatus</i>	0.1	0.1	158	10.2		1	0.1	0.1	26	1.7		1
<i>Pleuroploca filamentosa</i>	0.2	0.1	158	12.1	2.0	2	0.2	0.1	26	2.0	0.3	2
<i>Stichodactyla sp.</i>	0.7	0.3	158	15.0	2.3	7	0.7	0.3	26	3.5	0.7	5
<i>Stichopus chloronotus</i>	1.1	0.5	158	21.7	5.4	8	1.1	0.6	26	7.2	1.7	4
<i>Tectus pyramis</i>	1.1	0.6	158	34.7	11.3	5	1.1	0.6	26	5.8	1.9	5
<i>Thais armigera</i>	0.3	0.2	158	21.0	6.9	2	0.3	0.2	26	3.5	1.2	2
<i>Tridacna maxima</i>	0.9	0.4	158	19.8	4.2	7	0.9	0.4	26	3.8	0.8	6

3.1 Pohnpei reef-front search (RFs) assessment data review (All stations) continued

Species	Search period			Search period _P			Station			Station _P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Trochus maculata</i>	1.6	1.0	158	86.2	24.9	3	1.7	1.7	26	43.1		1
<i>Trochus niloticus</i>	104.0	10.1	158	127.4	11.3	129	103.8	21.4	26	103.8	21.4	26
<i>Turbo argyrostomus</i>	5.3	1.1	158	25.3	3.6	33	5.3	1.6	26	8.6	2.2	16
<i>Vasum ceramicum</i>	0.8	0.4	158	21.3	5.7	6	0.8	0.4	26	4.3	1.0	5

3.2 Pohnpei reef-front search (RFs) assessment data review outside MPA/Trochus sanctuary

Station: Six 5-min search periods, density given in specimen/ha. Qualifier (_P) describes results for only units when the species of interest was present.

Species	Search period			Search period _P			Station			Station _P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Acanthaster planci</i>	83.8	14.4	104	158.4	22.9	55	85.2	26.9	17	111.4	31.9	13
<i>Actinopyga mauritiana</i>	10.3	1.7	104	27.4	3.0	39	10.4	3.1	17	13.7	3.6	13
<i>Bohadschia argus</i>	0.1	0.1	104	13.6		1	0.1	0.1	17	2.3		1
<i>Bohadschia graeffei</i>	0.3	0.2	104	14.9	0.0	2	0.3	0.3	17	5.0		1
<i>Cerithium nodulosum</i>	0.2	0.2	104	11.2		2	0.2	0.2	17	2.8		1
<i>Conus distans</i>	2.1	1.0	104	24.1	9.7	9	2.1	1.3	17	7.2	3.7	5
<i>Conus miles</i>	0.1	0.1	104	11.5		1	0.1	0.1	17	1.9		1
<i>Conus sp.</i>	2.5	1.1	104	29.1	8.2	9	2.6	1.3	17	7.3	2.9	6
<i>Culcita novaeguineae</i>	1.5	0.6	104	21.7	4.8	7	1.4	0.8	17	7.8	2.3	3
<i>Dendropoma maximum</i>	3.7	2.0	104	63.7	24.7	6	3.7	3.2	17	15.9	13.1	4
<i>Echinothrix diadema</i>	1.6	0.6	104	18.6	2.7	9	1.6	0.7	17	5.5	1.3	5
<i>Holothuria atra</i>	1.6	0.7	104	33.3	5.1	5	1.6	0.8	17	6.9	1.7	4
<i>Holothuria edulis</i>	0.1	0.1	104	15.1		1	0.1	0.1	17	2.5		1
<i>Holothuria nobilis</i>	0.8	0.4	104	16.7	4.2	5	0.8	0.4	17	2.8	0.7	5
<i>Linckia guildingi</i>	5.7	1.2	104	23.6	2.6	25	5.7	2.0	17	9.7	2.8	10
<i>Linckia laevigata</i>	8.7	3.3	104	90.0	22.7	10	8.8	8.0	17	30.0	26.6	5
<i>Ovula ovum</i>	0.3	0.3	104	26.2		1	0.3	0.3	17	4.4		1
<i>Pleuroploca filamentosa</i>	0.1	0.1	104	14.1		1	0.1	0.1	17	2.4		1
<i>Stichodactyla sp.</i>	0.7	0.3	104	12.8	1.0	6	0.8	0.4	17	3.2	0.8	4
<i>Stichopus chloronotus</i>	1.2	0.7	104	30.2	9.2	4	1.2	0.7	17	6.7	2.3	3
<i>Tectus pyramis</i>	0.9	0.7	104	47.2	18.9	2	0.9	0.7	17	7.9	3.2	2
<i>Thais armigera</i>	0.1	0.1	104	14.1		1	0.1	0.1	17	2.4		1
<i>Tridacna maxima</i>	0.8	0.3	104	15.7	2.1	5	0.8	0.4	17	3.3	0.6	4
<i>Trochus niloticus</i>	98.8	10.4	104	119.5	11.4	86	98.4	21.7	17	98.4	21.7	17
<i>Turbo argyrostomus</i>	4.2	1.2	104	21.0	4.2	21	4.2	1.5	17	6.5	1.9	11
<i>Vasum ceramicum</i>	0.4	0.3	104	22.5	10.6	2	0.4	0.3	17	3.7	1.8	2

3.3 Pohnpei reef-front search (RFs) assessment data review inside MPA/Trochus sanctuary

Station: Six 5-min search periods, density given in specimen/ha. Qualifier (_P) describes results for only units when the species of interest was present.

Species	Search period			Search period _P			Station			Station _P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Acanthaster planci</i>	43.2	10.3	54	77.7	15.9	30	43.2	16.7	9	48.6	17.9	8
<i>Actinopyga mauritiana</i>	10.9	3.2	54	34.8	7.4	17	10.9	5.5	9	24.6	8.4	4
<i>Choriaster granulatus</i>	1.0	0.6	54	17.6	4.4	3	1.0	1.0	9	8.8		1
<i>Conus distans</i>	2.6	1.4	54	35.4	7.7	4	2.6	2.4	9	11.8	9.7	2
<i>Conus sp.</i>	0.2	0.2	54	12.5		1	0.2	0.2	9	2.1		1
<i>Culcita novaeguineae</i>	1.6	1.0	54	28.1	8.6	3	1.6	0.9	9	4.7	1.4	3
<i>Dendropoma maximum</i>	88.6	87.8	54	1593.9	1573.7	3	88.6	87.7	9	265.7	262.3	3
<i>Echinometra mathaei</i>	1.8	1.1	54	32.9	10.2	3	1.8	1.6	9	8.2	6.1	2
<i>Echinothrix diadema</i>	1.5	1.0	54	27.2	9.7	3	1.5	0.9	9	4.5	1.6	3
<i>Holothuria atra</i>	4.3	2.0	54	33.5	10.2	7	4.3	2.5	9	9.8	4.4	4
<i>Holothuria edulis</i>	1.6	1.1	54	43.1	0.0	2	1.6	1.6	9	14.4		1
<i>Holothuria nobilis</i>	0.2	0.2	54	13.2		1	0.2	0.2	9	2.2		1
<i>Linckia guildingi</i>	1.6	0.9	54	21.2	7.4	4	1.6	0.9	9	4.7	1.3	3
<i>Linckia laevigata</i>	16.3	4.3	54	58.6	8.4	15	16.3	8.3	9	36.6	12.9	4
<i>Octopus sp.</i>	0.8	0.8	54	43.1		1	0.8	0.8	9	7.2		1
<i>Panulirus penicillatus</i>	0.2	0.2	54	10.2		1	0.2	0.2	9	1.7		1
<i>Pleuroploca filamentosa</i>	0.2	0.2	54	10.2		1	0.2	0.2	9	1.7		1
<i>Stichodactyla sp.</i>	0.5	0.5	54	28.0		1	0.5	0.5	9	4.7		1
<i>Stichopus chloronotus</i>	1.0	0.5	54	13.2	0.0	4	1.0	1.0	9	8.8		1
<i>Tectus pyramis</i>	1.5	1.1	54	26.4	14.8	3	1.5	1.0	9	4.4	2.5	3
<i>Thais armigera</i>	0.5	0.5	54	28.0		1	0.5	0.5	9	4.7		1
<i>Tridacna maxima</i>	1.1	0.9	54	30.0	13.1	2	1.1	0.8	9	5.0	2.2	2
<i>Trochus maculata</i>	4.8	2.9	54	86.2	24.9	3	4.8	4.8	9	43.1		1
<i>Trochus niloticus</i>	114.1	21.6	54	143.2	25.4	43	114.1	48.4	9	114.1	48.4	9
<i>Turbo argyrostomus</i>	7.3	2.3	54	32.9	6.3	12	7.3	3.6	9	13.2	5.3	5
<i>Vasum ceramicum</i>	1.5	0.9	54	20.8	7.8	4	1.5	0.9	9	4.6	1.5	3

4.1 Pohnpei mother-of-pearl transect (MOPt) assessment All Pohnpei data review

Station: Six 1 m x 40 m, density given in specimen/ha. Qualifier (_P) describes results for only units when the species of interest was present.

Species	Transect			Transect _P			Station			Station _P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Acanthaster planci</i>	93.8	16.1	144	275.5	35.1	49	93.8	26.7	24	140.6	34.6	16
<i>Actinopyga mauritiana</i>	51.2	12.9	144	254.3	49.0	29	51.2	22.3	24	102.4	39.9	12
<i>Bohadschia argus</i>	1.7	1.2	144	125.0	0.0	2	1.7	1.2	24	20.8	0.0	2
<i>Bohadschia graeffei</i>	6.1	2.2	144	125.0	0.0	7	6.1	4.6	24	72.9	31.3	2
<i>Charonia tritonis</i>	0.9	0.9	144	125.0		1	0.9	0.9	24	20.8		1
<i>Choriaster granulatus</i>	2.6	1.5	144	125.0	0.0	3	2.6	1.9	24	31.3	10.4	2
<i>Conus distans</i>	16.5	4.6	144	182.7	18.0	13	16.5	5.5	24	49.5	7.8	8
<i>Conus imperialis</i>	0.9	0.9	144	125.0		1	0.9	0.9	24	20.8		1
<i>Culcita novaeguineae</i>	4.3	2.3	144	156.3	31.3	4	4.3	2.2	24	26.0	5.2	4
<i>Cypraea caputserpensis</i>	1.7	1.2	144	125.0	0.0	2	1.7	1.2	24	20.8	0.0	2
<i>Cypraea maculifera</i>	1.7	1.2	144	125.0	0.0	2	1.7	1.2	24	20.8	0.0	2
<i>Cypraea sp.</i>	0.9	0.9	144	125.0		1	0.9	0.9	24	20.8		1
<i>Dendropoma maximum</i>	30.4	12.6	144	397.7	122.5	11	30.4	17.8	24	104.2	53.8	7
<i>Echinometra mathaei</i>	2.6	2.6	144	375.0		1	2.6	2.6	24	62.5		1
<i>Echinothrix diadema</i>	13.0	4.6	144	208.3	29.5	9	13.0	7.8	24	78.1	33.3	4
<i>Holothuria nobilis</i>	0.9	0.9	144	125.0		1	0.9	0.9	24	20.8		1
<i>Linckia guildingi</i>	56.4	9.6	144	232.1	19.9	35	56.4	18.1	24	96.7	26.3	14
<i>Linckia laevigata</i>	13.9	5.2	144	181.8	45.7	11	13.9	5.0	24	37.0	9.0	9
<i>Octopus sp.</i>	2.6	1.5	144	125.0	0.0	3	2.6	1.4	24	20.8	0.0	3
<i>Pleuroploca trapezium</i>	0.9	0.9	144	125.0		1	0.9	0.9	24	20.8		1
<i>Spondylus sp.</i>	0.9	0.9	144	125.0		1	0.9	0.9	24	20.8		1
<i>Stichodactyla sp.</i>	0.9	0.9	144	125.0		1	0.9	0.9	24	20.8		1
<i>Stichopus chloronotus</i>	5.2	2.4	144	150.0	25.0	5	5.2	2.6	24	31.3	6.0	4
<i>Tectus pyramis</i>	22.6	5.9	144	180.6	25.2	18	22.6	8.6	24	60.2	16.8	9
<i>Thais armigera</i>	5.2	2.7	144	187.5	36.1	4	5.2	3.6	24	62.5	0.0	2
<i>Thelenota ananas</i>	1.7	1.2	144	125.0	0.0	2	1.7	1.2	24	20.8	0.0	2
<i>Tridacna maxima</i>	12.2	4.5	144	194.4	36.7	9	12.2	5.7	24	41.7	15.1	7
<i>Trochus maculata</i>	6.1	3.8	144	218.8	93.8	4	6.1	3.9	24	48.6	18.4	3

4.1 Pohnpei mother-of-pearl transect (MOPT) assessment All Pohnpei data review (continued)

Species	Transect			Transect_P			Station			Station_P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Trochus niloticus</i>	591.1	45.9	144	686.5	48.0	124	591.1	93.5	24	591.1	93.5	24
<i>Trochus sp.</i>	0.9	0.9	144	125.0		1	0.9	0.9	24	20.8		1
<i>Turbo argyrostomus</i>	87.7	14.5	144	268.6	30.9	47	87.7	24.0	24	110.7	28.0	19
<i>Tutufa bubo</i>	0.9	0.9	144	125.0		1	0.9	0.9	24	20.8		1
<i>Vasum ceramicum</i>	1.7	1.2	144	125.0	0.0	2	1.7	1.2	24	20.8	0.0	2
<i>Vasum turbinellum</i>	0.9	0.9	144	125.0		1	0.9	0.9	24	20.8		1

4.2 Pohnpei mother-of-pearl transect (MOPt) at open reefs

Species	Transect			Transect_P			Station			Station_P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Acanthaster planci</i>	112.7	21.9	102	310.8	44.6	37	112.7	35.8	17	159.7	44.3	12
<i>Actinopyga mauritiana</i>	68.6	17.8	102	259.3	52.5	27	68.6	30.6	17	116.7	46.9	10
<i>Bohadschia argus</i>	1.2	1.2	102	125.0		1	1.2	1.2	17	20.8		1
<i>Bohadschia graeffei</i>	2.5	1.7	102	125.0	0.0	2	2.5	2.5	17	41.7		1
<i>Charonia tritonis</i>	1.2	1.2	102	125.0		1	1.2	1.2	17	20.8		1
<i>Choriaster granulatus</i>	2.5	1.7	102	125.0	0.0	2	2.5	2.5	17	41.7		1
<i>Conus distans</i>	18.4	5.9	102	187.5	20.8	10	18.4	7.1	17	52.1	10.4	6
<i>Conus imperialis</i>	1.2	1.2	102	125.0		1	1.2	1.2	17	20.8		1
<i>Culcita novaeguineae</i>	3.7	2.1	102	125.0	0.0	3	3.7	2.0	17	20.8	0.0	3
<i>Cypraea caputserpensis</i>	2.5	1.7	102	125.0	0.0	2	2.5	1.7	17	20.8	0.0	2
<i>Cypraea maculifera</i>	2.5	1.7	102	125.0	0.0	2	2.5	1.7	17	20.8	0.0	2
<i>Cypraea sp.</i>	1.2	1.2	102	125.0		1	1.2	1.2	17	20.8		1
<i>Dendropoma maximum</i>	8.6	4.4	102	175.0	50.0	5	8.6	4.0	17	29.2	8.3	5
<i>Echinometra mathaei</i>	3.7	3.7	102	375.0		1	3.7	3.7	17	62.5		1
<i>Echinothrix diadema</i>	18.4	6.4	102	208.3	29.5	9	18.4	10.8	17	78.1	33.3	4
<i>Holothuria nobilis</i>	1.2	1.2	102	125.0		1	1.2	1.2	17	20.8		1
<i>Linckia guildingi</i>	71.1	12.9	102	250.0	22.4	29	71.1	24.7	17	134.3	35.3	9
<i>Linckia laevigata</i>	15.9	7.1	102	203.1	62.2	8	15.9	6.6	17	38.7	11.5	7
<i>Octopus sp.</i>	3.7	2.1	102	125.0	0.0	3	3.7	2.0	17	20.8	0.0	3
<i>Stichodactyla sp.</i>	1.2	1.2	102	125.0		1	1.2	1.2	17	20.8		1
<i>Stichopus chloronotus</i>	1.2	1.2	102	125.0		1	1.2	1.2	17	20.8		1
<i>Tectus pyramis</i>	28.2	8.0	102	191.7	29.5	15	28.2	11.7	17	68.5	20.7	7
<i>Thais armigera</i>	7.4	3.8	102	187.5	36.1	4	7.4	5.0	17	62.5	0.0	2
<i>Tridacna maxima</i>	12.3	5.1	102	178.6	37.2	7	12.3	7.4	17	41.7	20.8	5
<i>Trochus maculata</i>	7.4	5.2	102	250.0	125.0	3	7.4	5.3	17	62.5	20.8	2
<i>Trochus niloticus</i>	699.8	56.3	102	784.3	57.0	91	699.8	112.5	17	699.8	112.5	17
<i>Trochus sp.</i>	1.2	1.2	102	125.0		1	1.2	1.2	17	20.8		1
<i>Turbo argyrostomus</i>	102.9	19.3	102	283.8	38.0	37	102.9	31.9	17	125.0	36.2	14

4.2 Pohnpei mother-of-pearl transect (MOPt) at open reefs (continued)

Species	Transect			Transect_P			Station			Station_P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Tutufa bubo</i>	1.2	1.2	102	125.0		1	1.2	1.2	17	20.8		1
<i>Vasum ceramicum</i>	1.2	1.2	102	125.0		1	1.2	1.2	17	20.8		1
<i>Vasum turbinellum</i>	1.2	1.2	102	125.0		1	1.2	1.2	17	20.8		1

4.3 Pohnpei mother-of-pearl transect (MOPt) inside MPA/Trochus sanctuary

Species	Transect			Transect_P			Station			Station_P		
	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n	Mean density	SE	n
<i>Acanthaster planci</i>	47.6	13.4	42	166.7	23.5	12	47.6	23.1	7	83.3	29.5	4
<i>Actinopyga mauritiana</i>	8.9	6.6	42	187.5	62.5	2	8.9	6.2	7	31.3	10.4	2
<i>Bohadschia argus</i>	3.0	3.0	42	125.0		1	3.0	3.0	7	20.8		1
<i>Bohadschia graeffei</i>	14.9	6.3	42	125.0	0.0	5	14.9	14.9	7	104.2		1
<i>Choriaster granulatus</i>	3.0	3.0	42	125.0		1	3.0	3.0	7	20.8		1
<i>Conus distans</i>	11.9	7.1	42	166.7	41.7	3	11.9	7.7	7	41.7	0.0	2
<i>Culcita novaeguineae</i>	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
<i>Dendropoma maximum</i>	83.3	41.0	42	583.3	195.4	6	83.3	58.4	7	291.7	104.2	2
<i>Linckia guildingi</i>	20.8	8.4	42	145.8	20.8	6	20.8	6.4	7	29.2	5.1	5
<i>Linckia laevigata</i>	8.9	5.0	42	125.0	0.0	3	8.9	6.2	7	31.3	10.4	2
<i>Pleuroploca trapezium</i>	3.0	3.0	42	125.0		1	3.0	3.0	7	20.8		1
<i>Spondylus sp.</i>	3.0	3.0	42	125.0		1	3.0	3.0	7	20.8		1
<i>Stichopus chloronotus</i>	14.9	7.6	42	156.3	31.3	4	14.9	7.5	7	34.7	6.9	3
<i>Tectus pyramis</i>	8.9	5.0	42	125.0	0.0	3	8.9	6.2	7	31.3	10.4	2
<i>Thelenota ananas</i>	6.0	4.2	42	125.0	0.0	2	6.0	3.8	7	20.8	0.0	2
<i>Tridacna maxima</i>	11.9	9.3	42	250.0	125.0	2	11.9	8.9	7	41.7	20.8	2
<i>Trochus maculata</i>	3.0	3.0	42	125.0		1	3.0	3.0	7	20.8		1
<i>Trochus niloticus</i>	327.4	61.9	42	416.7	71.3	33	327.4	128.2	7	327.4	128.2	7
<i>Turbo argyrostomus</i>	50.6	16.0	42	212.5	32.5	10	50.6	24.8	7	70.8	30.6	5
<i>Vasum ceramicum</i>	3.0	3.0	42	125.0		1	3.0	3.0	7	20.8		1

5 Pohnpei species size review - all techniques

Species	Mean length (cm)	SE	n
<i>Trochus niloticus</i>	10.2	0.0	1932
<i>Turbo argyrostomus</i>	6.0	0.1	209
<i>Stichopus chloronotus</i>	16.8	0.8	137
<i>Holothuria atra</i>	16.7	0.7	124
<i>Actinopyga mauritiana</i>	19.5	0.3	210
<i>Tectus pyramis</i>	5.7	0.1	48
<i>Conus distans</i>	7.1	0.3	37
<i>Tridacna maxima</i>	9.9	1.1	27
<i>Trochus maculata</i>	3.6	0.2	31
<i>Holothuria nobilis</i>	24.6	0.9	10
<i>Holothuria edulis</i>	14.5	0.9	11
<i>Bohadschia argus</i>	20.6	2.0	9
<i>Vasum ceramicum</i>	9.6	0.7	14
<i>Bohadschia graeffei</i>	35.0	2.5	9
<i>Thais armigera</i>	4.3	0.1	8
<i>Thelenota ananas</i>	36.8	2.2	4
<i>Cypraea maculifera</i>	4.1	0.1	4
<i>Tutufa bubo</i>	20.0	0.8	4
<i>Trochus sp.</i>	2.1		2
<i>Conus sp.</i>	8.0		40
<i>Cypraea caputserpensis</i>	2.5		8
<i>Charonia tritonis</i>	31.0		1
<i>Conus imperialis</i>	4.5		1
<i>Cypraea arabica</i>	4.5		1
<i>Cypraea tigris</i>	7.3		1
<i>Lambis crocata</i>	15.0		1
<i>Pleuroploca trapezium</i>	4.0		1
<i>Thais sp.</i>	4.1		1
<i>Vasum turbinellum</i>	4.5		1
<i>Acanthaster planci</i>			909
<i>Dendropoma maximum</i>			313
<i>Linckia laevigata</i>			193
<i>Linckia guildingi</i>			118
<i>Echinothrix diadema</i>			73
<i>Culcita novaeguineae</i>			19
<i>Echinometra mathaei</i>			16
<i>Cypraea moneta</i>			10
<i>Choriaster granulatus</i>			9
<i>Stichodactyla sp.</i>			8
<i>Octopus sp.</i>			5
<i>Cerithium nodulosum</i>			2
<i>Ovula ovum</i>			2
<i>Pleuroploca filamentosa</i>			2
<i>Holothuria coluber</i>			1
<i>Spondylus sp.</i>			1
<i>Panulirus penicillatus</i>			1
<i>Conus miles</i>			1
<i>Cypraea sp.</i>			1

6 *Pohnpei calculated weight of the trochus sample per site and size*

Trochus size (mm)	Number per size			weight per specimen (g)		Wet weight (kg)			Dry weight (kg)		
	open reefs	MPA	All Pohnpei	Dry	Wet	open reefs	MPA	All	open reefs	MPA	All
132	0	1	1	580.0	799.0	0.0	0.8	0.8	0.0	0.6	0.6
130	2	1	3	554.7	762.4	1.5	0.8	2.3	1.1	0.6	1.7
129	1	0	1	542.4	744.6	0.7	0.0	0.7	0.5	0.0	0.5
128	1	0	1	530.2	727.0	0.7	0.0	0.7	0.5	0.0	0.5
126	2	1	3	506.3	692.7	1.4	0.7	2.1	1.0	0.5	1.5
125	4	5	9	494.7	675.9	2.7	3.4	6.1	2.0	2.5	4.5
124	7	1	8	483.2	659.5	4.6	0.7	5.3	3.4	0.5	3.9
123	3	3	6	471.9	643.3	1.9	1.9	3.9	1.4	1.4	2.8
122	6	3	9	460.8	627.4	3.8	1.9	5.6	2.8	1.4	4.1
121	7	5	12	449.9	611.7	4.3	3.1	7.3	3.1	2.2	5.4
120	20	10	30	439.1	596.3	11.9	6.0	17.9	8.8	4.4	13.2
119	13	5	18	428.5	581.2	7.6	2.9	10.5	5.6	2.1	7.7
118	9	2	11	418.1	566.3	5.1	1.1	6.2	3.8	0.8	4.6
117	5	4	9	407.8	551.7	2.8	2.2	5.0	2.0	1.6	3.7
116	13	8	21	397.7	537.4	7.0	4.3	11.3	5.2	3.2	8.4
115	36	19	55	387.8	523.3	18.8	9.9	28.8	14.0	7.4	21.3
114	22	10	32	378.0	509.4	11.2	5.1	16.3	8.3	3.8	12.1
113	11	8	19	368.4	495.8	5.5	4.0	9.4	4.1	2.9	7.0
112	24	11	35	359.0	482.5	11.6	5.3	16.9	8.6	3.9	12.6
111	18	8	26	349.7	469.4	8.4	3.8	12.2	6.3	2.8	9.1
110	57	31	88	340.6	456.5	26.0	14.2	40.2	19.4	10.6	30.0
109	5	5	10	331.6	443.9	2.2	2.2	4.4	1.7	1.7	3.3
108	6	4	10	322.8	431.5	2.6	1.7	4.3	1.9	1.3	3.2
107	12	3	15	314.2	419.4	5.0	1.3	6.3	3.8	0.9	4.7
106	16	4	20	305.7	407.5	6.5	1.6	8.1	4.9	1.2	6.1
105	54	17	71	297.3	395.8	21.4	6.7	28.1	16.1	5.1	21.1
104	17	12	29	289.1	384.3	6.5	4.6	11.1	4.9	3.5	8.4
103	13	7	20	281.1	373.1	4.9	2.6	7.5	3.7	2.0	5.6
102	23	6	29	273.2	362.1	8.3	2.2	10.5	6.3	1.6	7.9
101	13	8	21	265.4	351.3	4.6	2.8	7.4	3.5	2.1	5.6
100	52	18	70	257.8	340.7	17.7	6.1	23.9	13.4	4.6	18.0
99	9	4	13	250.4	330.4	3.0	1.3	4.3	2.3	1.0	3.3
98	13	0	13	243.1	320.2	4.2	0.0	4.2	3.2	0.0	3.2
97	7	2	9	235.9	310.3	2.2	0.6	2.8	1.7	0.5	2.1
96	4	4	8	228.9	300.6	1.2	1.2	2.4	0.9	0.9	1.8
95	31	4	35	222.0	291.1	9.0	1.2	10.2	6.9	0.9	7.8
94	8	3	11	215.2	281.8	2.3	0.8	3.1	1.7	0.6	2.4
93	5	4	9	208.6	272.7	1.4	1.1	2.5	1.0	0.8	1.9
92	11	2	13	202.1	263.8	2.9	0.5	3.4	2.2	0.4	2.6
91	8	3	11	195.8	255.1	2.0	0.8	2.8	1.6	0.6	2.2
90	22	6	28	189.6	246.6	5.4	1.5	6.9	4.2	1.1	5.3
89	3	0	3	183.5	238.2	0.7	0.0	0.7	0.6	0.0	0.6
88	5	2	7	177.5	230.1	1.2	0.5	1.6	0.9	0.4	1.2
87	3	4	7	171.7	222.2	0.7	0.9	1.6	0.5	0.7	1.2
86	5	5	10	166.0	214.4	1.1	1.1	2.1	0.8	0.8	1.7
85	6	3	9	160.4	206.9	1.2	0.6	1.9	1.0	0.5	1.4

6 Pohnpei calculated weight of the trochus sample per site and size
(continued)

Trochus size (mm)	Number per size			weight per specimen (g)		Wet weight (kg)			Dry weight (kg)		
	open reefs	MPA	All Pohnpei	Dry	Wet	open reefs	MPA	All	open reefs	MPA	All
84	6	0	6	155.0	199.5	1.2	0.0	1.2	0.9	0.0	0.9
83	3	0	3	149.6	192.3	0.6	0.0	0.6	0.4	0.0	0.4
82	4	1	5	144.4	185.3	0.7	0.2	0.9	0.6	0.1	0.7
80	11	2	13	134.4	171.7	1.9	0.3	2.2	1.5	0.3	1.7
78	2	1	3	124.8	158.9	0.3	0.2	0.5	0.2	0.1	0.4
77	1	0	1	120.2	152.7	0.2	0.0	0.2	0.1	0.0	0.1
76	2	2	4	115.7	146.7	0.3	0.3	0.6	0.2	0.2	0.5
75	8	0	8	111.3	140.9	1.1	0.0	1.1	0.9	0.0	0.9
74	5	0	5	107.0	135.2	0.7	0.0	0.7	0.5	0.0	0.5
72	1	2	3	98.8	124.3	0.1	0.2	0.4	0.1	0.2	0.3
71	4	1	5	94.8	119.1	0.5	0.1	0.6	0.4	0.1	0.5
70	9	4	13	91.0	114.0	1.0	0.5	1.5	0.8	0.4	1.2
69	1	1	2	87.3	109.1	0.1	0.1	0.2	0.1	0.1	0.2
68	2	0	2	83.6	104.3	0.2	0.0	0.2	0.2	0.0	0.2
67	2	0	2	80.1	99.6	0.2	0.0	0.2	0.2	0.0	0.2
66	3	1	4	76.6	95.1	0.3	0.1	0.4	0.2	0.1	0.3
65	5	0	5	73.3	90.8	0.5	0.0	0.5	0.4	0.0	0.4
64	3	0	3	70.0	86.6	0.3	0.0	0.3	0.2	0.0	0.2
63	2	0	2	66.9	82.5	0.2	0.0	0.2	0.1	0.0	0.1
62	1	0	1	63.8	78.5	0.1	0.0	0.1	0.1	0.0	0.1
61	2	0	2	60.9	74.7	0.1	0.0	0.1	0.1	0.0	0.1
60	1	4	5	58.0	71.0	0.1	0.3	0.4	0.1	0.2	0.3
59	1	0	1	55.2	67.4	0.1	0.0	0.1	0.1	0.0	0.1
58	0	1	1	52.5	64.0	0.0	0.1	0.1	0.0	0.1	0.1
57	0	1	1	49.9	60.7	0.0	0.1	0.1	0.0	0.0	0.0
55	2	1	3	45.0	54.4	0.1	0.1	0.2	0.1	0.0	0.1
54	0	1	1	42.7	51.4	0.0	0.1	0.1	0.0	0.0	0.0
53	0	1	1	40.4	48.5	0.00	0.05	0.05	0.00	0.04	0.04
51	1	1	2	36.1	43.1	0.04	0.04	0.09	0.04	0.04	0.07
50	1	0	1	34.1	40.6	0.04	0.0	0.04	0.03	0.00	0.03
48	0	1	1	30.2	35.8	0.0	0.04	0.04	0.0	0.03	0.03
40	0	1	1	17.8	20.5	0.0	0.02	0.02	0.0	0.02	0.02
31	1	0	1	8.4	9.4	0.01	0.0	0.01	0.01	0.0	0.01
29	1	0	1	6.9	7.6	0.01	0.0	0.01	0.01	0.0	0.01
23	1	0	1	3.5	3.7	0.004	0.0	0.004	0.004	0.0	0.004

7 *Trochus* production for Pohnpei State (1948-2005)

Year	Short tons	Metric tonnes Mt	Comments
1948		84.4	
1949		108.9	
1950		120.0	
1951		170.6	
1952		28.1	
1953		62.6	
1954		65.0	
1955		73.5	
1956		69.9	
1957			
1958			
1959			
1960			
1961			
1962			
1963			
1964			
1965			
1966			
1967			
1968			
1969	72	65.52	
1970	99	90.09	
1971			
1972	124	112.84	
1973	103	93.73	
1974			
1975	201	182.91	
1976	30	27.3	
1977	101	91.91	
1978	87	79.17	
1979	121	110.11	
1980			
1981	81	73.71	
1982	67	60.97	
1983			
1984	149	135.59	
1985			
1986	200	182	
1987			
1988	211	192.01	
1989			
1990	95	86.45	
1991	76	69.16	
1992	85.76	78.04	
1993			
1994	124.98	113.73	
1995			
1996			

7 *Trochus* production for Pohnpei State (1948-2005) continued

Year	Short tons	Metric tonnes Mt	
1997			
1998			
1999		121	
2000			
2001		6	From Ngatik
2002			
2003			
2004	73,186 lb	33.2	
2005	15.35	14	From Sapwuafik
2006			
2007			
		Average 93.3 mt	

Source: Pohnpei Marine Resource Development Division

*open harvest season

**production from the named outer islands

8 *Habitat descriptors for independent assessment – Pohnpei*

