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## **Assessment of the trochus resources of Kosrae in June 2008 and recommendations for management**

Emmanuel Tardy,<sup>1</sup> Kalo Pakoa,<sup>1</sup> Kim Friedman<sup>1</sup>



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# 1 Introduction

## 1.1 General overview

The Federated States of Micronesia (FSM) is located in the Micronesian region between the Marshall Islands and Palau. FSM is divided into four distinctively separate states: Chuuk, Yap, Kosrae and the capital state of 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 new 20-year (2004–2023) compact's financial terms aim to encourage sustainable development. Present population stands at about 108,000 people of predominantly Micronesian origin. Chuuk is the most populous state, with 48.8% of total population, while 24.2% live in Pohnpei, 6.2% in Kosrae and 5.2% in Yap State. The states are separated by vast distances and have different cultures and languages.

Kosrae is the easternmost island in the Caroline Islands, situated only 390 km north of the equator. Unlike the other three states of the FSM, Kosrae State consists of only one volcanic island. Most of Kosrae is mountainous, with a large part of the island surrounded by marsh alimented with high rainfall, making it one of the wettest places on earth (average annual rainfall around 5000 mm). The total land area is about 110 km<sup>2</sup> and the total population of Kosrae State was 7686 people at the 2000 census (Government of the Federated States of Micronesia 2000). Traditional farming and fishing are the principal sources of the islanders' subsistence, but a small tourism industry based mostly on scuba diving also exists.

## 1.2 Trochus fisheries in Kosrae

### 1.2.1 *Trochus* introduction

The commercial mother-of-pearl topshell (*Trochus niloticus*) does not naturally occur on most islands in FSM except the main island of Yap (Figure 1). Trochus were first introduced in the FSM when shells were brought to Chuuk Lagoon from Palau in 1931 (Asano 1991). According to Benito Nero, Mayor of Piis-Panewu (pers. com. 2006), the shells were introduced by the Japanese administration from Rabaol Province in Papua New Guinea (where they had perhaps been stolen) and transported by cargo ship to Chuuk, earning it the name *Rabaol Moat* in Chuukese, meaning 'Rabaol shell'. Trochus successfully spread over the lagoon reefs and developed into a fishery. From Chuuk, trochus were later introduced to Pohnpei, Palau and Yap in 1939.

Introduction of trochus to Kosrae was first attempted in 1937, but was unsuccessful (McGowan 1957). A new attempt was made in the late 1940s or early 1950s with stock from Pohnpei, but was also unsuccessful. In 1959, 500 live trochus were imported from Pohnpei and released at 13 sites in Kosrae. In 1973, a large number of trochus were observed on the reefs, showing a successful introduction (Wass 1973). Between 1992 and 1994, a propagation programme was conducted to produce a population for transplantation, but there is no record of an active transplantation programme during the following years.



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

### 1.2.2 Biology and ecology of trochus

The average life span for trochus is 15–20 years and most animals reach reproductive maturity by 2 years of age in the wild and 12 months in captivity. The size at which trochus first become sexually mature is between 5 and 6.5 cm in diameter. Lacombe (1993) found that growth rates for animals in the range of 10–14 cm vary between locations, with the general trend for smaller shell sizes to be found on southern reefs. Trochus are dioecious (separate male and female) broadcast spawners and fertilization 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 a full or new moon (Hyland 1993). 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. Subsequent to fertilization, the eggs hatch into trochophore larvae (planktonic phase) after approximately 12 hours. The larval phase lasts approximately 3 to 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, mollusks and crustaceans. Small to medium-sized shells are cryptic, while larger specimens are less cryptic and visible on the reef.



### **1.2.3 *Trochus* fishery in Kosrae**

The trochus fishery became active at different times in FSM and may have begun much earlier in Yap. From 1985 to 1994, FSM production was high, at an average of 206 metric tonnes per year. FSM then became the fifth most important trochus producing country in the Pacific Islands region, producing as much as 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 the level is likely to have fallen below those reached in the 1980s and 1990s.

Although some information is available about the trochus resource in Pohnpei, very little information is available about the resource in Kosrae. According to Robinson et al (1984), trochus fishing in Kosrae started in 1984. This first open season lasted for 11 days, from 22 August to 6 September, and was restricted to the six reef areas of Okat, Lelu, Mutunlik, Malem, Utwa and Walung. The size limitation of 3 to 4 inches was imposed and no scuba was allowed. The total harvest was worth US \$8000.

Only fractional and controversial information is available on trochus harvests between 1984 and 2007; Tsutsui and Sigrah (1994) reported that '*Trochus niloticus* have not been harvested in Kosrae since 1987 because stocks have been reduced by overfishing,' but Ikeguchi and Sigrah (1996) reported that the fishery was open between 1986 and 1990, and that revenue for exportation of trochus shell during that period was between US \$6562 and \$32,810.

According to Simpson Abraham, Director of the Kosrae Island Resource Management Authority (KIRMA) (pers. comm. 2008), a 10-year fishing closure was instituted around 1995–1996. The most recent harvest was in 2007 and lasted for a period of five days. Approximately 26 metric tonnes of trochus were harvested and sold at a total value of US \$78,255 (US \$3 per kg). Trochus is one of only a few income options for the population of Kosrae.

### **1.2.4 Management of trochus fishery**

Coastal fisheries and aquaculture are under the state government jurisdiction in FSM, while oceanic fisheries are under the jurisdiction of the national government. Traditional ownership and management of reef resources remain strong in Yap, and to a certain extent in Chuuk, but are no longer recognised in Kosrae and Pohnpei (SPREP 1993).

Coastal fisheries management in Kosrae State is under the jurisdiction of KIRMA. The existing size regulation sets the lower limit at 3 inches (7.6 cm) and the upper limit at 4 inches (10.2 cm). One trochus sanctuary was established on the island, at Okat, to protect the spawning population. During harvests, both KIRMA and Fisheries Department staff members are present in all the communities to monitor harvest sizes and quantity.

### **1.2.5 Past trochus stock assessments**

The first *T. niloticus* survey in Kosrae was conducted in 1979 by Mark Bartholomew, a Peace Corps fisheries advisor. He surveyed eight areas, conducting counts at 120

stations. He didn't report on his methodology and his results seem a bit fanciful, with some surprising conclusions (i.e., he reports that *T. niloticus* burrows deep in the sand—up to 5' (1.52 meters!) under the surface—or that it reach maturity at six years old). Other conclusions indicate that *T. niloticus* was very scarce and that it could 'never be a commercial species'.

The second survey was conducted by Tony Abraham, an employee of the Secretariat of the Pacific Community's (SPC's) Marine Resource Division (MRD). His survey covered most of the island, but he didn't use reference point and transect belt techniques. He reported only on the number of trochus he saw, and his conclusion was that trochus were abundant. As a result of this survey, the trochus sanctuary in Tafunsak (from Salem to Fin Lum) was proposed (Robinson et al. 1984).

A third survey was conducted by Isao Tsutsui and Roland Sigrah in 1993 to assess the status of the adult topshell in Kosrae. They used the fixed time swimming method for the survey (Nash 1985). Their results are the only ones available for Kosrae and they will be the base line for our comparison and discussion.

## **2 Purpose of the survey**

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

In response, two Reef Fisheries Officers from the coastal component of the Pacific Regional Oceanic and Coastal Fisheries project (PROCFish/C) were sent to FSM during the month of June 2008. Field work was completed between 2 and 9 June in Kosrae. Similar surveys had previously been conducted at two sites each in the states of Chuuk and Yap under the PROCFish project. The resulting 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/CountryReports.aspx?CountryCode=FM](http://www.spc.int/coastfish/sections/reef/PROCFish_Web/Countries/CountryReports.aspx?CountryCode=FM). Resource information from Kosrae will add to the existing data on the present status of invertebrate resources in FSM.

## **3 Survey site**

Kosrae Island is surrounded by a relatively narrow reef on the southern and eastern part of the island and a much larger fringing reef system along the northern and western part of the island. The reef system also contains large mangrove swamps that surround a large part of the island, three main large embayments and some deep pools on the widest parts of the fringing reef. Trochus are found on the barrier reef mainly at the outer slopes and on reefs on the sides of the embayments where suitable habitat exists. The shoals outside the reef crests are moderately extensive (estimated between 300 m and less than 100 m), with steep slopes dropping off to abyssal depths commencing at about 20 meters. The reef flats behind the crests are scattered with large boulders and coral rubble, which are exposed during low tides.

## 4 Survey design and methodologies

### 4.1 Survey design and dedicated techniques

The main aim of the survey was to cover a relatively large part of the trochus habitat around the island of Kosrae and collect as much information as possible, given the time allocated for this work, to understand the 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. Consideration was also given to providing adequate coverage of the trochus sanctuary to contrast trochus densities inside and outside the sanctuary. The four main survey protocols adopted were: 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*

RFs or timed swims, which were conducted when permitted by swell conditions, were performed by snorkelling (Figure 3) along the reef front just behind the swells where trochus (*Trochus niloticus*), green snail (*Turbo marmoratus*) and the surf redfish (*Actinopyga mauritiana*) generally congregate. Two observers snorkel along side-by-side, separated by 10–15 meters, each observer counts and records the abundance of conspicuous sedentary species observed on the way (but focusing on trochus, surf redfish, clams and other gastropods) during 3 five-minute search periods each (for a total of 30 minutes searching). The start and end positions for each RFs station swim were recorded on a GPS receiver. Using MapInfo, the distance of each swim can be calculated, although they vary between stations depending on wind, current and wave conditions. Observation from the surface can also vary with depth and visibility; therefore, this technique is used to give general indications on resource status, not to determine precise density.

#### *Mother-of-pearl search (MOPs) and mother-of-pearl transects (MOPt)*

Initially, two divers (using scuba) actively searched for trochus for 3 five-minute search periods (30 minutes total). Distance searched was estimated from marked GPS start and end waypoints. If on these searches more than three individual shells were found, the stock was considered dense enough to proceed with a fine scale assessment with transect (MOPt). Mother-of-pearl transects (MOPt) were conducted on scuba by two divers along three 40-meter transects (2 m wide) parallel to the reef edge in depths usually not greater than 15 m. In most cases, the depth ranged between 2 and 8 m, although dives could reach 15 m at some sites where stocks were found deeper. In cases where the reef dropped off steeply, more oblique transect lines were followed. On MOPt, a hip-mounted Chainman measurement system (thread release) was adopted to measure out 40-meter transects. This left the divers' hands free and saved time and energy in retrieving the tape in the often dynamic water conditions where *Trochus niloticus* were found. Invertebrates observed within a two-meter swathe were measured and recorded, but particular attention was paid to mother-of-pearl species (see Figure 2).

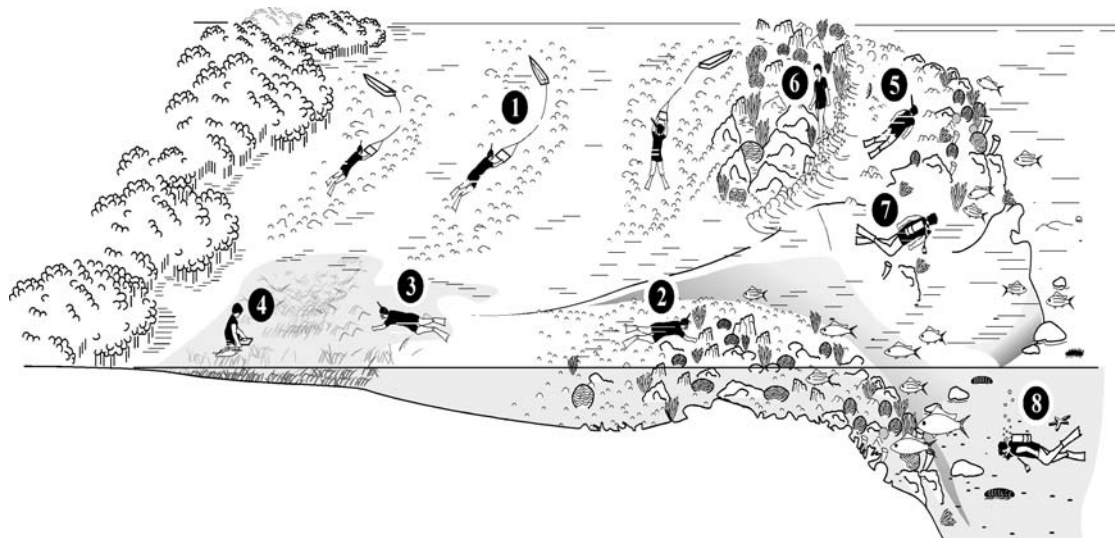


Figure 2: Bruno Ned (Marine Resource and Development, Kosrae) and Emmanuel Tardy (SPC) measuring trochus along a MOPt station. Note the string line used to measure the length of a transect and dynamic water conditions moving the observers back and forth across the string line.

### *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-meter transects (1 m wide) were examined per station by two observers snorkelling on 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 or less) and habitat recordings were made for each transect.

Figure 3 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 3 denote typical trochus surveys.



**Figure 3: Invertebrate survey techniques used by PROCFish/C surveys specific to trochus: 2 - reef benthos transects (RBt), 5 - reef front searches (RFs), 6 - reef front search walk (RFsw), 7 - mother-of-pearl transects (MOPt) and mother-of-pearl searches (MOPs)**

Actual position (longitude and latitude) of the sampling stations (one waypoint for RBt stations and two waypoints for RFs and MOP stations) were logged at 10 m accuracy using a Garmin GPS 72 receiver. 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 names, dates 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.

## 4.2 Methodology of stock estimation

The translation of resource assessment results into management advice is always difficult. Estimation of the stock of trochus in a given area provides a clear indication on the potential of the fishery and can form a basis for management guidelines.

In 1993, a trochus stock assessment was realised by Tsutsui & Sigrah. Their survey targeted adult trochus (over 60 mm) in areas 1 to 7 m deep outside the reef crest. Using scuba, they counted and measured trochus during a timed period, covering 7 m<sup>2</sup> per station. They divided the island into 18 sites, and recorded densities at each one. They come up with a global broodstock biomass. For comparative purposes, we will extract a similar set of data from our survey, though we covered a larger depth range than the previous study.

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) calculated that a density of 600–800 shells per hectare constitutes a dense population. In Aitutaki, 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 in order to permit the resource to be replenished. This threshold density will be used in determining trochus stock level for Kosrae.

## 5 Results

### 5.1 Coverage and general recordings

The joint PROCFish/C–KIRMA–Marine Resource and Development (MR&D) team surveyed all reef zones starting from the barrier reef and extending to about 15 meters of depth on the outer slope to ascertain the distribution and density of commercial topshell. In addition to standard RBt surveys, trochus information is usually collected using RFs and MOPt. If too few trochus are present, the dive team resorts to MOPs, which allow a more comprehensive coverage of the bottom without the need to conform to the linearity of strip transects (see survey design and methodology). In total, 50 stations of scuba transects (MOPt), timed swims (RFs) and belt transects (RBt) were completed as shown on the coverage map; 6 stations were completed inside the trochus sanctuary and 44 stations at the open reefs (Table 1 and Figure 4). The surface area covered in this survey is estimated at 89,457 m<sup>2</sup>.

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

Site	Survey method	Stations	Replicate measures	Surface area covered (m <sup>2</sup> )
All Kosrae	RBt	4	24 transects	960
	MOP search	1	6 search periods	1 080
	MOP transects	23	138 transects	11,040
	Reef front search walks	4	24 search periods	16,088
	Reef front searches	18	108 search periods	60,289
Open reef areas only	RBt	3	18 transects	720
	MOP search	1	6 search periods	1080
	MOP trochus transects	20	120 transects	9600
	Reef front search walks	4	24 search periods	16,088
	Reef front searches	16	96 search periods	53,815
Trochus sanctuaries only	RBt	1	6 transects	240
	MOP search	0	0	0
	MOP trochus transects	3	18 transects	1440
	Reef front search walks	0	0	0
	Reef front searches	2	12 search periods	6474

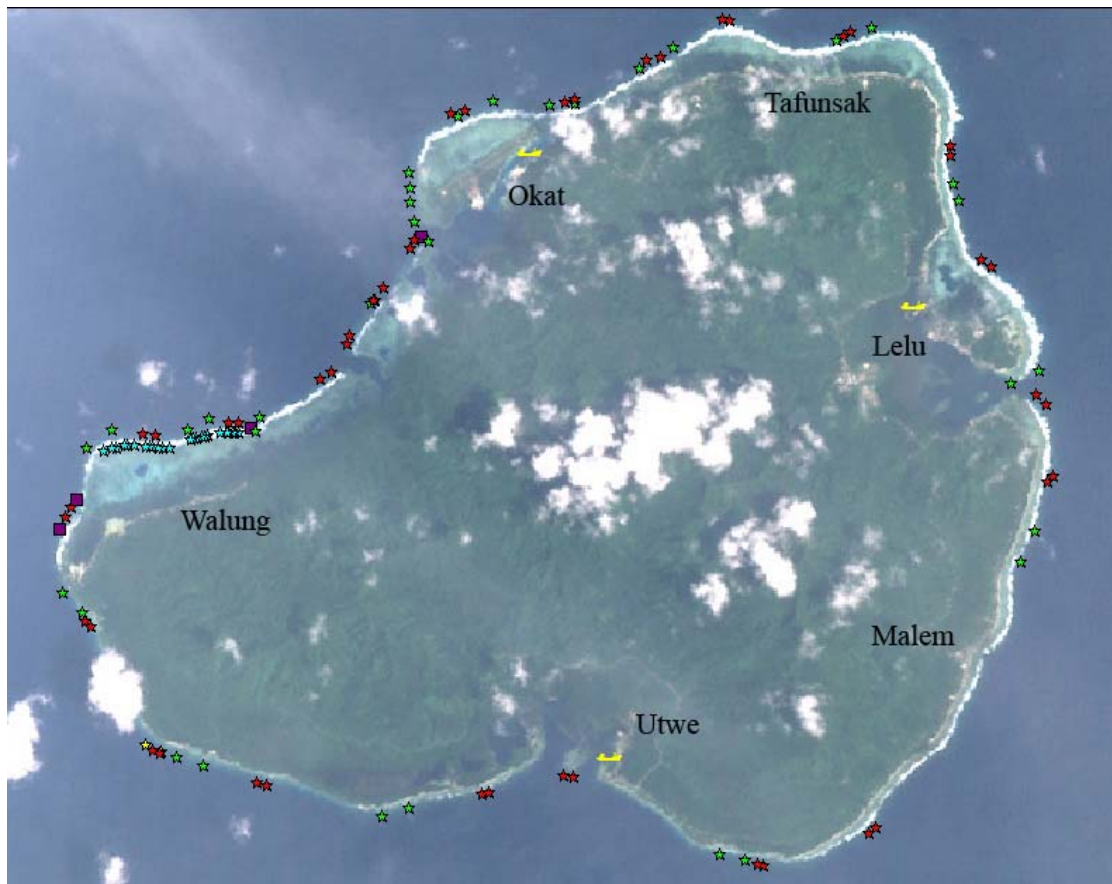


Figure 4: Survey coverage on Kosrae, green stars = RFs stations, blue stars = RFsw stations, red stars = MOPt stations (scuba), purple squares = RBt stations (swim), yellow stars = MOPs stations (scuba), yellow boats = mooring places

## 5.2 Number of invertebrate species recorded

A total of 32 species or species groupings of interest (groups of species within a genus) were recorded in the Kosrae invertebrate surveys. Among these were 1 bivalve, 18 gastropods, 10 sea cucumbers, 2 urchins, 5 sea stars and 4 crustaceans. The species recorded most often was *Trochus niloticus*. Information on key families and species is detailed in Appendices 1 to 7.

## 5.3 *Trochus* presence, distribution and density

*Trochus* were numerous and found at all stations but one station around Kosrae (total  $n = 791$  individuals recorded). In Kosrae, as in Pohnpei, *trochus* do not occur in the typical horizontal pattern of distribution usually observed for this species, characterised by low-density areas between high-density areas. Here, the species is recorded everywhere along the ocean side of the barrier reefs. Presence of *trochus* is high, with 98% of stations holding *trochus*. In the marine protected area (MPA), 83% of all RBt replicates, RFs and MOPt searches reported *trochus*, while these proportions at open reefs fell to 50%, 61% and 75%, respectively.

Density of *trochus* was higher in the northern part of the island, where fringing reefs are larger, than in the southern part of the island where the shoal is narrow with a quick drop-off (see distribution map Figure 7).

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 or greater is required, as explained above.

At open reefs, the average trochus densities recorded in RBt and MOPt assessments were under this limit, with  $194.4 \pm 36.7$  standard error (SE) and  $377.1 \pm 75.3$  SE specimens per ha, respectively, while areas assessed with RFs held a much lower density of  $46.0 \pm 11.9$  SE specimens per ha. Inside the MPA/trochus sanctuary, trochus density for RBt stations was high, at 1250 specimen per ha (only one station, no SE), whereas the density for MOPt assessments was close to the density observed at open reef, with  $354.2 \pm 102.8$  SE specimens per ha. The density for RFs stations was higher than that on the open reef, at  $242.3 \pm 163.1$  SE specimens per ha on average (Table 2).

**Table 2: Presence and mean density of mother-of-pearl species (individuals per ha,  $\pm$  SE) from targeted assessments (reef benthos transects [RBt], reef front searches [RFs], reef front search walks [RFsw] and MOPt stations)**

	<i>Trochus niloticus</i>	Density	SE	% of stations with species	% of transects or search periods with species
RBt	All Kosrae	458.3	265.2	4/4 = 100%	14/24 = 58%
	open reefs	194.4	36.7	3/3 = 100%	9/18 = 50%
	MPA	1250		1/1 = 100%	5/6 = 83%
RFs	All Kosrae	67.8	22.5	18/18 = 100%	69/108 = 64%
	open reefs	46	11.9	16/16 = 100%	59/96 = 61%
	MPA	242.3	163.1	2/2 = 100%	10/12 = 83%
RFsw	All Kosrae	3.9	2.7	2/4 = 50%	2/24 = 8%
	open reefs	3.9	2.7	2/4 = 50%	2/24 = 8%
	MPA	—	—	—	—
MOPt	All Kosrae	374.1	66.2	23/23 = 100%	105/138 = 76%
	open reefs	377.1	75.3	20/20 = 100%	90/120 = 75%
	MPA	354.2	102.8	3/3 = 100%	15/18 = 83%

Furthermore, Table 3 and Figure 5 show that at fishable reefs (open reefs), 25% of the MOPt stations, but none of the RBt and RFs stations, were above the benchmark density. At the trochus sanctuary, 33% of the MOPt and 100% of the RBt, but none of the RFs stations, were above the benchmark (Table 3 and Figure 6). The most important results lie in the records from the MOPt stations, as this technique was used far more often than the others and it therefore gives the most accurate result.

**Table 3: percentage of stations over the benchmark of 500 specimens per ha**

Station type	MOPt	RBt	RFs	RFsw
All Kosrae	6/23 = 26%	1/4 = 25%	0/18 = 0%	0/4 = 0%
MPA	1/3 = 33%	1/1 = 100%	0/2 = 0%	-
Open areas	5/20 = 25%	0/3 = 0%	0/16 = 0%	0/4 = 0%



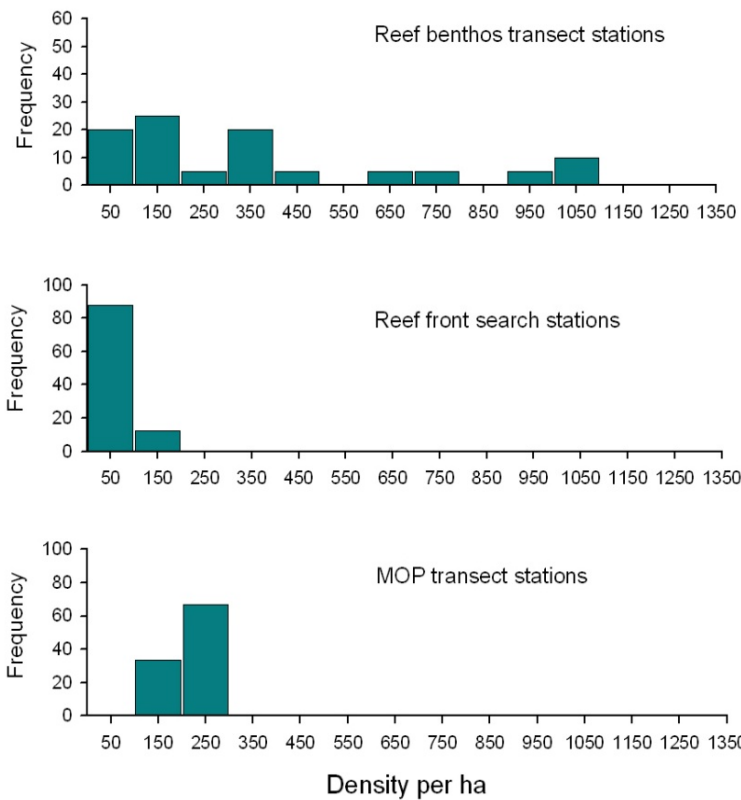


Figure 5: Trochus station frequency classified in density classes at open reefs

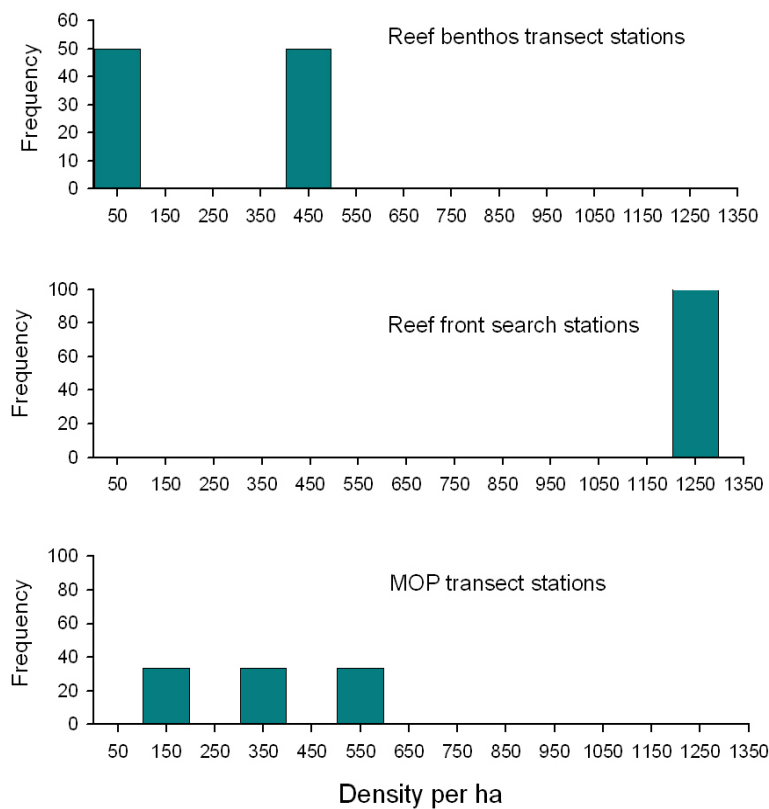


Figure 6: Trochus stations frequency classified in density classes at MPA/trochus sanctuaries



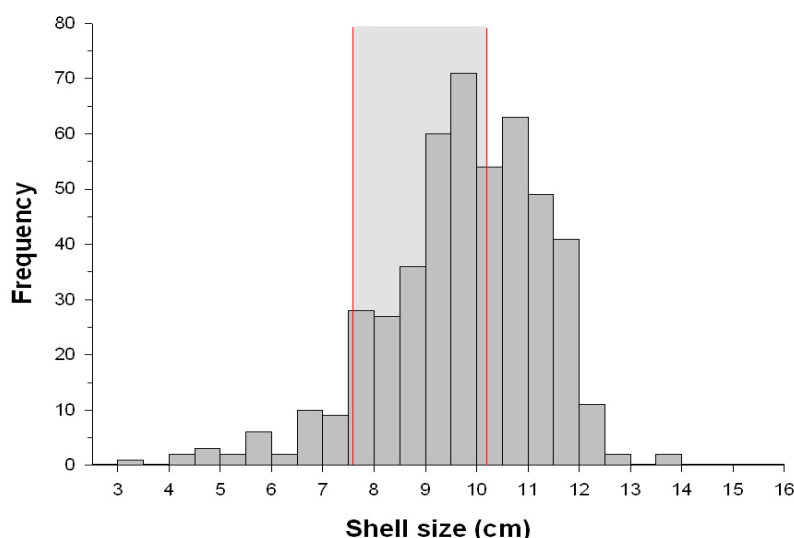


Figure 8: Histograms of trochus (*Trochus niloticus*) shell base diameter for all Kosrae, with current legal shell size classes falling into the paler grey band (3 to 4 inches, i.e., 7.6 to 10.2 cm)

Overall, 786 *Trochus niloticus* were noted during the survey, of which 474 were measured (60%). We recorded a mean size of 9.9 cm  $\pm$  0.1 SE for all areas. This average varies little between the MPA and open-access reefs (Table 4).

Table 4: Average trochus size by area (in cm)

Area	mean length in cm	SE	number measured / number observed
Open reefs	9.9	0.1	379/603
MPA	9.7	0.2	95/183
All Kosrae	9.9	0.1	474/786

Of this measured portion of the stock, at the open reefs, 50.1% were from size classes legal on Kosrae (between 3 and 4 inches or 7.6 and 10.2 cm), and 44.1% of the stock was ‘oversize’ (over 10.2 cm basal width) (Table 5).

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

Number of trochus recorded and percentage per size class	MPA	Open reefs	All Kosrae
Size class $L > 10.2$ cm	42	167	209
% $L > 10.2$ cm	44.2%	44.1%	44.1%
Current legal size $7.6 \leq L \leq 10.2$ cm	40	190	230
% $7.6 \leq L \leq 10.2$ cm	42.1%	50.1%	48.5%
Size class $L < 7.6$ cm	13	22	35
% $L < 7.6$ cm	13.7%	5.8%	7.4%
All sizes	95	379	474

Current legal size limit = 3–4 inches or 7.6–10.2 cm. L = length.

If the proposed alternative harvestable size class of 8 to 11 cm is considered (as used in several Pacific Island fishery regulations), the proportions of the legal size class and oversize class change dramatically to 72.3% and 20.1% respectively, of the stock in the open access reefs (Table 6).

**Table 6: Number and percentage of trochus per size class given the proposed alternative legal size limit**

No of trochus recorded and percentage per size class	MPA	Open reefs	All Kosrae
Size class $L > 11.0$ cm	29	76	105
% $L > 11.0$ cm	30.5%	20.1%	22.2%
<b>Proposed alternative legal size <math>8.0 \leq L \leq 11.0</math> cm</b>	<b>49</b>	<b>274</b>	<b>323</b>
<b>% <math>8.0 \leq L \leq 11.0</math> cm</b>	<b>51.6%</b>	<b>72.3%</b>	<b>68.1%</b>
Size class $L < 8.0$ cm	17	29	46
% $L < 8.0$ cm	17.9%	7.7%	9.7%
All size classes	95	379	474

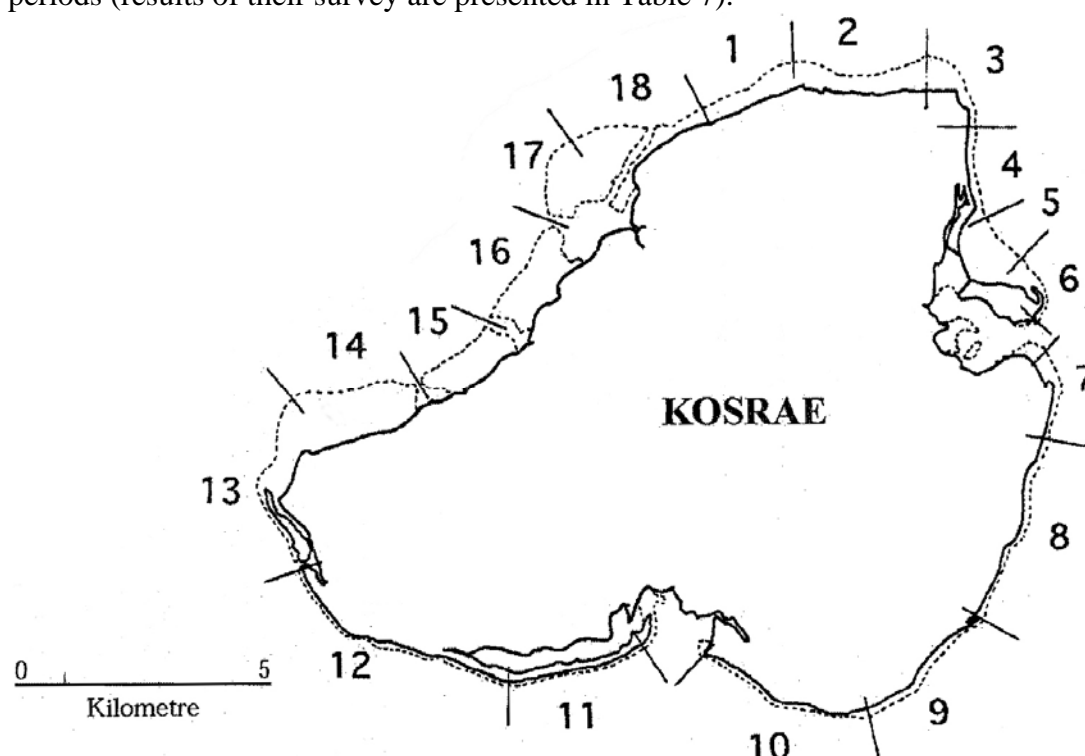
Proposed alternative legal size = 8–11 cm. L = length

## 5.5 Estimation of stock

In this section, we will make two separate analyses. One will use a subset of the present survey data to compare results with the those of the 1993 survey, which assessed only adult trochus (over 6.0 cm) living in the depth zone between 1 and 7 meters. A second analysis will include all size classes and all depth ranges assessed during the 2008 survey.

### 5.5.1 Comparison of stock estimate with 1993 estimate

In 1993, Tsutsui and Sigrah, made the first documented assessment of the adult trochus stock on Kosrae. Their survey was divided into 18 sites covering the entire reef around Kosrae (Figure 9) and their assessments were based on timed search periods (results of their survey are presented in Table 7).



**Figure 9: Map of Kosrae sites for 1993 survey (Tsutsui and Sigrah 1994)**

Table 7: Stock of adult trochus (over 6.0 cm) in the depth zone between 1 and 7 meters in 1993 (Tsutsui and Sigrah 1994)

Site	Total survey time (min.)	Number of topshells found	Topshells density (tr/m <sup>2</sup> )	Estimated site area (m <sup>2</sup> )	Estimated biomass
1	60	8	0.019	334,400	6,370
2	60	16	0.038	180,000	6,857
3	60	5	0.012	241,500	2,875
4	60	2	0.005	132,300	630
5	60	3	0.007	81,270	581
6	60	6	0.014	423,150	6,045
7	60	5	0.012	114,000	1,375
8	60	0	0.000	258,020	0
9	60	0	0.000	197,470	0
10	60	2	0.005	135,750	646
11	75	6	0.014	339,010	4,843
12	60	0	0.000	454,020	0
13	60	18	0.043	260,010	11,143
14	60	4	0.010	220,400	2,112
15	60	24	0.057	223,290	12,759
16*	60	54	0.129	191,100	24,570
17	60	4	0.010	182,700	1,740
18	60	26	0.062	328,250	20,320
<b>Total</b>					<b>102,866</b>

\*trochus sanctuary

The present survey assessed all size classes of trochus and a broader range of depth (from less than 1 meter to 12 meters).

In order to have some comparative results, we analyzed a subset of data fitting the 1993 surveys' size class and depth range. As the present study was not initially designed to copy the 1993 survey, and as trochus data were not collected in the 1–7 meter depth range at each of the 18 sites, we have merged the 18 sites into six zones to have a decent dataset to analyze for each zone (Table 8 and Figure 10).

Table 8: Zones created by merging sites from the 1993 survey and related estimated surface areas

	corresponding sites from 1993 survey	estimated surface area (in m <sup>2</sup> ) at 1–7 m of depth
Zone 1	1, 2, 17, 18	1,025,350
Zone 2	3, 4, 5, 6	878,220
Zone 3	7, 8, 9	569,490
Zone 4	10, 11, 12	928,780
Zone 5	13, 14, 15	703,700
Zone 6	16	191,100

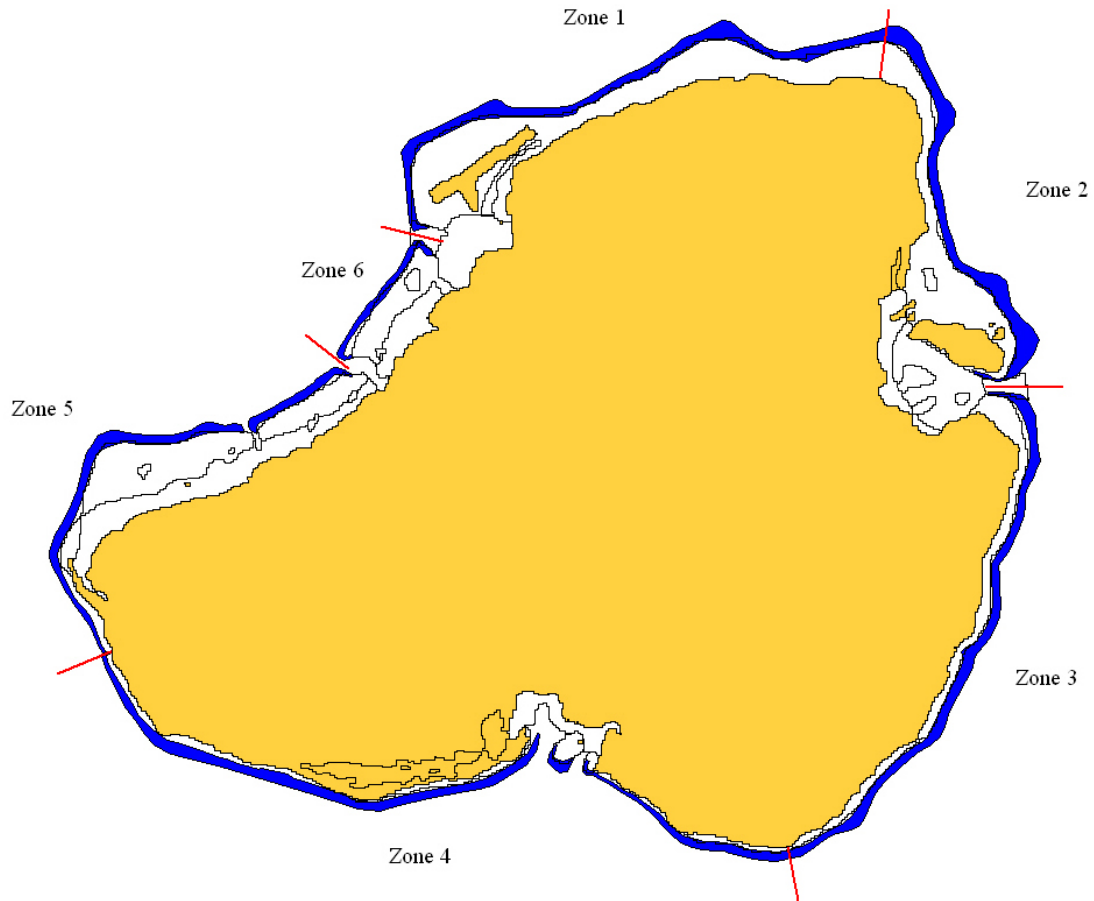


Figure 10: map of the current zones used for comparative analysis (in blue, estimation of the trochus habitat between 0 and 15 meters used in the global analysis)

The estimated numbers of trochus aggregated by zone for the 1993 survey are given in Table 9.

Table 9: Estimated numbers of trochus aggregated by zone in 1993

	Estimated adult stock in 1993 (number of trochus over 6.0 cm)
Zone 1	35,287
Zone 2	10,131
Zone 3	1375
Zone 4	5489
Zone 5	26,014
Zone 6*	24,570
<b>Total</b>	<b>102,866</b>

\*trochus sanctuary

The densities and stock estimate results for the 2008 subset of data for trochus over 6.0 cm found in a depth range of 1 to 7 m are given in Table 10.

**Table 10: Density and number of adult trochus (over 6.0 cm) found at a depth of 1 to 7 m**

	Estimated area (ha)	Density		Estimated stock		
		mean	weighted SE	mean	95% confidence interval values (min. and max.)	
Zone 1	102.5	587.5	90.3	60,239	42,097	78,382
Zone 2	87.8	677.1	177.8	59,463	28,866	90,059
Zone 3	56.9	145.8	38.4	8305	4017	12,593
Zone 4	92.9	125.0	0.0	11,610	11,610	11,610
Zone 5	70.4	275.0	45.7	19,352	13,042	25,662
1+2+3+4+5	410.6	408.3	46.0	167,629	130,614	204,645
Zone 6 *	19.1	464.3	125.3	8873	4179	13,566
total	429.7	410.8	49.5	176,502	134,793	218,210

\*trochus sanctuary

The estimated average number of adult trochus (over 6.0 cm) found at a depth of 1 to 7 meters is **176,502** (confidence interval [CI]: 134,793 to 218,210), which is an **increase of 71.5%** compared to the 1993 estimate. These averages vary between zones, with zones 1, 2, 3 and 4 increasing by 71%, 487% 504% and 112% respectively, while zones 5 and 6 decreased by 26% and 64%, respectively. It shows that three quarters of the island (the north, east and south) has seen a spectacular increase in its trochus population, while the northwestern side has seen a decrease. The main decrease is observed in the trochus sanctuary, where the estimated number dropped from 24,570 to 8,873 (CI 4,179 to 13,566) specimens. There is no straightforward explanation for this drop in densities. It could be related to an overestimation of the stock in 1993, or it could be the result of poaching if the ban on fishing in the trochus sanctuary was not properly enforced during the last harvest.

As all stations do not have the same surface area, it was necessary to weight the average and standard error (weighted SE) of the density. The calculation of the weighted SE 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  $i^{\text{th}}$  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 area at  $i^{\text{th}}$  station,  $(x_i)$  is the mean density of the  $i^{\text{th}}$  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 with the following formula:

$$se_w = \frac{sd_w}{\sqrt{N}}$$

Given the densities calculated per zone, and using the areas estimated by zone, we calculated the estimated number of trochus by zone, with a 95% CI.

### 5.5.2 Stock estimate for 2008

#### Calculation of density per zone

The calculation of density includes all trochus (all sizes) recorded at all depths assessed during the 2008 survey (**Table 11**).

**Table 11: Density of all trochus (all depths)**

	sampled area (m <sup>2</sup> )	Density	
		mean	weighted SE
Zone 1	2400	633.3	101.9
Zone 2	960	677.1	177.8
Zone 3	1440	229.2	35.4
Zone 4	2880	66	15.3
Zone 5	3120	359	55.7
Open reefs (1+2+3+4+5)	10,800	352.8	37.0
Zone 6 *	1680	482.1	130.5
total	12,480	370.2	36.6

\*trochus sanctuary

#### Estimation of surface area per zone

To extrapolate densities to numbers of trochus in each zone, we must have the surface area of habitat in each zone. We used MapInfo geographical information system (GIS) software on a high resolution IKONOS image of Kosrae in order to delineate the estimated habitat of trochus in each zone (the areas are highlighted in blue in Figure 10). In order to take a conservative approach to the stock extrapolation, we decided to take 80% of these areas for stock (number of trochus) calculations (Table 12).

**Table 12: Estimated surface area of trochus main habitat**

	estimated surface area with GIS (ha)	80% of estimated surface area (ha)
Zone 1	151.2	120.96
Zone 2	131.2	104.96
Zone 3	128.7	102.96
Zone 4	160.0	128.0
Zone 5	102.8	82.24
Open access reefs (1+2+3+4+5)	673.9	539.12
Zone 6*	25.8	20.64
total	699.7	559.76

\*trochus sanctuary

The total estimated surface area of trochus habitat is close to 700 ha, which is 63% larger than the estimated surface area between 1 and 7 m. The area that will be used for stock calculation is close to 560 ha, which is 30% larger than the estimated surface area between 1 and 7 m. The value used for extrapolation of stock is therefore very conservative, as we roughly double the depth range of the habitat.



### Extrapolation of trochus numbers

Given the densities recorded and the estimated surface area of available habitat for trochus, extrapolation of trochus numbers per zone were calculated in Table 13 with CI values at 95%

**Table 13: Estimated number of trochus in the main habitat**

	80% of estimated surface (ha)	Density		Estimated stock		
		mean	weighted SE	mean	95% CI values (min and max)	
Zone 1	120.96	633.3	101.9	76,608	52,456	100,760
Zone 2	104.96	677.1	177.8	71,067	34,489	107,644
Zone 3	102.96	229.2	35.4	23,598	16,455	30,742
Zone 4	128.0	66	15.3	8448	4610	12,286
Zone 5	82.24	359	55.7	29,524	20,546	38,502
Open access reefs (1+2+3+4+5)	539.12			209,245	128,555	289,936
Zone 6*	20.64	482.1	130.5	9951	4671	15,230
total	559.76			219,196	133,226	305,165

\*trochus sanctuary

The total estimated number of trochus is 219,196 (CI: 133,226 to 305,165). At the open reef, the number of trochus is 209,245 (CI: 128,555 to 289,936), and in the trochus sanctuary the number is 9,951 (CI: 4671 to 15,230).

### Extrapolation of the harvestable stock

#### *Length-weight relationship*

From the trochus size distribution recorded, we built a weight distribution using the Length-weight relationships established with Wallis Island *Trochus niloticus* (C. Chauvet 2006) (see Appendix 6.1).

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

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

Where W = weight,  $\emptyset$  = diameter in cm

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.

#### *Weight class composition of the trochus stock per zone*

For each zone, the wet weight (whole live shell) and dry weight (shell without meat) of the trochus stock were estimated by size class. The simulations are based on two sets of size classes, one on the current legal size to harvest trochus (7.6 to 10.2 cm), and the second one on the proposed alternative legal size (8 to 11 cm—the limits in use in several Pacific Island fishery regulations). For each of the two size classes, we have therefore three categories: undersize, legal size and oversize. The composition per size class for each zone is given in Appendices 8 and 9. Results for only the harvestable parts of the stock are in Table 14 and Table 15.

**Table 14: harvestable stock by zone, in number, kg of wet trochus and kg of dry trochus (shell without meat), given the current size limits (3–4 inches or 7.6–10.2 cm)**

trochus class size 7.6<L<10.2 cm	Numbers			Wet weight (in kg)			Dry weight (in kg)		
	mean	95% CI values (min and max)		mean	95% CI values (min and max)		mean	95% CI values (min and max)	
Zone 1	38,405	26,297	50,513	10,511	7197	13,825	8032	5500	10,564
Zone 2	35,627	17,290	53,964	9751	4732	14,769	7451	3616	11,286
Zone 3	11,830	8249	15,412	3238	2258	4218	2474	1725	3223
Zone 4	4235	2311	6159	1159	633	1686	886	483	1288
Zone 5	14,801	10,300	19,302	4051	2819	5283	3095	2154	4037
All open reef	104,899	64,448	145,349	28,709	17,638	39,780	21,938	13,479	30,398

**Table 15: harvestable stock by zone, in number, kg of wet trochus and kg of dry trochus (shell without meat), given the proposed alternative size limits (8–11 cm)**

trochus class size 8<L<11 cm	Numbers			Wet weight (in Kg)			Dry weight (in Kg)		
	mean	95% CI values (min and max)		mean	95% CI values (min and max)		mean	95% CI values (min and max)	
Zone 1	55,384	37,923	72,845	17,999	12,324	23,673	13,633	9335	17,931
Zone 2	51,378	24,934	77,822	16,697	8,103	25,291	12,647	6138	19,156
Zone 3	17,060	11,896	22,225	5544	3866	7223	4199	2928	5471
Zone 4	6108	3333	8882	1985	1083	2887	1503	820	2186
Zone 5	21,345	14,854	27,835	6937	4827	9046	5254	3656	6852
All open reef	151,275	92,940	209,609	49,162	30,204	68,120	37,236	22,877	51,595

The stock of legal size trochus at open reefs is estimated to be 104,899 individuals (CI: 64,448 to 145,349), which is equivalent to 28.7 metric tonnes (mt) of wet weight (CI: 17.6 to 39.8 mt) and to 21.9 mt of dry weight (CI: 13,479 to 30,398).

The stock of trochus at proposed alternative legal size is estimated to be 151,275 specimens (CI: 92,940 to 209,609). This is equivalent to 49.2 mt of wet weight (CI: 30.2 to 68.1 mt) and 37.2 mt of dry weight (CI: 22.9 to 51.6 mt).

The number of specimens available for the proposed alternative legal size is 44.2% higher than the number available for current legal size, and the wet weight available for the proposed alternative size class is 71.2% higher than for current legal size.

### **5.5.3 Other mother-of-pearl shell records**

The other common mother-of-pearl shell, the green topshell (*Tectus pyramis*) has been recorded at low density (total of 21 specimens), and no black lip pearl oyster (*Pinctada margaritifera*) was recorded.

## 5.6 Other invertebrate resources

### 5.6.1 Giant clams

Only the elongate giant clam (*Tridacna maxima*) was recorded in this survey. A total of 29 specimens were recorded at Kosrae.

Outside the MPA, density of *Tridacna maxima* was critically low, with  $10.4 \pm 5.1$  SE and  $1.9 \pm 0.7$  SE specimen per ha, respectively, for MOpt and RFs. No *Tridacna maxima* was found outside the MPA at RBT stations.

Inside the MPA, density of *Tridacna maxima* was still low, with 83.3 and  $48.6 \pm 13.9$  SE specimen per ha, respectively, for RBt (only one station) and MOpt. No *Tridacna maxima* was found in RFs inside the MPA (only two stations were done).

Such a low density makes resource recovery difficult, as sparse distribution negatively affects the success of spawning and fertilisation, and therefore the ongoing sustainability of this resource.

Size class distribution of *Tridacna maxima* reveals that only specimens larger than 80 mm were recorded, indicating a lack of recruitment in the recent past (an 80 mm *Tridacna maxima* is about four years old) (Figure 11).

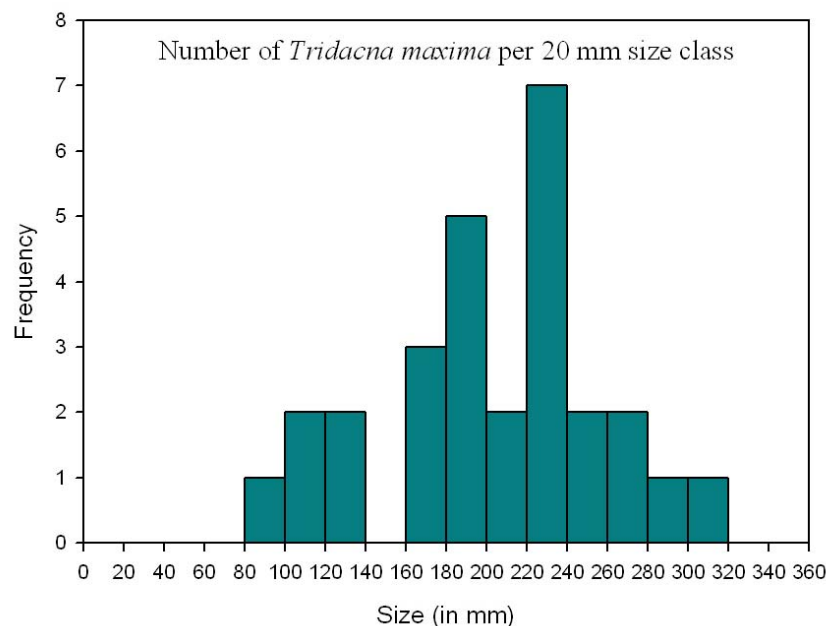


Figure 11: Histogram of giant clam shell length (mm)

### 5.6.2 Sea cucumbers

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

The medium value surf redfish, *Actinopyga mauritiana*, was well distributed all around the island (75% of RBt, 72% of RFs, 100% of RFsw and 43% of MOPt stations), and recorded at low-to-good densities (average of  $375.0 \pm 271.6$  SE,  $25.4 \pm 10.9$  SE,  $88.2 \pm 56.6$  SE and  $13.6 \pm 3.8$  SE per ha in RBt, RFs, RFsw 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*), was present but only recorded once at an RFs station.

The medium value greenfish (*Stichopus chloronotus*) was recorded in all assessment types. It was only commonly distributed at RBt stations and RFsw (75% of RBt and RFsw stations), and at an average density of  $843.8 \pm 584.4$  SE and  $272.3 \pm 264.4$  SE per ha at RBt and RFsw stations. Note that only four stations of both RBt and RFsw were realised, and that these densities are not representative of the whole island.

Lollyfish (*Holothuria atra*), a lower value species of sea cucumber, was well distributed at shallow depths (in 75%, 33% and 100% of RBt, RFs and RFsw stations, respectively), but was quite uncommon at MOPt stations (9%). Density recorded was  $468.8 \pm 187.4$  SE,  $56.4 \pm 38.9$  SE and  $3585.4 \pm 441.1$  SE per ha at RBt, RFs and RFsw stations, respectively. At MOPt stations, density dropped to  $2.7 \pm 2.0$  SE per ha. Pinkfish (*H. edulis*) was recorded at one RFs station with only two specimens.

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 (*H. nobilis*) were present. Leopardfish was present at 25%, 11% and 9% of RBt, RFs and MOPt stations, respectively, and black teatfish at 11% of RFs and 4% of MOPt stations. Both were recorded at low densities. Leopardfish densities were recorded at  $10.4 \pm 10.4$  SE,  $1.0 \pm 0.7$  SE and  $1.8 \pm 1.3$  SE at RBt, RFs and MOPt stations, respectively, and black teatfish at  $1.3 \pm 0.9$  SE at RFs stations and  $0.9 \pm 0.9$  SE at MOPt stations.

Table 16: Sea cucumber species records from Kosrae, FSM

Species	Common name	Commercial value <sup>(1)</sup>	Reef benthos stations n = 4			RFs stations n = 18 RFsw stations n = 4			MOPt stations n = 23		
			D <sup>(2)</sup>	DwP <sup>(3)</sup>	PP <sup>(4)</sup>	D	DwP	PP	D	DwP	PP
<i>A. mauritiana</i>	Surf redfish	M/H	375.0	500.0	3/4 = 75%	25.4 88.2	35.2 88.2	13/18 = 72% 4/4 = 100%	13.6	31.3	10/23 = 43%
<i>A. miliaris</i>	Blackfish	M				0.4	6.4	1/18 = 6%			
<i>B. argus</i>	Leopardfish	M	10.4	41.7	1/4 = 25%	1.0	8.7	2/18 = 11%	1.8	20.8	2/23 = 9%
<i>B. graeffei</i>	Flowerfish	L	10.4	41.7	1/4 = 25%	4.3	4.3	1/18 = 6%	1.8	20.8	2/23 = 9%
<i>H. atra</i>	Lollyfish	L	468.8	625.0	3/4 = 75%	56.4 3585.4	169.2 3585.4	6/18 = 33% 4/4 = 100%	2.7	31.3	2/23 = 9%
<i>H. coluber</i>	Snakefish	L				5.8	11.7	2/4 = 50%			
<i>H. edulis</i>	Pinkfish	L				0.7	13.1	1/18 = 6%			
<i>H. nobilis</i> <sup>(5)</sup>	Black teatfish	H				1.3	11.6	2/18 = 11%	0.9	20.8	1/23 = 4%
<i>S. chloronotus</i>	Greenfish	H/M	843.8	1125.0	3/4 = 75%	36.3 272.3	163.4 363.0	4/18= 22% ¾ = 75%	27.2	125.0	5/23 = 22%
<i>S. horrens</i>	Dragonfish					1.4	5.7	¼ = 25%			
<i>T. ananas</i>	Prickly redfish	H				0.3	5.5	1/18 = 6%			

<sup>(1)</sup> L = Low value; M = Medium value; H = High value <sup>(2)</sup> D = mean density per hectare; <sup>(3)</sup> DwP = mean density per hectare for transects or stations where the species was present; <sup>(4)</sup> PP = percentage presence (units where the species was found); <sup>(5)</sup> There has been a recent variation to sea cucumber taxonomy that 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.

## 5.7 Environmental parameters

### 5.7.1 Coral cover

The survey covers a large part of the reef slopes and passages. Corals are globally very healthy, with an average of about 32% live coral cover on the outer slope (green colored portions of the pies charts in Figure 13). We observed that live coral cover was higher in the east than in the rest of the island, and that pavement cover was higher on the northern shore than on the rest of the island (Figure 12 and Figure 13 ).



Figure 12: Typical reef habitat of the northern reefs of Kosrae

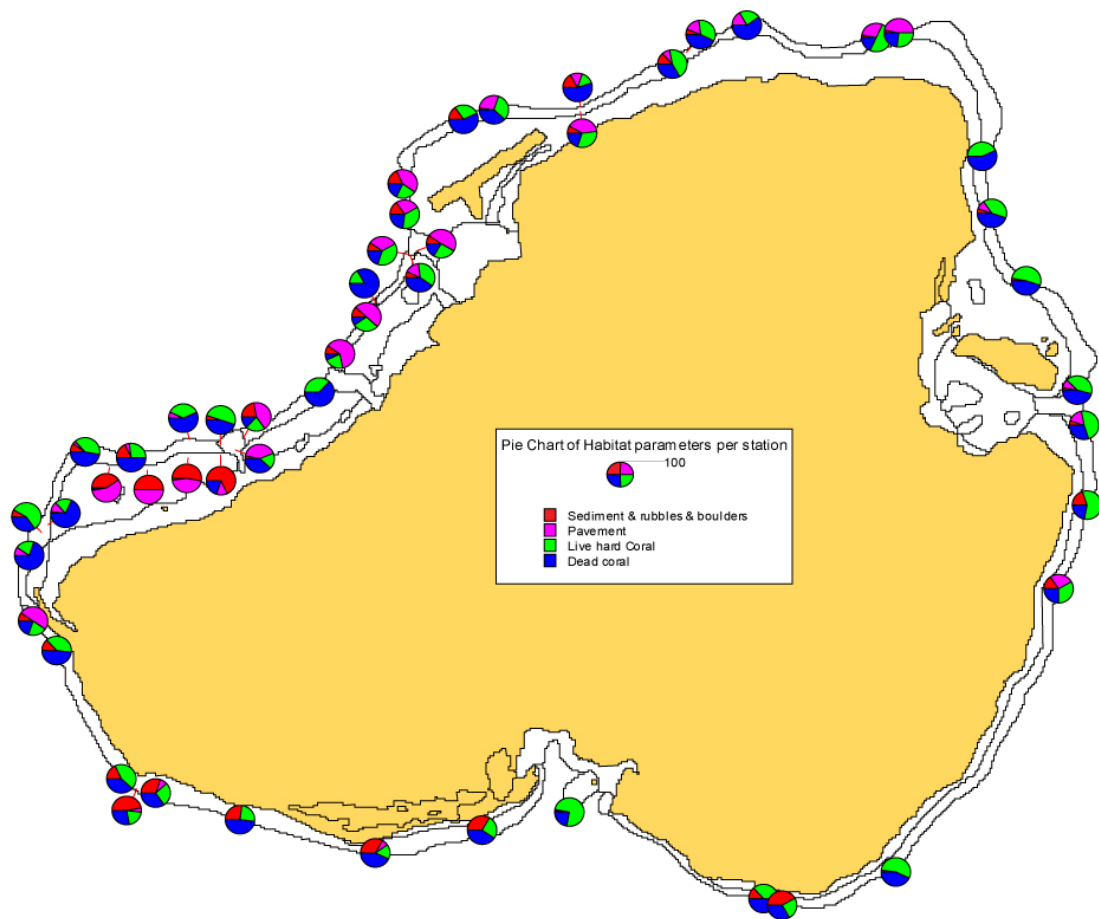


Figure 13: Habitat composition at Kosrae survey stations

### 5.7.2 Crown-of-thorns starfish

Crown-of-thorns starfish (*Acanthaster planci*) were recorded at 25.0%, 38.9% and 47.8% of RBt, RFs and MOPt stations, respectively. The distribution was not even, with crown-of-thorns starfish found only on the northern shore, roughly from the northeast tip to the western tip of the island (from Foko Finaunpes to the Molsron Tukunsru passage). In this area, they were recorded at 25.0%, 58.3% and 92.3% of RBt, RFs and MOPt stations, respectively, and at a density above their natural density (Figure 15). A total of 137 specimens was recorded. 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 m<sup>2</sup>/year of coral. 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 m<sup>2</sup>, 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%; it can take up to a decade for the reef to recover (Figure 14).





Figure 14: *Acanthaster planci* feeding on corals, a common sight at the north and western reefs of Kosrae

Densities recorded per assessment type for all Kosrae were  $10.4 \pm 10.4$  SE,  $10.5 \pm 6.9$  SE, and  $58.0 \pm 23.0$  SE per ha at RBt, RFs and MOPt stations, respectively. In the northern area where crown-of-thorns starfish were recorded, these densities reached  $10.4 \pm 10.4$  SE,  $18.9 \pm 10.1$  SE, and  $102.5 \pm 36.5$  SE per ha at RBt, RFs and MOPt stations, respectively. The few stations in the trochus sanctuary recorded the starfish at similar densities as on the 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 two-minute manta tow, or over 30 adults and subadults per ha using scuba diving counts. (Starfish may be mature at two years or at a size of 20 cm diameter, but for the definition of an outbreak, an indicator size of over 26 cm is used.)
- **Active outbreak:** crown-of-thorns starfish densities are over 1.0 adults per two-minute manta tow or, if scuba diving, over 30 adult starfish per ha.

The outbreak in Kosrae hasn't spread to the eastern and southern reefs yet and the damage is limited. Nevertheless, the problem is potentially serious and some eradication programme should be considered.



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

Area	Station type	Densities		% of stations where present
		Average	SE	
Open reefs	RBt	13.9	13.9	33.3%
	RFs	11.4	7.7	37.5%
	MOPt	53.1	24.3	45.0%
MPA	RBt	0	0	0%
	RFs	3.2	3.2	50.0%
	MOPt	90.3	80.1	66.6%
All areas	RBt	10.4	10.4	25.0%
	RFs	10.5	6.9	38.9%
	MOPt	58.0	23.0	47.8%

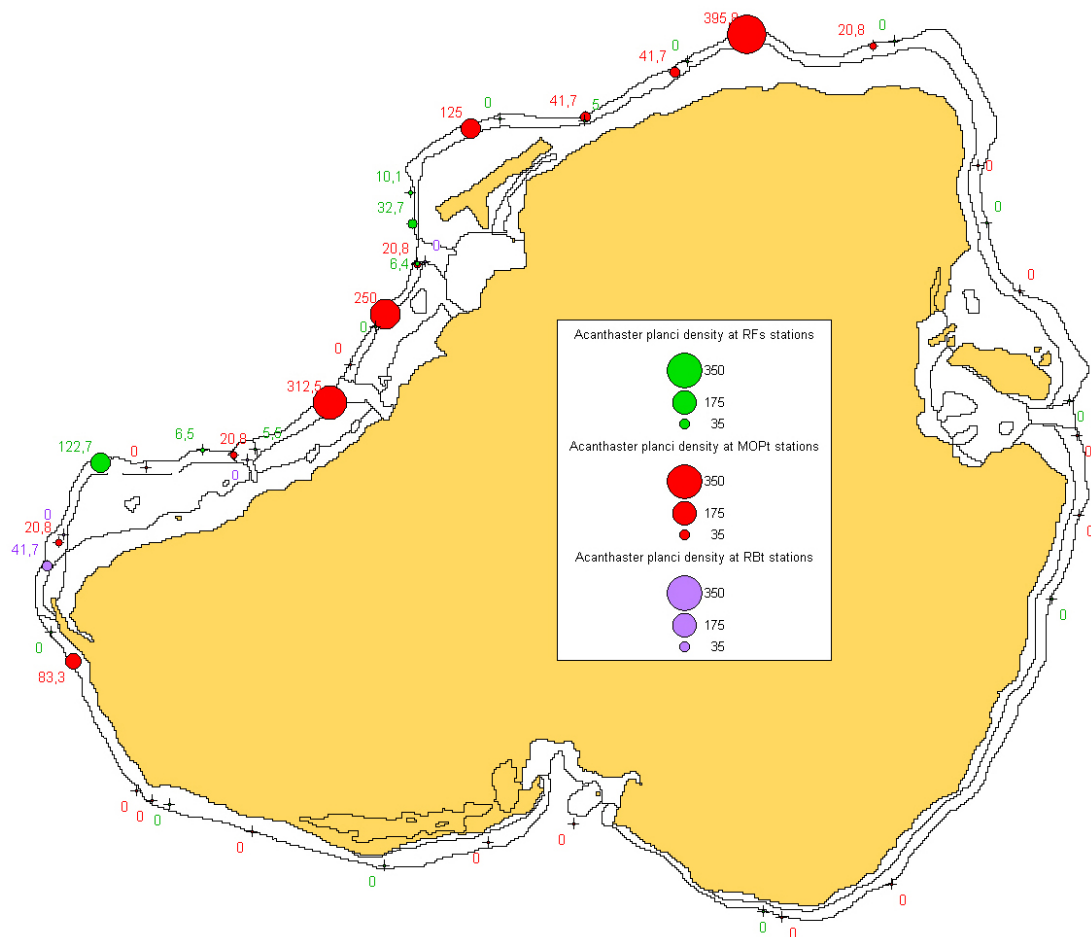


Figure 15: Crown-of-thorns sea star (*Acanthaster planci*) densities (specimens per ha) at survey stations

## 6 Summary of results

### 6.1 Trochus

- The habitat for trochus was relatively good on Kosrae. Lelu (in the east), Tafunsak, Okat and Walung have extensive fringing reef crests and back reef, and some shallow water shoaling on the reef slope, which can support an increase in trochus population.
- *Trochus niloticus* was common all around Kosrae (recorded at 95% of stations surveyed) at many easily accessible shallow-water reefs, as well as in deeper areas of the outer slope. This is common in large populations, where aggregations become diffuse as the population increases. The highest trochus densities were recorded in the northern reefs of Kosrae, where suitable extensive habitat is present.
- The mean trochus density at 95% CI for all stations at Kosrae was 297 to 444 individuals per ha. At open-access reefs (where fishing would normally occur), the trochus mean density at 95% CI was 279 to 427 individuals per ha, while at the sanctuary it was 163 to 802 individuals per ha.
- Trochus density at open-access reefs was under the minimum sustainable harvest benchmark of 500 individuals per ha. This indicates that the stock has not fully recovered from the last harvest and should stay at rest.
- Compared to the results of the 1996 survey, *Trochus niloticus* has spread toward the southern and eastern side of the island.
- *Trochus niloticus* was found at depths beyond 7 meters and down to at least 12 meters (which was the lower limit of our assessment).
- The total average number of specimens estimated in 2008 for the area between 1 and 7 meters deep was greater than the estimate from the 1996 survey (176,502 specimens in 2008 compared to 102,866 specimens in 1996).
- 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 approximately 2 million ova, whereas a 13-cm shell produces 3 times more—approximately 6 million ova). However, some early researchers (e.g., Asano 1963), suggested that this proportion of the stock must not become too dominant, and that it was better for the productivity of the fishery to fish the stock periodically, maintaining a number of large trochus but not letting them build up to become the dominant size class of the population. This is due to the fact that although a high density of larger trochus contributes to successful reproduction, large trochus can also dominate the best trochus habitat, using available food sources for the maintenance rather than production of new nacre.
- The population of young trochus (under 7 cm) recorded in this survey was small. This is expected considering this survey covered just a small section of 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 trochus in this survey

(under 2 cm in size) indicates that recruitment is ongoing, with all representative size classes from 2.5 cm to 7.5 cm recorded.

## 6.2 Giant clams

- Only one species of giant clam, *Tridacna maxima* was recorded in Kosrae. It was recorded at a low density.
- Size frequency distributions of giant clams revealed that there had been a lack in recruitment in the past three to four years.

## 6.3 Sea cucumbers

- The small high island of Kosrae does not have a complex lagoonal system and therefore possesses a limited 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.
- The most important sea cucumber species in Kosrae are lollyfish (*H. atra*), greenfish (*S. chloronotus*) and surf redfish (*Actinopyga mauritiana*). *Actinopyga mauritiana* share the same habitat as trochus and can be picked up through reef front search stations and MOP stations. Greenfish and lollyfish were found on the reef flat and inner reef areas.
- The stock of the medium value *S. chloronotus* and of the low value *H. atra* may offer limited potential for commercialisation if short, limited harvests controlled by the fishery department could be interspersed between longer time periods, which allow stocks to recover from the harvest. This would 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 (*Acanthaster planci*) is one of the invertebrates recorded most often in Kosrae reefs, with aggregations above its natural density. A total of 137 crown-of-thorns starfish were observed, essentially on the northern side of the island. The density recorded suggests an outbreak. Crown-of-thorns starfish are destructive to live coral (they feed on coral polyps) thus it is urgent to remove them from the environment.

## 7 Recommendations

### 7.1 Trochus

- Trochus densities at zone 1 (Tafunsak) and zone 2 (Lelu) were above the 500 per ha minimum sustainable harvest benchmark, while densities at all other zones were below this benchmark. The overall trochus density for Kosrae, however, was below the benchmark, which indicates that the resource density is too low to consider a harvest.
- Nevertheless, present trochus densities, distributions and active recruitment are good enough to expect a fast recovery of the resource. In addition, the extensive suitable reef habitat at the northern reefs of Kosrae can potentially support a further increase in population.
- Any future 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 allow more shells to be harvested, at least for the first open season, and would reduce the large population of oversized individuals. Reducing the older stocks would revitalise the population by making way for new settlement of young trochus to build up the base of the fishery. Raising the minimum size limit would protect young trochus 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 quality of the mother-of-pearl usually decreases as the size of the shell increases. It would be profitable to investigate if switching to larger legal size limits would alter the overall value of the product.
- 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 used.
- The trochus population at the Kosrae's only trochus sanctuary, at Okat, was healthier than the population at open access areas (density of 163 to 802 individuals per ha). But trochus were aggregated at the northern end of the sanctuary at shallow waters near the harbour entrance. Relatively low trochus presence in the rest of the sanctuary area despite the presence of extensive suitable trochus habitat suggests that there might have been harvesting activities within the sanctuary during the last open season. Effective monitoring is needed during harvest seasons.
- Trochus are unevenly distributed around Kosrae; relatively low densities were recorded in some areas. Movement of a fraction of the oversized broodstock from the high density areas (both on the open reefs and in the sanctuary) toward the low density areas should be encouraged. This should also help thin down the population of older trochus and allow space for recruitment to settle.
- In the case of a 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) would provide a

strong baseline for estimating stocks. We therefore recommended that SPC be contacted in advance of the next open season to conduct a mark-recapture survey.

## 7.2 Giant clams

- ↪ The stock of *Tridacna maxima* on Kosrae is depleted. Giant clam fishing should be discouraged to allow the stock to recover.

## 7.3 Sea cucumbers

- ↪ The three most important commercial sea cucumbers recorded during our survey were lollyfish (*H. atra*), greenfish (*S. chloronotus*), and surf redfish (*Actinopyga mauritiana*), which were present mostly at reef flats, crests and slopes in the areas assessed. The resource based on these species could support a short pulse commercial fishery on Kosrae. However, any harvesting activity should wait until further assessments are completed in the inner reef areas to expand the current picture based on this survey.

## 7.4 Crown-of-thorns starfish (*Acanthaster planci*)

- ↪ Kosrae has the healthiest live coral cover recorded in FSM by our team; however, this is under threat from the coral-eating crown-of-thorns starfish. Populations of *Acanthaster planci* were mostly recorded at the north and west of the island. It is an urgent environmental problem for the Kosrae government. Responsible agencies should coordinate efforts for a cleanup campaign. Reducing the number of crown-of-thorns starfish 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 north shore, as indicated on the map (Figure 15). Alternative uses of crown-of-thorns starfish (e.g., for fertiliser or food) should be investigated; Dr Soon-Kil Yi, from the Korean Ocean Research & Development Institute in Chuuk, noted during a debriefing meeting after the trochus stock assessment in Pohnpei that the gonads of crown-of-thorns starfish are eaten by some populations in China.

# 8 Acknowledgements

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## 10 Appendices

### 1.1 Invertebrate species recorded in different assessments in Kosrae

Group	Species	RFs	RBt	MOPt	RFs_walk
Bêche-de-mer	<i>Actinopyga mauritiana</i>	+	+	+	+
Bêche-de-mer	<i>Actinopyga miliaris</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>Stichopus horrens</i>				+
Bêche-de-mer	<i>Thelenota ananas</i>	+			
Bivalve	<i>Tridacna maxima</i>	+		+	+
Crustacean	<i>Eriphia sebana</i>				+
Crustacean	<i>Parribacus caledonicus</i>				+
Crustacean	<i>Thalamita sp</i>				+
Crustacean	<i>Thalassina sp</i>			+	
Gastropod	<i>Astraliun sp.</i>	+		+	
Gastropod	<i>Bursa bufonia</i>	+			
Gastropod	<i>Conus distans</i>	+	+	+	
Gastropod	<i>Conus sp.</i>	+	+	+	
Gastropod	<i>Conus tulipa</i>				+
Gastropod	<i>Cypraea arabica</i>				+
Gastropod	<i>Cypraea caputserpensis</i>	+	+	+	+
Gastropod	<i>Cypraea isabella</i>				+
Gastropod	<i>Cypraea maculifera</i>				+
Gastropod	<i>Dendropoma maximum</i>			+	+
Gastropod	<i>Lambis truncata</i>			+	
Gastropod	<i>Tectus pyramis</i>	+		+	+
Gastropod	<i>Thais armigera</i>				+
Gastropod	<i>Trochus maculata</i>	+			+
Gastropod	<i>Trochus niloticus</i>	+	+	+	+
Gastropod	<i>Turbo argyrostomus</i>	+	+	+	+
Gastropod	<i>Vasum ceramicum</i>	+		+	
Gastropod	<i>Vasum turbinellum</i>			+	+
Star	<i>Acanthaster planci</i>	+	+	+	
Star	<i>Choriaster granulatus</i>	+			
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 Kosrae 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>	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
<i>Actinopyga mauritiana</i>	375.0	124.1	24	900.0	204.8	10	375.0	271.6	4	500.0	341.1	3
<i>Bohadschia argus</i>	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
<i>Bohadschia graeffei</i>	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
<i>Conus distans</i>	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
<i>Conus sp.</i>	20.8	14.4	24	250.0	0.0	2	20.8	12.0	4	41.7	0.0	2
<i>Cypraea caputserpensis</i>	52.1	33.6	24	416.7	166.7	3	52.1	31.3	4	104.2	20.8	2
<i>Dendropoma maximum</i>	20.8	20.8	24	500.0		1	20.8	20.8	4	83.3		1
<i>Echinometra mathaei</i>	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
<i>Echinothrix diadema</i>	177.1	43.8	24	354.2	48.2	12	177.1	57.4	4	177.1	57.4	4
<i>Holothuria atra</i>	468.8	150.7	24	937.5	234.6	12	468.8	187.4	4	625.0	146.3	3
<i>Linckia laevigata</i>	72.9	38.3	24	437.5	119.7	4	72.9	72.9	4	291.7		1
<i>Stichopus chloronotus</i>	843.8	226.1	24	1 557.7	297.1	13	843.8	584.4	4	1 125.0	724.5	3
<i>Tridacna maxima</i>	20.8	14.4	24	250.0	0.0	2	20.8	20.8	4	83.3		1
<i>Trochus maculata</i>	62.5	62.5	24	1 500.0		1	62.5	62.5	4	250.0		1
<i>Trochus niloticus</i>	458.3	157.6	24	785.7	235.7	14	458.3	265.2	4	458.3	265.2	4
<i>Turbo argyrostomus</i>	72.9	28.1	24	291.7	41.7	6	72.9	46.2	4	97.2	55.6	3
<i>Vasum turbinellum</i>	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1



## 2.2 *Kosrae reef-benthos (RBt) assessment data review outside 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>	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
<i>Actinopyga mauritiana</i>	402.8	158.0	18	1 035.7	269.6	7	402.8	382.1	3	604.2	562.5	2
<i>Bohadschia argus</i>	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
<i>Conus distans</i>	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
<i>Conus sp.</i>	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
<i>Cypraea caputserpensis</i>	27.8	19.1	18	250.0	0.0	2	27.8	27.8	3	83.3		1
<i>Echinometra mathaei</i>	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
<i>Echinothrix diadema</i>	152.8	50.1	18	343.8	65.8	8	152.8	73.5	3	152.8	73.5	3
<i>Holothuria atra</i>	458.3	190.9	18	1 178.6	352.3	7	458.3	264.6	3	687.5	229.2	2
<i>Stichopus chloronotus</i>	847.2	299.9	18	2 178.6	414.4	7	847.2	826.5	3	1 270.8	1 229.2	2
<i>Trochus niloticus</i>	194.4	55.6	18	388.9	60.5	9	194.4	36.7	3	194.4	36.7	3
<i>Turbo argyrostomus</i>	83.3	35.0	18	300.0	50.0	5	83.3	63.6	3	125.0	83.3	2

### 2.3 Kosrae 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>Actinopyga mauritiana</i>	291.7	163.5	6	583.3	220.5	3	291.7		1	291.7		1
<i>Bohadschia graeffei</i>	41.7	41.7	6	250.0		1	41.7		1	41.7		1
<i>Conus sp.</i>	41.7	41.7	6	250.0		1	41.7		1	41.7		1
<i>Cypraea caputserpensis</i>	125.0	125.0	6	750.0		1	125.0		1	125.0		1
<i>Dendropoma maximum</i>	83.3	83.3	6	500.0		1	83.3		1	83.3		1
<i>Echinothrix diadema</i>	250.0	91.3	6	375.0	72.2	4	250.0		1	250.0		1
<i>Holothuria atra</i>	500.0	214.1	6	600.0	231.8	5	500.0		1	500.0		1
<i>Linckia laevigata</i>	291.7	119.3	6	437.5	119.7	4	291.7		1	291.7		1
<i>Stichopus chloronotus</i>	833.3	153.7	6	833.3	153.7	6	833.3		1	833.3		1
<i>Tridacna maxima</i>	83.3	52.7	6	250.0	0.0	2	83.3		1	83.3		1
<i>Trochus maculata</i>	250.0	250.0	6	1 500.0		1	250.0		1	250.0		1
<i>Trochus niloticus</i>	1250.0	508.3	6	1 500.0	542.0	5	1 250.0		1	1 250.0		1
<i>Turbo argyrostomus</i>	41.7	41.7	6	250.0		1	41.7		1	41.7		1
<i>Vasum turbinellum</i>	41.7	41.7	6	250.0		1	41.7		1	41.7		1

### 3.1 Kosrae 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>	10.5	5.1	108	103.1	42.7	11	10.5	6.9	18	27.0	16.4	7
<i>Actinopyga mauritiana</i>	25.4	7.2	108	80.7	20.1	34	25.4	10.9	18	35.2	14.2	13
<i>Actinopyga miliaris</i>	0.4	0.4	108	38.6		1	0.4	0.4	18	6.4		1
<i>Astridium sp.</i>	0.4	0.3	108	15.9	1.0	3	0.4	0.3	18	4.0	1.0	2
<i>Bohadschia argus</i>	1.0	0.6	108	34.9		3	1.0	0.7	18	8.7	2.2	2
<i>Bohadschia graeffei</i>	4.3	2.0	108	92.7	15.4	5	4.3	4.3	18	77.2		1
<i>Bursa bufonia</i>	0.3	0.3	108	32.8		1	0.3	0.3	18	5.5		1
<i>Choriaster granulatus</i>	0.2	0.2	108	20.0		1	0.2	0.2	18	3.3		1
<i>Conus distans</i>	5.6	3.2	108	75.8	37.3	8	5.6	4.5	18	20.2	15.5	5
<i>Conus sp.</i>	0.6	0.4	108	23.0	8.1	3	0.6	0.4	18	5.7	0.8	2
<i>Cypraea caputserpensis</i>	0.6	0.6	108	60.7		1	0.6	0.6	18	10.1		1
<i>Echinometra mathaei</i>	0.5	0.4	108	27.6	12.5	2	0.5	0.4	18	4.6	2.1	2
<i>Echinothrix diadema</i>	6.9	2.8	108	53.6	17.5	14	6.9	3.5	18	15.6	6.8	8
<i>Holothuria atra</i>	56.4	24.1	108	320.5	122.3	19	56.4	38.9	18	169.2	107.8	6
<i>Holothuria edulis</i>	0.7	0.5	108	39.2	0.0	2	0.7	0.7	18	13.1		1
<i>Holothuria nobilis</i>	1.3	0.8	108	46.4	7.2	3	1.3	0.9	18	11.6	1.5	2
<i>Linckia guildingi</i>	0.6	0.5	108	30.7	18.4	2	0.6	0.6	18	10.2		1
<i>Linckia laevigata</i>	8.2	4.1	108	148.3	48.3	6	8.2	5.6	18	49.4	24.2	3
<i>Stichodactyla sp.</i>	0.7	0.7	108	77.2		1	0.7	0.7	18	12.9		1
<i>Stichopus chloronotus</i>	36.3	12.0	108	217.9	55.6	18	36.3	20.8	18	163.4	63.9	4
<i>Tectus pyramis</i>	2.1	1.2	108	46.2	18.5	5	2.1	1.5	18	9.6	5.6	4
<i>Thelenota ananas</i>	0.3	0.3	108	32.8		1	0.3	0.3	18	5.5		1
<i>Tridacna maxima</i>	1.7	0.6	108	22.3	3.9	8	1.7	0.7	18	4.3	1.1	7
<i>Trochus maculata</i>	0.4	0.4	108	39.2		1	0.4	0.4	18	6.5		1
<i>Trochus niloticus</i>	67.8	13.2	108	106.1	19.2	69	67.8	22.5	18	67.8	22.5	18
<i>Turbo argyrostomus</i>	5.9	2.6	108	53.3	18.8	12	5.9	3.0	18	17.8	7.3	6
<i>Vasum ceramicum</i>	0.3	0.3	108	32.8		1	0.3	0.3	18	5.5		1

### 3.2 Kosrae 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>	11.4	5.8	96	109.5	46.6	10	11.4	7.7	16	30.4	18.9	6
<i>Actinopyga mauritiana</i>	27.7	8.1	96	88.6	22.4	30	27.7	12.1	16	40.3	16.5	11
<i>Astrarium</i> sp.	0.5	0.3	96	15.9	1.0	3	0.5	0.4	16	4.0	1.0	2
<i>Bohadschia argus</i>	1.1	0.6	96	34.9	2.2	3	1.1	0.8	16	8.7	2.2	2
<i>Bursa bufonia</i>	0.3	0.3	96	32.8		1	0.3	0.3	16	5.5		1
<i>Choriaster granulatus</i>	0.2	0.2	96	20.0		1	0.2	0.2	16	3.3		1
<i>Conus distans</i>	6.1	3.6	96	83.1	42.3	7	6.1	5.1	16	24.2	19.3	4
<i>Conus</i> sp.	0.7	0.5	96	23.0	8.1	3	0.7	0.5	16	5.7	0.8	2
<i>Cypraea caputserpensis</i>	0.6	0.6	96	60.7		1	0.6	0.6	16	10.1		1
<i>Echinometra mathaei</i>	0.6	0.4	96	27.6	12.5	2	0.6	0.4	16	4.6	2.1	2
<i>Echinothrix diadema</i>	6.4	2.9	96	55.5	21.0	11	6.4	3.8	16	16.9	9.0	6
<i>Holothuria atra</i>	61.8	27.1	96	349.2	135.3	17	61.8	43.7	16	197.9	127.3	5
<i>Holothuria edulis</i>	0.8	0.6	96	39.2	0.0	2	0.8	0.8	16	13.1		1
<i>Holothuria nobilis</i>	1.4	0.8	96	46.4	7.2	3	1.4	1.0	16	11.6	1.5	2
<i>Linckia guildingi</i>	0.6	0.5	96	30.7	18.4	2	0.6	0.6	16	10.2		1
<i>Linckia laevigata</i>	5.2	3.6	96	167.8	78.4	3	5.2	5.1	16	42.0	39.9	2
<i>Stichopus chloronotus</i>	25.1	11.6	96	301.3	100.6	8	25.1	19.6	16	200.8	102.8	2
<i>Tectus pyramis</i>	2.0	1.3	96	48.2	23.7	4	2.0	1.6	16	10.7	7.7	3
<i>Thelenota ananas</i>	0.3	0.3	96	32.8		1	0.3	0.3	16	5.5		1
<i>Tridacna maxima</i>	1.9	0.7	96	22.3	3.9	8	1.9	0.7	16	4.3	1.1	7
<i>Trochus maculata</i>	0.4	0.4	96	39.2		1	0.4	0.4	16	6.5		1
<i>Trochus niloticus</i>	46.0	6.8	96	74.8	9.3	59	46.0	11.9	16	46.0	11.9	16
<i>Turbo argyrostomus</i>	5.1	2.8	96	70.5	30.5	7	5.1	3.2	16	16.5	8.7	5
<i>Vasum ceramicum</i>	0.3	0.3	96	32.8		1	0.3	0.3	16	5.5		1

### 3.3 Kosrae 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>	3.2	3.2	12	38.6		1	3.2	3.2	2	6.4		1
<i>Actinopyga mauritiana</i>	7.3	3.6	12	21.8	6.3	4	7.3	0.8	2	7.3	0.8	2
<i>Actinopyga miliaris</i>	3.2	3.2	12	38.6		1	3.2	3.2	2	6.4		1
<i>Bohadschia graeffei</i>	38.6	15.0	12	92.7	15.4	5	38.6	38.6	2	77.2		1
<i>Conus distans</i>	2.0	2.0	12	24.4		1	2.0	2.0	2	4.1		1
<i>Echinothrix diadema</i>	11.7	9.6	12	46.7		3	11.7	7.6	2	11.7	7.6	2
<i>Holothuria atra</i>	12.9	9.9	12	77.2	38.6	2	12.9	12.9	2	25.7		1
<i>Linckia laevigata</i>	32.2	22.7	12	128.7	71.7	3	32.2	32.2	2	64.4		1
<i>Stichodactyla sp.</i>	6.4	6.4	12	77.2		1	6.4	6.4	2	12.9		1
<i>Stichopus chloronotus</i>	126.0	49.0	12	151.2	55.7	10	126.0	105.7	2	126.0	105.7	2
<i>Tectus pyramis</i>	3.2	3.2	12	38.6		1	3.2	3.2	2	6.4		1
<i>Trochus niloticus</i>	242.3	94.7	12	290.8	107.7	10	242.3	163.1	2	242.3	163.1	2
<i>Turbo argyrostomus</i>	12.2	6.2	12	29.3	11.3	5	12.2	12.2	2	24.4		1

#### 4.1 Kosrae reef-front search walk (RFs W) assessment data review (only out of 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>Actinopyga mauritiana</i>	88.2	22.7	24	162.9	28.5	13	88.2	56.6	4	88.2	56.6	4
<i>Conus tulipa</i>	0.8	0.8	24	18.6		1	0.8	0.8	4	3.1		1
<i>Culcita novaeguineae</i>	0.5	0.5	24	12.6		1	0.5	0.5	4	2.1		1
<i>Cypraea arabica</i>	0.8	0.8	24	18.6		1	0.8	0.8	4	3.1		1
<i>Cypraea caputserpensis</i>	4.3	3.1	24	51.4	17.1	2	4.3	4.3	4	17.1		1
<i>Cypraea isabella</i>	1.5	1.5	24	37.1		1	1.5	1.5	4	6.2		1
<i>Cypraea maculifera</i>	2.2	1.6	24	26.4	7.8	2	2.2	1.4	4	4.4	1.3	2
<i>Dendropoma maximum</i>	0.4	0.4	24	9.5		1	0.4	0.4	4	1.6		1
<i>Echinothrix diadema</i>	24.9	7.4	24	49.9	10.8	12	24.9	6.6	4	24.9	6.6	4
<i>Eriphia sebana</i>	0.8	0.8	24	18.6		1	0.8	0.8	4	3.1		1
<i>Holothuria atra</i>	3585.4	480.6	24	3585.4	480.6	24	3585.4	444.1	4	3585.4	444.1	4
<i>Holothuria coluber</i>	5.8	4.5	24	69.9	32.8	2	5.8	4.0	4	11.7	5.5	2
<i>Linckia guildingi</i>	0.5	0.5	24	12.6		1	0.5	0.5	4	2.1		1
<i>Linckia laevigata</i>	12.6	4.6	24	37.9	8.5	8	12.6	4.5	4	16.8	2.4	3
<i>Parribacus caledonicus</i>	0.8	0.8	24	18.6		1	0.8	0.8	4	3.1		1
<i>Stichopus chloronotus</i>	272.3	144.2	24	726.0	343.9	9	272.3	264.4	4	363.0	351.2	3
<i>Stichopus horrens</i>	1.4	1.4	24	34.2		1	1.4	1.4	4	5.7		1
<i>Tectus pyramis</i>	3.6	2.1	24	29.0	5.2	3	3.6	2.7	4	7.3	4.2	2
<i>Thais armigera</i>	2.9	2.9	24	68.5		1	2.9	2.9	4	11.4		1
<i>Thalamita sp</i>	2.9	2.0	24	34.2	0.0	2	2.9	2.9	4	11.4		1
<i>Tridacna maxima</i>	0.4	0.4	24	9.5		1	0.4	0.4	4	1.6		1
<i>Trochus maculata</i>	42.6	14.1	24	85.2	22.3	12	42.6	16.4	4	56.8	11.6	3
<i>Trochus niloticus</i>	3.9	3.0	24	46.8	21.7	2	3.9	2.7	4	7.8	3.6	2
<i>Turbo argyrostomus</i>	9.2	7.8	24	109.9	75.7	2	9.2	7.4	4	18.3	12.6	2
<i>Vasum turbinellum</i>	0.8	0.8	24	18.6		1	0.8	0.8	4	3.1		1

### 5.1 *Kosrae mother-of-pearl search (MOPs) assessment data review*

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>Astraliu sp.</i>	18.5	18.5	6	111.1		1	18.5		1	18.5		1
<i>Lambis truncata</i>	18.5	18.5	6	111.1		1	18.5		1	18.5		1
<i>Tectus pyramis</i>	9.3	9.3	6	55.6		1	9.3		1	9.3		1
<i>Trochus maculata</i>	9.3	9.3	6	55.6		1	9.3		1	9.3		1

### 6.1 Kosrae mother-of-pearl transect (MOPt) assessment 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>	58.0	15.3	138	296.3	60.1	27	58.0	23.0	23	121.2	40.8	11
<i>Actinopyga mauritiana</i>	13.6	4.2	138	156.3	22.4	12	13.6	3.8	23	31.3	4.7	10
<i>Astrarium sp.</i>	3.6	2.2	138	166.7	41.7	3	3.6	2.8	23	41.7	20.8	2
<i>Bohadschia argus</i>	1.8	1.3	138	125.0	0.0	2	1.8	1.3	23	20.8	0.0	2
<i>Bohadschia graeffei</i>	1.8	1.3	138	125.0	0.0	2	1.8	1.3	23	20.8	0.0	2
<i>Conus distans</i>	8.2	3.5	138	160.7	35.7	7	8.2	4.5	23	46.9	15.6	4
<i>Conus sp.</i>	2.7	1.6	138	125.0	0.0	3	2.7	2.0	23	31.3	10.4	2
<i>Culcita novaeguineae</i>	0.9	0.9	138	125.0		1	0.9	0.9	23	20.8		1
<i>Cypraea caputserpensis</i>	0.9	0.9	138	125.0		1	0.9	0.9	23	20.8		1
<i>Dendropoma maximum</i>	19.0	19.0	138	2 625.0		1	19.0	19.0	23	437.5		1
<i>Echinothrix diadema</i>	19.0	8.3	138	262.5	86.3	10	19.0	11.7	23	109.4	49.9	4
<i>Holothuria atra</i>	2.7	1.6	138	125.0	0.0	3	2.7	2.0	23	31.3	10.4	2
<i>Holothuria nobilis</i>	0.9	0.9	138	125.0		1	0.9	0.9	23	20.8		1
<i>Lambis truncata</i>	30.8	13.4	138	386.4	131.1	11	30.8	20.7	23	236.1	109.1	3
<i>Linckia guildingi</i>	7.2	3.1	138	166.7	26.4	6	7.2	5.0	23	83.3	0.0	2
<i>Stichopus chloronotus</i>	27.2	8.1	138	250.0	44.0	15	27.2	13.8	23	125.0	41.7	5
<i>Tectus pyramis</i>	9.1	2.8	138	125.0	0.0	10	9.1	3.4	23	29.8	6.2	7
<i>Thalassina sp</i>	2.7	2.0	138	187.5	62.5	2	2.7	2.0	23	31.3	10.4	2
<i>Tridacna maxima</i>	15.4	4.0	138	141.7	11.4	15	15.4	5.4	23	44.3	9.2	8
<i>Trochus niloticus</i>	374.1	37.2	138	491.7	42.9	105	374.1	66.2	23	374.1	66.2	23
<i>Turbo argyrostomus</i>	96.9	17.7	138	361.5	42.4	37	96.9	24.6	23	171.5	29.9	13
<i>Vasum ceramicum</i>	0.9	0.9	138	125.0		1	0.9	0.9	23	20.8		1
<i>Vasum turbinellum</i>	0.9	0.9	138	125.0		1	0.9	0.9	23	20.8		1



## 6.2 Kosrae mother-of-pearl transect (MOPt) outside 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>	53.1	16.5	120	289.8	71.4	22	53.1	24.3	20	118.1	46.6	9
<i>Actinopyga mauritiana</i>	14.6	4.7	120	159.1	24.4	11	14.6	4.3	20	32.4	5.0	9
<i>Astrarium sp.</i>	3.1	2.3	120	187.5	62.5	2	3.1	3.1	20	62.5		1
<i>Bohadschia argus</i>	2.1	1.5	120	125.0	0.0	2	2.1	1.4	20	20.8	0.0	2
<i>Bohadschia graeffei</i>	2.1	1.5	120	125.0	0.0	2	2.1	1.4	20	20.8	0.0	2
<i>Conus distans</i>	5.2	2.3	120	125.0	0.0	5	5.2	3.3	20	34.7	13.9	3
<i>Conus sp.</i>	3.1	1.8	120	125.0	0.0	3	3.1	2.3	20	31.3	10.4	2
<i>Culcita novaeguineae</i>	1.0	1.0	120	125.0		1	1.0	1.0	20	20.8		1
<i>Cypraea caputserpensis</i>	1.0	1.0	120	125.0		1	1.0	1.0	20	20.8		1
<i>Dendropoma maximum</i>	21.9	21.9	120	2 625.0		1	21.9	21.9	20	437.5		1
<i>Echinothrix diadema</i>	4.2	3.3	120	250.0	125.0	2	4.2	3.2	20	41.7	20.8	2
<i>Holothuria nobilis</i>	1.0	1.0	120	125.0		1	1.0	1.0	20	20.8		1
<i>Lambis truncata</i>	35.4	15.4	120	386.4	131.1	11	35.4	23.7	20	236.1	109.1	3
<i>Linckia guildingi</i>	4.2	2.5	120	166.7	41.7	3	4.2	4.2	20	83.3		1
<i>Stichopus chloronotus</i>	14.6	7.4	120	350.0	100.0	5	14.6	13.5	20	145.8	125.0	2
<i>Tectus pyramis</i>	8.3	2.9	120	125.0	0.0	8	8.3	3.8	20	33.3	8.3	5
<i>Thalassina sp</i>	3.1	2.3	120	187.5	62.5	2	3.1	2.3	20	31.3	10.4	2
<i>Tridacna maxima</i>	10.4	3.8	120	156.3	20.5	8	10.4	5.1	20	41.7	13.2	5
<i>Trochus niloticus</i>	377.1	40.1	120	502.8	47.6	90	377.1	75.3	20	377.1	75.3	20
<i>Turbo argyrostomus</i>	100.0	19.9	120	387.1	49.0	31	100.0	27.9	20	181.8	34.6	11
<i>Vasum ceramicum</i>	1.0	1.0	120	125.0		1	1.0	1.0	20	20.8		1
<i>Vasum turbinellum</i>	1.0	1.0	120	125.0		1	1.0	1.0	20	20.8		1

### 6.3 Kosrae 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>	90.3	42.6	18	325.0	93.5	5	90.3	80.1	3	135.4	114.6	2
<i>Actinopyga mauritiana</i>	6.9	6.9	18	125.0		1	6.9	6.9	3	20.8		1
<i>Astrarium sp.</i>	6.9	6.9	18	125.0		1	6.9	6.9	3	20.8		1
<i>Conus distans</i>	27.8	21.6	18	250.0	125.0	2	27.8	27.8	3	83.3		1
<i>Echinothrix diadema</i>	118.1	55.8	18	265.6	106.8	8	118.1	72.5	3	177.1	72.9	2
<i>Holothuria atra</i>	20.8	11.3	18	125.0	0.0	3	20.8	12.0	3	31.3	10.4	2
<i>Linckia guildingi</i>	27.8	16.2	18	166.7	41.7	3	27.8	27.8	3	83.3		1
<i>Stichopus chloronotus</i>	111.1	31.8	18	200.0	38.2	10	111.1	18.4	3	111.1	18.4	3
<i>Tectus pyramis</i>	13.9	9.5	18	125.0	0.0	2	13.9	6.9	3	20.8	0.0	2
<i>Tridacna maxima</i>	48.6	14.8	18	125.0	0.0	7	48.6	13.9	3	48.6	13.9	3
<i>Trochus niloticus</i>	354.2	86.5	18	425.0	93.5	15	354.2	102.8	3	354.2	102.8	3
<i>Turbo argyrostomus</i>	76.4	28.8	18	229.2	38.4	6	76.4	38.7	3	114.6	10.4	2

## 7.1 Kosrae species size review - all techniques

Species	Mean length (cm)	SE	n
<i>Holothuria atra</i>	15.4	0.5	5519
<i>Trochus niloticus</i>	9.9	0.1	791
<i>Stichopus chloronotus</i>	16.2	0.4	724
<i>Actinopyga mauritiana</i>	18.6	0.3	256
<i>Turbo argyrostomus</i>	6.2	0.2	149
<i>Trochus maculata</i>	3.6	0.8	58
<i>Lambis truncata</i>	24.6	0.3	36
<i>Conus distans</i>	7.6	0.3	32
<i>Tridacna maxima</i>	20.6	1.1	29
<i>Tectus pyramis</i>	6.4	0.3	21
<i>Conus sp.</i>	7.5	0.5	9
<i>Bohadschia argus</i>	21.0	2.1	6
<i>Holothuria nobilis</i>	22.3	1.8	4
<i>Bohadschia graeffei</i>	31.0		15
<i>Vasum turbinellum</i>	12.0		3
<i>Cypraea maculifera</i>	4.0		2
<i>Vasum ceramicum</i>	11.2		2
<i>Stichopus horrens</i>	14.0		1
<i>Thelenota ananas</i>	34.0		1
<i>Bursa bufonia</i>	5.5		1
<i>Cypraea arabica</i>	5.2		1
<i>Acanthaster planci</i>			137
<i>Echinothrix diadema</i>			98
<i>Linckia laevigata</i>			56
<i>Dendropoma maximum</i>			24
<i>Linckia guildingi</i>			14
<i>Cypraea caputserpensis</i>			10
<i>Astrarium sp.</i>			9
<i>Holothuria coluber</i>			5
<i>Echinometra mathaei</i>			4
<i>Thalassina sp</i>			3
<i>Holothuria edulis</i>			2
<i>Stichodactyla sp.</i>			2
<i>Thalamita sp</i>			2
<i>Cypraea isabella</i>			2
<i>Thais armigera</i>			2
<i>Culcita novaeguineae</i>			2
<i>Actinopyga miliaris</i>			1
<i>Eriphia sebana</i>			1
<i>Parribacus caledonicus</i>			1
<i>Conus tulipa</i>			1
<i>Choriaster granulatus</i>			1

8 *extrapolated stock of trochus per zone and per size class given current legal size.*

	Numbers			Dry weight (in Kg)			Wet weight (in Kg)		
	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean
<b>zone 1</b>									
L>10.2	23114	44398	33756	8287	15917	12102	11146	21410	16278
% oversize	44.1	44.1	44.1	59.2	59.2	59.2	59.9	59.9	59.9
7.6<L<10.2	26297	50513	38405	5500	10564	8032	7197	13825	10511
% legal size	50.1	50.1	50.1	39.3	39.3	39.3	38.7	38.7	38.7
L<7.6	3045	5849	4447	213	410	312	265	510	387
% undersize	5.8	5.8	5.8	1.5	1.5	1.5	1.4	1.4	1.4
All	52456	100760	76608	14000	26891	20445	18609	35744	27176

	Numbers			Dry weight (in Kg)			Wet weight (in Kg)		
	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean
<b>zone 2</b>									
L>10.2	15197	47432	31314	5448	17005	11227	7328	22873	15101
% oversize	44.1	44.1	44.1	59.2	59.2	59.2	59.9	59.9	59.9
7.6<L<10.2	17290	53964	35627	3616	11286	7451	4732	14769	9751
% legal size	50.1	50.1	50.1	39.3	39.3	39.3	38.7	38.7	38.7
L<7.6	2002	6248	4125	140	438	289	174	544	359
% undersize	5.8	5.8	5.8	1.5	1.5	1.5	1.4	1.4	1.4
All	34489	107644	71067	9205	28729	18967	12235	38186	25211

	Numbers			Dry weight (in Kg)			Wet weight (in Kg)		
	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean
<b>zone 3</b>									
L>10.2	7251	13546	10398	2599	4856	3728	3496	6532	5014
% oversize	44.1	44.1	44.1	59.2	59.2	59.2	59.9	59.9	59.9
7.6<L<10.2	8249	15412	11830	1725	3223	2474	2258	4218	3238
% legal size	50.1	50.1	50.1	39.3	39.3	39.3	38.7	38.7	38.7
L<7.6	955	1784	1370	67	125	96	83	155	119
% undersize	5.8	5.8	5.8	1.5	1.5	1.5	1.4	1.4	1.4
All	16455	30742	23598	4392	8205	6298	5837	10906	8371

**8**      *extrapolated stock of trochus per zone and per size class given current legal size.*  
*(continued)*

	Numbers			Dry weight (in Kg)			Wet weight (in Kg)		
	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean
<b>zone 4</b>									
L>10.2	2031	5414	3722	728	1941	1335	980	2611	1795
% oversize	44.1	44.1	44.1	59.2	59.2	59.2	59.9	59.9	59.9
7.6<L<10.2	2311	6159	4235	483	1288	886	633	1686	1159
% legal size	50.1	50.1	50.1	39.3	39.3	39.3	38.7	38.7	38.7
L<7.6	268	713	490	19	50	34	23	62	43
% undersize	5.8	5.8	5.8	1.5	1.5	1.5	1.4	1.4	1.4
All	4610	12286	8448	1230	3279	2255	1635	4358	2997

	Numbers			Dry weight (in Kg)			Wet weight (in Kg)		
	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean
<b>zone 5</b>									
L>10.2	9053	16965	13009	3246	6082	4664	4366	8181	6273
% oversize	44.1	44.1	44.1	59.2	59.2	59.2	59.9	59.9	59.9
7.6<L<10.2	10300	19302	14801	2154	4037	3095	2819	5283	4051
% legal size	50.1	50.1	50.1	39.3	39.3	39.3	38.7	38.7	38.7
L<7.6	1193	2235	1714	84	157	120	104	195	149
% undersize	5.8	5.8	5.8	1.5	1.5	1.5	1.4	1.4	1.4
All	20546	38502	29524	5483	10276	7880	7289	13658	10474

	Numbers			Dry weight (in Kg)			Wet weight (in Kg)		
	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean
<b>Zone 6</b> (trochus sanctuary)									
L>10.2	2065	6733	4399	791	2578	1684	1067	3478	2272
% oversize	44.2	44.2	44.2	65.3	65.3	65.3	66.2	66.2	66.2
7.6<L<10.2	1967	6413	4190	373	1216	795	486	1585	1035
% legal size	42.1	42.1	42.1	30.8	30.8	30.8	30.2	30.2	30.2
L<7.6	639	2084	1362	48	155	101	59	193	126
% undersize	13.7	13.7	13.7	3.9	3.9	3.9	3.7	3.7	3.7
All	4671	15230	9951	1211	3949	2580	1612	5255	3434

**9**      *extrapolated stock of trochus per zone and per size class given proposed alternative legal size*

	Numbers			Dry weight (in Kg)			Wet weight (in Kg)		
	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean
<b>zone1</b>									
L>11.0	10519	20205	15362	4333	8323	6328	5868	11272	8570
% oversize (given proposed alternative legal size)	20.1	20.1	20.1	31.0	31.0	31.0	31.5	31.5	31.5
8.0<L<11.0	37923	72845	55384	9335	17931	13633	12324	23673	17999
% legal sizes (given proposed alternative legal size)	72.3	72.3	72.3	66.7	66.7	66.7	66.2	66.2	66.2
L<8.0	4014	7710	5862	332	637	485	416	799	607
% undersize (given proposed alternative legal size)	7.7	7.7	7.7	2.4	2.4	2.4	2.2	2.2	2.2
All	52456	100760	76608	14000	26891	20445	18609	35744	27176

	Numbers			Dry weight (in Kg)			Wet weight (in Kg)		
	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean
<b>zone 2</b>									
L>11.0	6916	21586	14251	2849	8892	5870	3858	12042	7950
% oversize (given proposed alternative legal size)	20.1	20.1	20.1	31.0	31.0	31.0	31.5	31.5	31.5
8.0<L<11.0	24934	77822	51378	6138	19156	12647	8103	25291	16697
% legal sizes (given proposed alternative legal size)	72.3	72.3	72.3	66.7	66.7	66.7	66.2	66.2	66.2
L<8.0	2639	8237	5438	218	681	450	273	853	563
% undersize (given proposed alternative legal size)	7.7	7.7	7.7	2.4	2.4	2.4	2.2	2.2	2.2
All	34489	107644	71067	9205	28729	18967	12235	38186	25211

	Numbers			Dry weight (in Kg)			Wet weight (in Kg)		
	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean
<b>zone3</b>									
L>11.0	3300	6165	4732	1359	2539	1949	1841	3439	2640
% oversize (given proposed alternative legal size)	20.1	20.1	20.1	31.0	31.0	31.0	31.5	31.5	31.5
8.0<L<11.0	11896	22225	17060	2928	5471	4199	3866	7223	5544
% legal sizes (given proposed alternative legal size)	72.3	72.3	72.3	66.7	66.7	66.7	66.2	66.2	66.2
L<8.0	1259	2352	1806	104	194	149	130	244	187
% undersize (given proposed alternative legal size)	7.7	7.7	7.7	2.4	2.4	2.4	2.2	2.2	2.2
All	16455	30742	23598	4392	8205	6298	5837	10906	8371

**9**      *extrapolated stock of trochus per zone and per size class given proposed alternative legal size (continued)*

	Numbers			Dry weight (in Kg)			Wet weight (in Kg)		
	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean
<b>zone 4</b>									
L>11.0	924	2464	1694	381	1015	698	516	1374	945
% oversize (given proposed alternative legal size)	20.1	20.1	20.1	31.0	31.0	31.0	31.5	31.5	31.5
8.0<L<11.0	3333	8882	6108	820	2186	1503	1083	2887	1985
% legal sizes (given proposed alternative legal size)	72.3	72.3	72.3	66.7	66.7	66.7	66.2	66.2	66.2
L<8.0	353	940	646	29	78	53	37	97	67
% undersize (given proposed alternative legal size)	7.7	7.7	7.7	2.4	2.4	2.4	2.2	2.2	2.2
All	4610	12286	8448	1230	3279	2255	1635	4358	2997

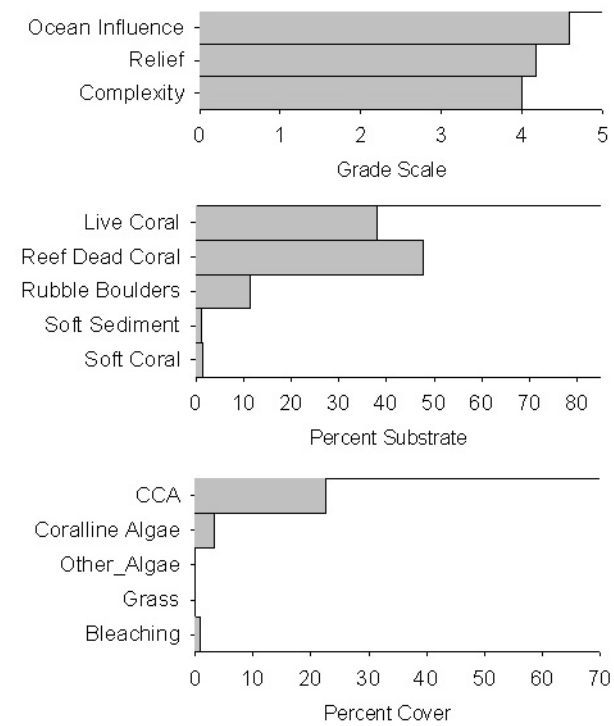
	Numbers			Dry weight (in Kg)			Wet weight (in Kg)		
	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean
<b>zone 5</b>									
L>11.0	4120	7721	5920	1697	3180	2439	2298	4307	3303
% oversize (given proposed alternative legal size)	20.1	20.1	20.1	31.0	31.0	31.0	31.5	31.5	31.5
8.0<L<11.0	14854	27835	21345	3656	6852	5254	4827	9046	6937
% legal sizes (given proposed alternative legal size)	72.3	72.3	72.3	66.7	66.7	66.7	66.2	66.2	66.2
L<8.0	1572	2946	2259	130	244	187	163	305	234
% undersize (given proposed alternative legal size)	7.7	7.7	7.7	2.4	2.4	2.4	2.2	2.2	2.2
All	20546	38502	29524	5483	10276	7880	7289	13658	10474

	Numbers			Dry weight (in Kg)			Wet weight (in Kg)		
	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean	95% confidence interval values (min and max)		mean
<b>Zone 6 (trochus sanctuary)</b>									
L>11.0	1426	4649	3038	589	1922	1256	798	2603	1701
% oversize (given proposed alternative legal size)	30.5	30.5	30.5	48.7	48.7	48.7	49.5	49.5	49.5
8.0<L<11.0	2409	7855	5133	550	1793	1172	724	2360	1542
% legal sizes (given proposed alternative legal size)	51.6	51.6	51.6	45.4	45.4	45.4	44.9	44.9	44.9
L<8.0	836	2725	1781	72	234	153	90	293	191
% undersize (given proposed alternative legal size)	17.9	17.9	17.9	5.9	5.9	5.9	5.6	5.6	5.6
All	4671	15230	9951	1211	3949	2580	1612	5255	3434

10 *Habitat descriptors for independent assessment – Kosrae*

**Mother Of Pearl  
transect Stations**

All stations



**Reef Benthos  
transect Stations**

All stations

