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AUTONOMOUS BOUGAINVILLE GOVERNMENT

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Northern Bougainville Marine Resource Assessment

Autonomous Region of Bougainville

Technical report of survey conducted from the 1st - 25th November 2008

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Executive Summary

This survey was conducted in the northern part of the Autonomous Region of Bougainville between 1st – 25th of November 2008. The survey covered the western side and outer islands of Buka Island, the Saposa and Buka Town region and the Tinputz region on north eastern side of Bougainville Island. The survey team was comprised of marine scientists, conservationists and fisheries' officers. The survey provided an assessment of the status of sea cucumbers, reef fish and corals in Northern Bougainville, with recommendations for their conservation and management.

The survey showed that the Northern Bougainville sea cucumbers have been severely overfished. Sea cucumbers were present in low or very low densities at all sites surveyed. A comparison of historical 1992 survey data from around Buka Island with results from this survey revealed major reductions in sea cucumber abundances over this 16 year period. These changes were typically extreme, with six of the eight species sighted declining to between 1% and 5% of 1992 levels. The size frequency distribution of high value species such as Sandfish also support a conclusion that sea cucumber stocks have been overfished. Most of the Sandfish sighted in this survey were juveniles; with the vast majority being below the minimum legal size of 22 cm. The only site in this survey that had a high density of sea cucumbers was a reef crest site in the Tinputz. The high densities at this site were due to high abundances of Lollyfish, and it is noteworthy that this site is closed to fishing under a customary tambu. The much higher than average densities of Lollyfish at this site provide evidence for the positive impact that protection can have for this species.

Reef fishes were also in very low densities compared to nearby regions in the Solomon and Bismarck Sea, indicative of overfishing. The large humphead wrasse was rarely seen in this survey and the Bumphead parrotfish was never sighted. These two species are considered key indicators of general reef fisheries health, and their low densities or complete absence from long swim surveys suggest overfishing, particularly by night spear fishers with flashlights. Analysis of the fish data by the four regions surveyed revealed the densities and biomass of a reef fishes were significantly higher in the Tinputz than in all other regions surveyed. The higher densities and biomass of reef fishes in the Tinputz correlates positively with live hard coral cover, which was significantly higher in the Tinputz and Pororan region than in the Saposa or Buka town region.

Coral reef health ranged from extremely poor to excellent across the sites and regions surveyed. At one site in the Tinputz live hard coral cover exceeded 80% which is remarkably high, but at many sites reef health was very poor. A third of sites surveyed had crown-of-thorns starfish populations that were high enough to indicate developing outbreaks, and at one site in Buka town region an active outbreak was occurring. Unfortunately many reefs in the Saposa and Buka town region reefs were devastated with less than 5% live coral cover remaining. In these regions extensive areas of complex coral reef have shifted from a coral dominated system to an algal dominated system. The extensive reef mortality seen at many sites appears to have occurred several years prior to this survey, with, crown-of-thorn starfish, disease and coral bleaching the likely causes of this devastation. It is likely that historical overfishing of herbivorous coral reef fish had reduced the resilience of many of the coral reefs surveyed, and hence inhibited their ability to recover following crown-of-thorns starfish outbreaks or bleaching events.

Conservation & Management Recommendations

- There needs to be a concentrated and sustained environmental awareness campaign throughout Bougainville that is targeted at coastal communities and highlights the links between healthy reefs and healthy fisheries and livelihoods.

- The use of coral reefs for building material should not be encouraged. Alternative building materials should be sought.

- All sea cucumber species appear to be severely overfished, and the current national ban on the harvest and sale of sea cucumbers needs to be strictly enforced. It is likely that a total ban of at least ten years will be needed before sea cucumbers abundances begin to approach the densities seen in 1992.

- It is desirable that in the future a follow up sea cucumber survey be conducted in Northern Bougainville to assess the effectiveness of the current ban on harvesting and selling sea cucumbers.

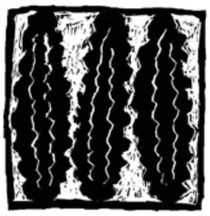
- Total fish densities and biomasses were low in all areas surveyed, indicating that this region has already been fairly heavily fished by subsistence and artisanal fisheries. The implication of this is that it is very unlikely that the current coral reef fish populations can support further commercial fisheries developments. Instead, management is clearly desirable.

- Applicable management regimes need to be imposed for the protection of vulnerable fisheries species and also the marine diversity in Bougainville. Such regimes should entail temporal and spatial closures; gear restrictions; the banning of blast fishing and night spear fishing; and the use of undersized nets. Traditionally many regions in Bougainville placed tambus on reefs in order to allow stocks to recover. Encouraging the reestablishment of such practices would be one means of allowing sea cucumber and reef fish stocks the chance to rebuild.

- Spear fishing at night should be banned. The effect of such fishing on parrotfish populations and critical sites such as spawning aggregations of groupers has been well documented in the pacific. The very low abundances of parrotfishes sighted in this survey point to overfishing by night spearfishing. Low abundances of herbivorous fishes (such as parrotfishes, surgonfishes and drummers) make it easy for reefs to become dominated in algae once they are subjected to disturbances such as crown-of-thorns starfish or coral bleaching.

- We recommend a species specific ban on the harvest and sale of Bumphead parrotfish (*Bolbometopon muricatum*). Bumphead parrotfish is the largest of all parrotfishes and is listed as Vulnerable on the IUCN Red list in recognition of the slow growth and late sexual maturity of this species, and the ease with which nocturnal aggregations of this species can be overfished by night-time spear fishers. No Bumphead parrotfish were sighted on this survey; however this fish was reported to be abundant in northern Bougainville prior to night spearfishing commencing in the 1970s.

- We also recommend a ban on the harvest and sale of the Humphead wrasse (*Cheilinus undulatus).* This species is a conspicuous indicator of general fishing pressure throughout the coral triangle region and it is listed as Endangered on the IUCN Red list in recognition of its slow population turnover and vulnerability to overfishing by the Live Reef Food Fish Trade. In this survey *C. undulatus* were present in low numbers.



Chapter 1: Sea Cucumber Survey

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1.0 INTRODUCTION

Sea cucumbers or their dried form (beche-de-mer) are either eaten or used for medicinal purposes, and they have been a highly sought after commodity in Asia for centuries (Toral-Granda et al. 2008). In the coral triangle most sea cucumbers occupy shallow clear seas; making harvesting these sessile and often conspicuous animals a relatively simple procedure. The combination of high value plus ease of capture has meant that many sea cucumber stocks around the world are now heavily overfished (Toral-Granda et al. 2008). Papua New Guinea is the third largest producer of beche-de-mer, producing approximately 10 percent of all beche-de-mer entering the global market (Kinch et al. 2008a). In most communities in PNG sea cucumbers are not eaten and they typically have low cultural value. Consequently, the sea cucumber fishery in PNG is almost exclusively an export fishery. The importance of the sea cucumber fishery to rural coastal communities in Papua New Guinea cannot be understated. For example, in a recent socio-economic survey of the sea cucumber fisheries in Manus Province, 75 percent of all households interviewed stated that beche-de-mer was their most important source of income (Kinch et al. 2007).

In Papua New Guinea the sea cucumber fishery is a multi species fishery, with at least 26 species of sea cucumber harvested in PNG waters (Kinch et al. 2008b). In shallow habitats sea cucumbers are typically gleaned from the reef flats and reef crest on the low tide, and in deeper areas free divers using masks and fins will pick up sea cucumbers. In water that is too deep to easily access (typically below 20 m) free divers will often use 'bombs' – a small harpoon or series of straitened hooks inserted into a lead weight – to harpoon sea cucumbers that are beyond their reach. Night diving for sea cucumbers with the aid of underwater flashlights is a common practice, even though it is illegal under PNG law (Kinch et al. 2008b).

The first written accounts of the sea cucumber fishery in Papua New Guinea are from 1873, however it is likely exploitation of this fishery occurred earlier than that (Kinch et al. 2008b). Like other regions in Western pacific, most sea cucumber fisheries in PNG have exhibited boom and bust cycles. Initially sea cucumber fisheries target only one or two high value species, but once these stocks are over fished the fishery typically shifts it focus to lower value species (e.g. Lokani 1990; Lokani et al. 1996). Stocks of high value species are often quickly depleted, as evidenced by a case study on the Carteret Islands that are located north east of Bougainville Island. In 1982 a beche-de-mer fishery that targeted white and black teatfish (*Holothuria fuscogilva* and *H. whitmaei*) harvested approximately 10 tonnes of sea cucumber from the Carteret Islands, but by 1983 total production had fallen to just over 2000 kg and large high grade beche-de-mer was virtually eliminated from the fishery (Dalzell 1990).

Several recent surveys in PNG have shown that sea cucumber stocks in many provinces are seriously overfished. In Milne Bay province many high value species were present in extremely low densities (Skewes et al. 2002), and a recent survey of New Ireland concluded that sea cucumber densities were only a fraction of their former abundances and that the stocks were severely depleted (National Fisheries Authority 2007).

The purpose of this survey was to provide information on:

- The distribution and abundance of sea cucumbers in different coastal habitats of northern Bougainville.
- Identify areas of poor or good sea cucumber stocks.
- Compare sea cucumber densities in late 2008 with any suitable earlier surveys to examine changes over time and trends in the resources.
- Evaluate the overall status of sea cucumber stocks in Northern Bougainville.
- Provide baseline data upon which any future management initiatives could be evaluated.

2.0 STUDY SITES AND SAMPLING METHODS

In this resource assessment a total of 80 sites were surveyed for sea cucumbers. 19 of these sites were intertidal reef flats, 11 sites were the outertidal reef crest, 26 sites were the shallow reef slopes, 14 sites were the deep reef slope and 10 sites were the lagoon floor. Sites were selected the night prior to the surveys by examining satellite maps of the various habitats in the region of interest. GPS readings were taken for all sites surveyed. Study sites were all located in the Northern portion of Bougainville, and for fine scale data analysis purposes the survey was broken down into four regions, that being the Pororan, Saposa, Tinputz and Buka Town region (Figure 1). In all four regions the reef flat, reef crest and shallow reef slope habitats were surveyed. However in the Pororan region deep reef slope was not surveyed. Instead we focused our deep water surveys on the extensive lagoon habitat that is present in this region, as this lagoon historically supported large abundances of sea cucumbers (Paul Lokani personal observations). The number of sites surveyed within each region and habitat is shown in Table 1. The exact location of each site surveyed in each habitat is shown in the results section.

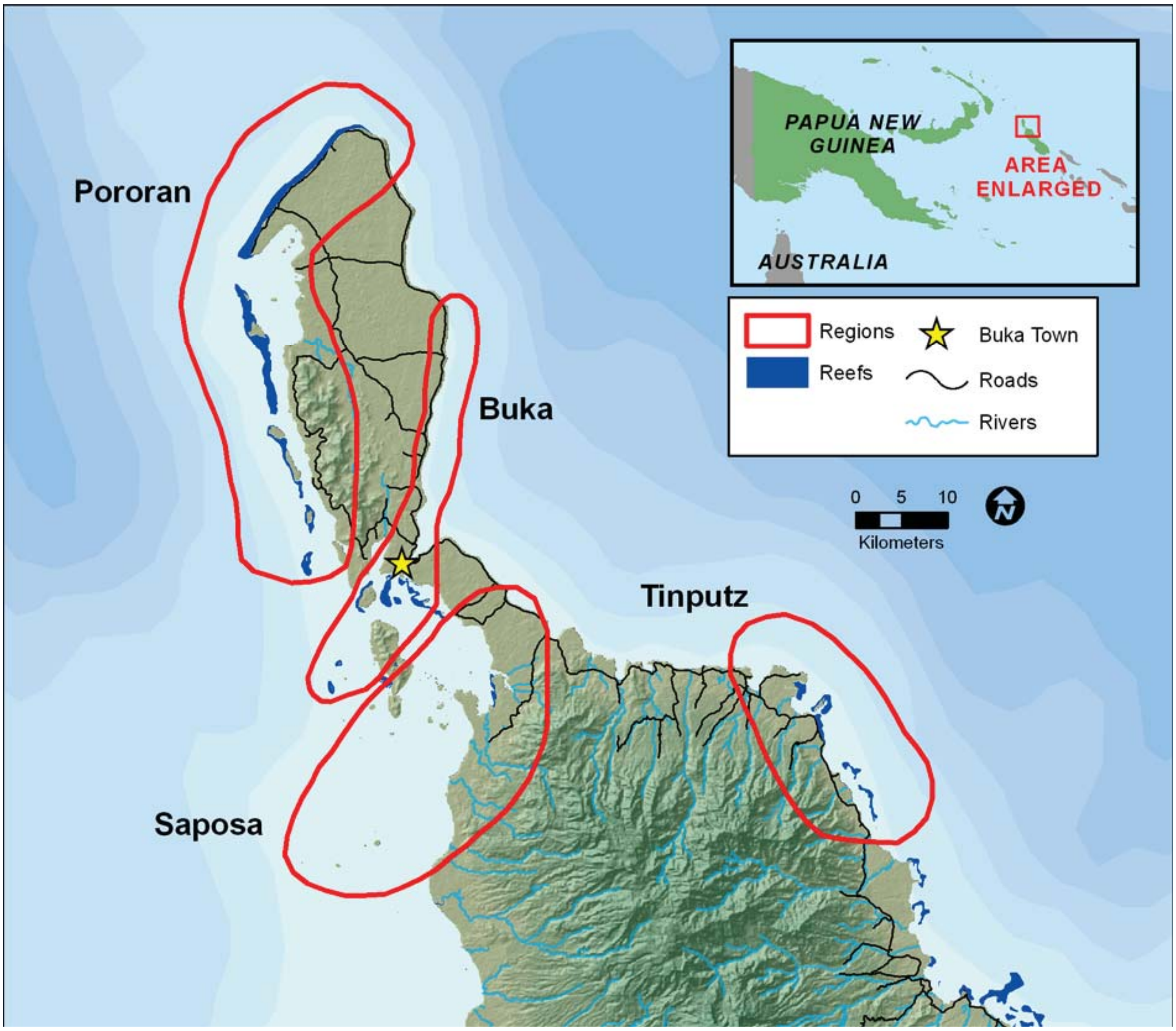

Figure 1. Locations of the four regions surveyed.

Table 1. The number of sites surveyed within each region and habitat.

	Pororan	Saposa	Tinputz	Buka Town	Total (habitat)
Shallow reef Slope (10m)	8	7	5	6	26
Deep Reef Slope (20m +)	0	7	2	5	14
Reef flat (<1m)	9	3	2	5	19
Reef crest	1	2	4	4	11
Lagoon	10	0	0	0	10
Total (region)	28	19	13	20	80

2.1. SURVEY TEAMS

Three teams conducted this sea cucumber survey. A reef flat and reef crest team, a shallow reef slope team and a deep reef slope and lagoon team. The methods that each team used are outlined below.

2.1.1. Reef flat and reef crest team

The reef flat and reef crest team worked on foot and with snorkel gear. This team consisted of two individuals. On both reef flats and reef crests between 5 to 10 replicate transects were surveyed at each site. Reef flats were typically in water depths of 0.5 – 1 m, while reef crests were typically 1 -2 m deep. All transects were 50 m long by 8 m wide, giving a total area surveyed of 400 m^2 per transect. Transect lengths were measured by laying down a 50 m measuring tape across the reef flat prior to conducting the survey. Transect width was measured by pulling an 8 metre length of rope between two observers, with observers keeping the midpoint of the rope on the 50 m transect line. In each pass of a transect the number of individual sea cucumber species was recorded onto underwater paper. The size of a subset of sea cucumbers (length in cm) sighted at each site was also recorded.

2.1.2. The shallow reef slope team

The shallow reef slope team worked on SCUBA. Two individuals sampled invertebrates on the shallow reef slopes. Five replicate transects were surveyed at each site in depths that ranged from 8-10 m. Each transect was 50 m long and 5 m wide, giving a total area surveyed of 250m^2 per transect. Transect lengths were measured using 50 m tapes, and transect widths were visually estimated. In each pass of a transect the number of individual sea cucumber species was recorded onto underwater paper. The size of a subset of sea cucumbers (length in cm) sighted at each site was also recorded. Trochus abundances and sizes were also recorded on the shallow slope.

2.1.3. The deep reef slope and lagoon team

The deep reef slope and lagoon team worked on SCUBA. Two individuals sampled sea cucumbers in these habitats. Five replicate transects were surveyed at each site in depths that ranged from 20 - 30 m. Each transect was 50 m long and 8 m wide, giving a total area surveyed of 400 m^2 per transect. Transect lengths were measured using 50 m tapes, and transect widths were estimated by running an eight meter length of string between the two divers as they swam along the transect. In each pass of a transect the number of individual sea cucumber species was recorded onto underwater paper. The size of a subset of sea cucumbers (length in cm) sighted at each site was also recorded.

2.2. DATA ANALYSIS

Sea cucumber density estimates per transect were converted to the number of individuals per hectare (ind. ha^{-1}), and the mean densities per site and the size distributions of common species were graphed in SigmaPlot. Differences in total sea cucumber densities between the four regions were investigated using Kruskal-Wallis One Way Analysis of Variance on Ranks (SigmaStat) since data was non-normal. A Multiple Pairwise Comparison Procedure (Dunn's Method) was used to identify where the significant difference between regions existed. Mann-Whitney Rank Sum Tests were used to compare mean densities of sea cucumbers sighted on reef flat areas in the Pororan region in 1992 and 2008.

3.0 RESULTS

3.1. SEA CUCUMBER DENSITIES

A total of 3318 sea cucumbers from 19 commercial species were identified and counted during in this survey: ten species of high-commercial value (see Kinch et al. 2008) (*Actinopyga mauritiana, A. miliaris, Bohadschia argus, B. vitiensis, Holothuria fuscogilva, H. whitmaei, H. scabra, Stichopus hermanni, Thelenota ananas, T. rubralineata*) and nine species of low- commercial value (*Actinopyga echinites, Bohadschia similes, Holothuria atra, H. coluber, H. edulis, H. fuscopunctata, Pearsonothuria graeffei, Stichopus horrens, Thelenota anax*). 72.51% of sea cucumbers sighted were low value species and 27.49% were high value species (Table 2). *H. atra* was the most abundant species making up 55.15% of all sea cucumbers seen, followed by the *H. scabra* which made up 12.84% of the sea cucumbers sighted (Table 2).

Table 2. Relative densities of each species of sea cucumber recorded in transect counts during this survey. Shaded rows represent low value species; unshaded rows represent high value species (as per Kinch et al. 2008). NB: Common names follow Secretariat of the Pacific Community (2003).

Scientific name	Common name	Relative density (%)
Holothuria atra	Lollyfish	55.15
Holothuria scabra	Sandfish	12.84
Actinopyga mauritiana	Surf redfish	6.45
Bohadschia similes	Chalkfish	5.70
Bohadschia vitiensis	Brown sandfish	4.25
Pearsonothuria graeffei	Flowerfish	3.68
Holothuria edulis	Pinkfish	3.19
Actinopyga echinites	Deep-water redfish	2.44
Thelenota anax	Amberfish	1.27
Holothuria whitmaei	Black teatfish	1.08
Bohadschia argus	Tigerfish	0.90
Holothuria coluber	Snakefish	0.69
Holothuria fuscogilva	White teatfish	0.66
Thelenota rubralineata	Candy-cane	0.42
Thelenota ananas	Prickly redfish	0.33
Stichopus hermanni	Curryfish	0.27
Actinopyga miliaris	Blackfish	0.27
Stichopus horrens	Dragonfish	0.24
Holothuria fuscopunctata	Elephant trunkfish	0.15
Total		**100.00**

The mean density (per ha-1) of sea cucumbers in each of these five 5 habitats is shown in Table 3. Overall mean densities per hectare were low for all species in all habitats. Only *H. atra* had moderately high densities in more than one habitat, with 570.4 ind. ha^{-1} and 54 ind. ha^{-1} on the reef crests and reef flats respectively. *H. atra* was also sighted in reef slope and lagoon habitats in much lower densities. *H. atra* is one of the most common sea cucumber species in shallow waters, with densities estimates for this species ranging between 9.8 to 4870 ind. ha^{-1} in other regions of Papua New Guinea (Kinch et al. 2008b). It is noteworthy that in this study the high mean densities of *H. atra* on reef crests is due to very high densities of this species being recorded at a single site that is closed to fishing (see Reef crest section below).

The species with the second highest density was the high value *H. scabra*. *H. scabra* had a mean density of 71.2 ind. ha^{-1} on the reef flats. Previous sea cucumber surveys in other regions of Papua New Guinea have estimated *H. scabra* densities between <0.1 to 2900 ind. ha^{-1}. In this survey H. *scabra* was almost exclusively sighted on reef flats, with highest abundances occurring on reef flats that had seagrass cover.

The species with the third highest density was the low value species *Pearsonothuria graeffei*. This species was only found on reef slopes, with highest abundances (33.52 ind. ha^{-1}) found on the shallow slopes. This density estimate falls within the range (17-200 ind. ha^{-1}) reported for this species on shallow slopes throughout the Solomon Islands (Ramohia 2006). No other species had mean densities that exceed 30 ind. ha^{-1}, with the majority of species having densities below 5 ind. ha^{-1}.

Table 3. Mean sea cucumber densities (ind. ha^{-1}) in each of the habitats surveyed.

	Reef flat (n=19)	Reef crest (n=11)	Shallow reef slope (n=26)	Deep reef slope (n =14)	Lagoon (n=10)
Low value species					
Actinopyga echinites	11.5	4.6			
B. similis	28.7	6.9			
Holothuria atra	54	570.4	5.5	1.4	0.5
H. edulis			12.6	13.2	14
H. coluber	3.2	1.2	0.3		
H. fuscopunctata				1.8	
Pearsonothuria graeffei			33.5	4.7	
S. horrens				2.9	
T. anax			3.4	8.9	3
High value species					
A. mauritiana	23	29.2			
A. miliaris	1.5				
Bohadschia argus	0.5	2.7	2.5	2.1	3
B. vitiensis	18.4	9.2		2.1	1.5
H. fuscogilva		0.4		6.1	2
H. whitmaei	2.22	0.4	2.8	0.7	
H. scabra	71.3	0.4			
S. hermanni	1				1.5
Thelenota ananas			1.5		0.5
T. rubralineata				5	

3.2. REGIONAL VARIATION IN SEA CUCUMBER DENSITIES

The relatively high level of sampling conducted made it possible to compare sea cucumbers densities among the four regions surveyed. These results are presented below by habitat.

3.2.1. Reef flat

A total of 1296 sea cucumbers (made up of 11 different species) were recorded at the 19 reef flat sites surveyed (Figure 2).

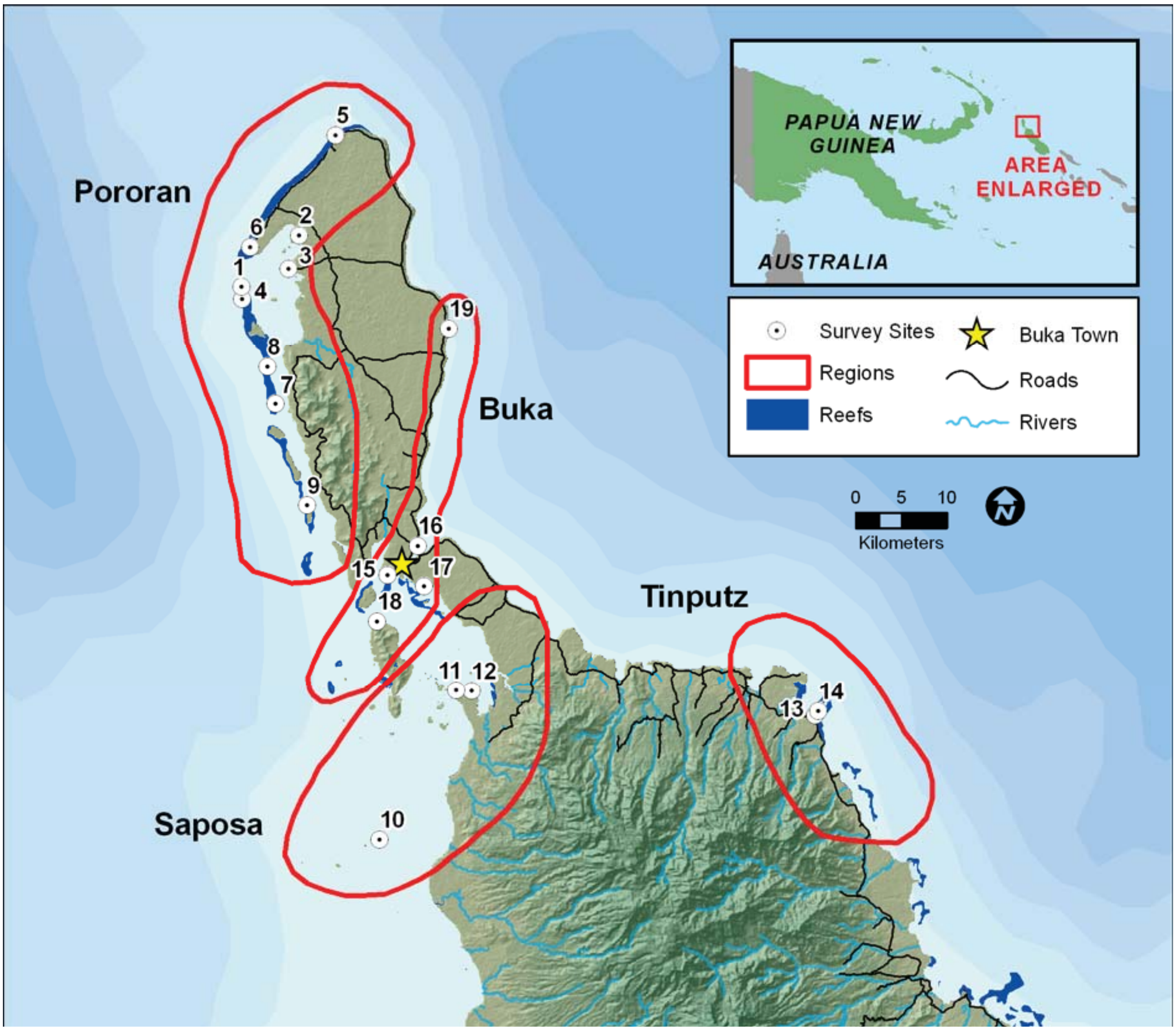

Figure 2. Locations of the 19 reef flat sites surveyed.

The relative densities of these species is shown in Table 4. The most frequently sighted species was the high value species *H scabra* which accounted for 33% (425) of all sea cucumbers recorded on reef flats. The second most abundant species was the low value species *H. atra* which accounted for 25% (324) of sea cucumbers sighted on reef flats. The size-frequency distributions of *H. scabra* and *H. atra* are shown in Figures 3 and 4.

Table 4. Relative densities of each species of sea cucumber on the reef flats.

Species	**Common name**	**Relative density**
Holothuria scabra	Sandfish	34.03
Holothuria atra	Lollyfish	25.00
Bohadschia similis	Brownspotted sandfish	13.19
Actinopyga mauritiana	Surf redfish	10.65
Bohadschia vitiensis	Brown sandfish	8.33
Actinopyga echinites	Deep-water redfish	5.32
Holothuria coluber	Snakefish	1.47
Actinopyga miliaris	Hairy blackfish	0.69
Holothuria whitmaei	Black teatfish	0.62
Stichopus hermanni	Curryfish	0.46
Bohadschia argus	Leopardfish	0.23
Total		**100**

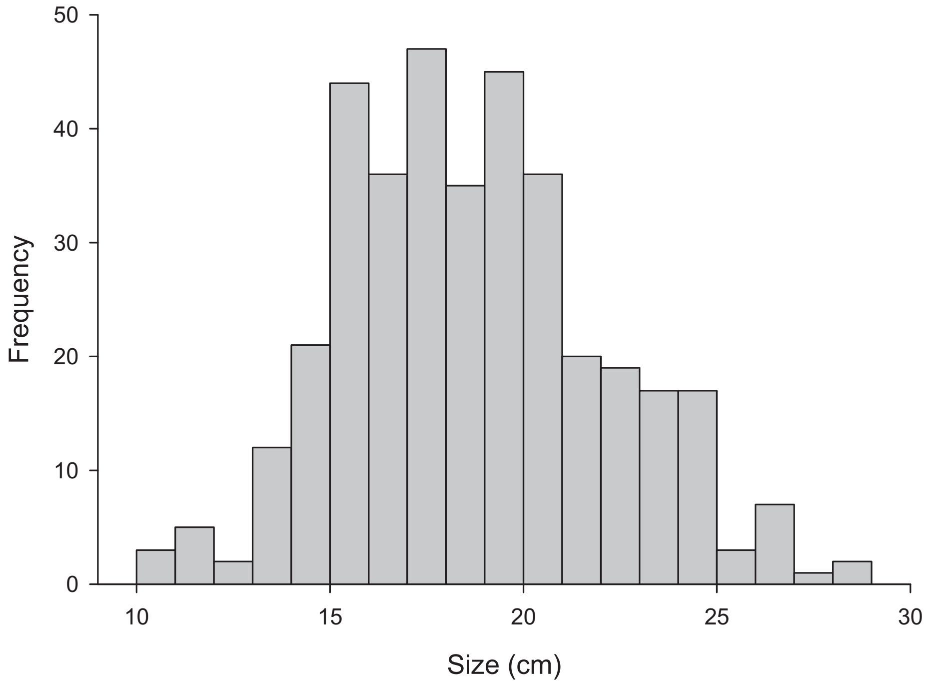

Figure 3. Size-frequency distribution of *H. scabra* on reef flats (n=372). Mean size = 18.2 cm (standard deviation = 3.4 cm).

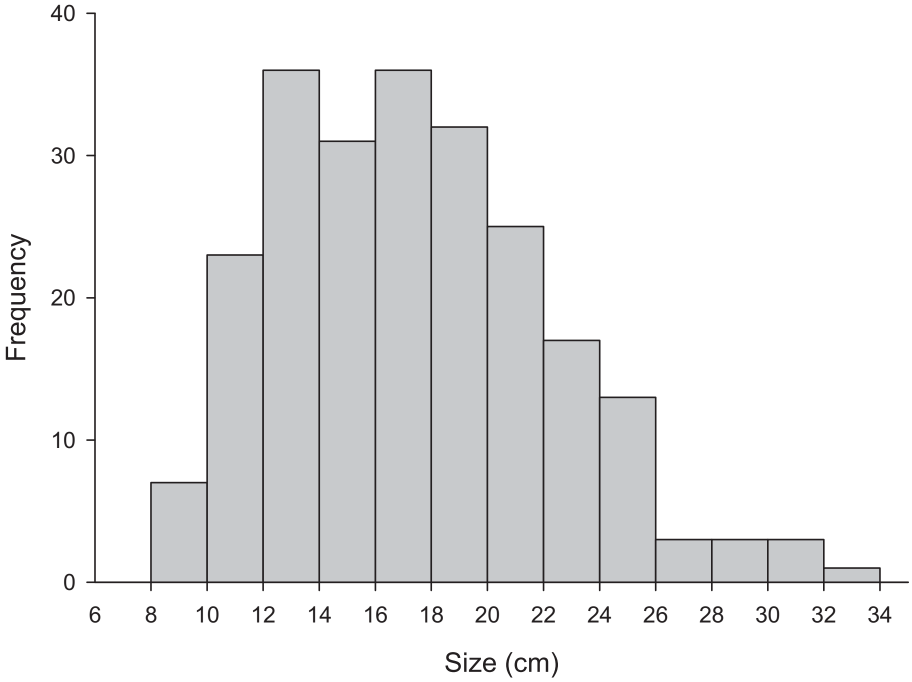

Figure 4. Size-frequency distribution of *H. atra* on reef flats (n=230). Mena size = 16.9 cm (standard deviation = 4.9 cm).

The mean density of all sea cucumbers at each site is shown in Figure 5. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean densities of sea cucumbers on reef flats were significantly different between the four regions surveyed ($P<0.001$). A Dunn's Multiple Pairwise Comparison test revealed that Tinputz, Pororan and Buka Town had significantly higher densities of sea cucumbers on reef flats than Saposa ($P<0.05$).

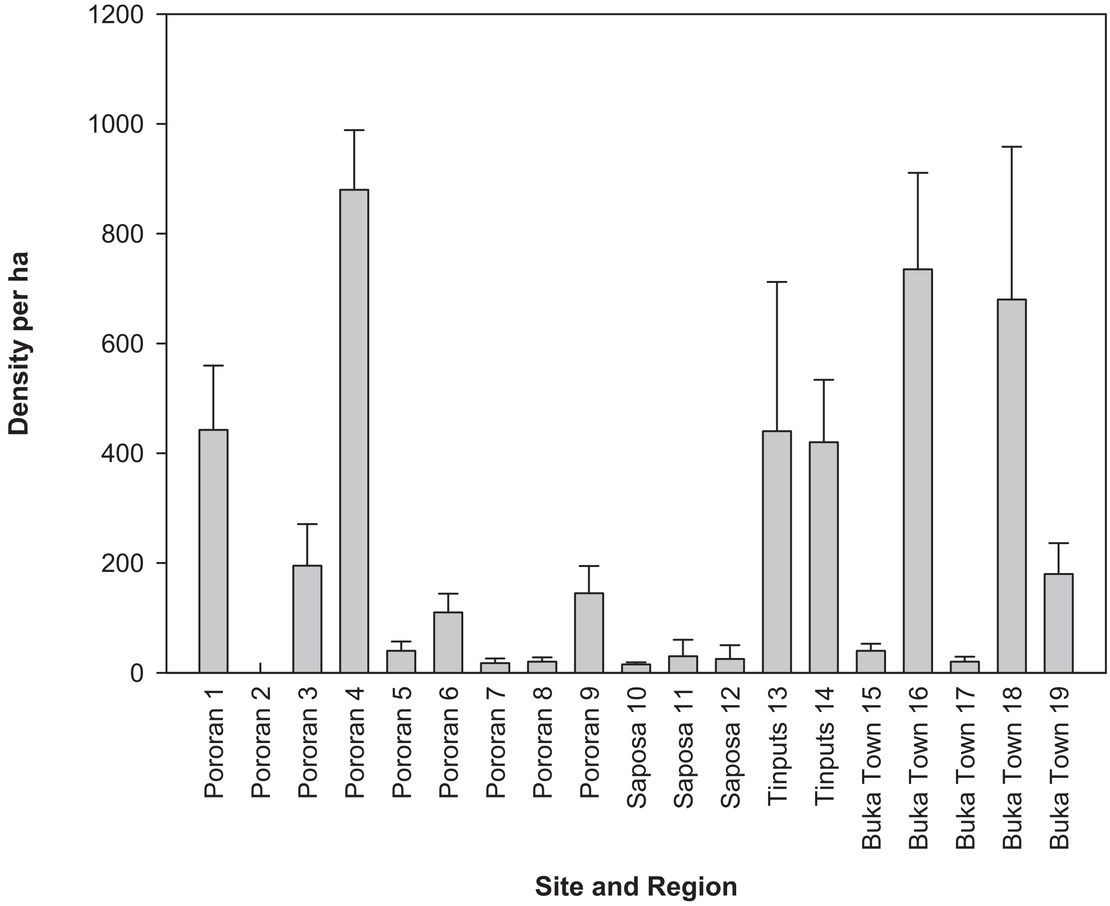

Figure 5. Mean sea cucumber densities (+ 1SE) on reef flats.

The mean densities of sea cucumbers on the reef flats in the four regions surveyed are shown in Table 5. There was considerable regional variation in species densities. For example, the most abundant species *H. scabra* had regional density estimates that ranged from 0 ind. ha^{-1} (Saposa) to 410 ind. ha^{-1} in Tinputz.

Table 5. Mean sea cucumber densities on reef flats in the four regions surveyed.

Species	Region	Density (ind. ha^{-1})	Standard deviation (ha^{-1})
Low value species			
Actinopyga echinites	Pororan	1.9	6.7
	Saposa	0	0
	Tinputz	0	0
	Buka town	51.7	118.7
B. similis	Pororan	43.8	117.1
	Saposa	0	0
	Tinputz	2.5	7.9
	Buka town	11.7	48.6
Holothuria atra	Pororan	40	71.2
	Saposa	21.3	41.6
	Tinputz	7.5	23.7
	Buka town	133.3	343.3
H. coluber	Pororan	1.1	8.3
	Saposa	0	0
	Tinputz	2.5	7.9
	Buka town	11.7	19.4
High value species			
A. mauritiana	Pororan	37.8	99.1
	Saposa	0	0
	Tinputz	5	10.6
	Buka town	0	0
A. miliaris	Pororan	2.2	8.1
	Saposa	0	0
	Tinputz	2.5	7.9
	Buka town	0	0
Bohadschia argus	Pororan	0.6	3.7
	Saposa	0	0
	Tinputz	0	0
	Buka town	0.8	4.6
B. vitiensis	Pororan	28.2	63
	Saposa	0	0
	Tinputz	0	0
	Buka town	8.3	20.1
Holothuria whitmaei	Pororan	2.22	11.65
	Saposa	0	0
	Tinputz	0	0
	Buka town	0	0
H. scabra	Pororan	48.33	137.9
	Saposa	0	0
	Tinputz	410	435.5
	Buka town	87.5	231.4
S. hermanni	Pororan	1.4	7.8
	Saposa	0	0
	Tinputz	0	0
	Buka town	0.8	4.6

3.2.2. Reef crest

A total of 1626 sea cucumbers (made up of ten different species) were recorded at the 11 reef crest sites surveyed (Figure 6).

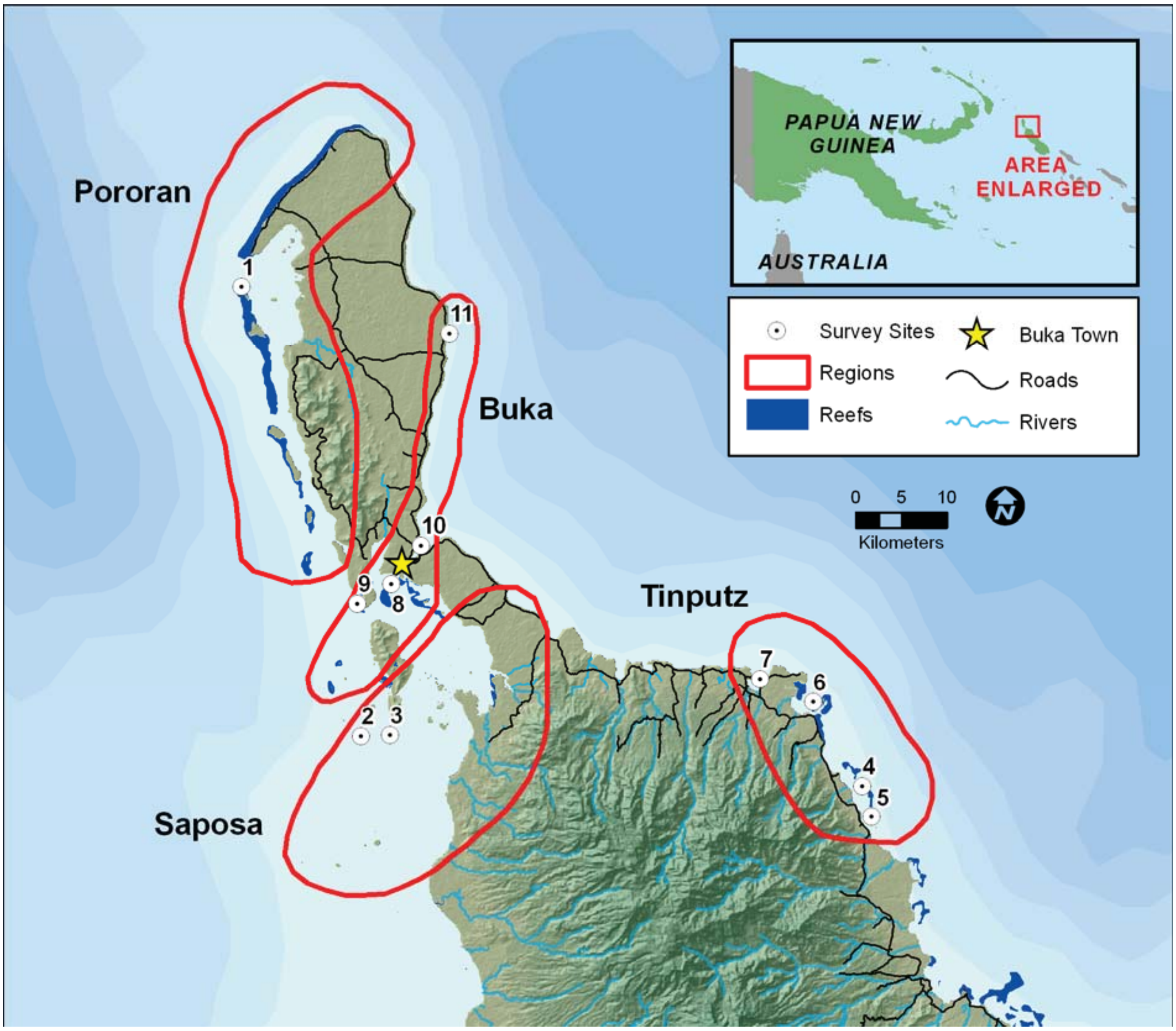

Figure 6. Locations of the 11 reef crest sites surveyed.

The relative density of each of these species is shown in Table 6. The most frequently sighted species was the low value species *H atra* which accounted for 91.21% (1483) of all sea cucumbers recorded on reef crests. The second most abundant species was the high value species *Actinopyga mauritiana* which accounted for 4.67% (76) of sea cucumbers recorded on reef flats. The size-frequency distribution of *H. atra* is shown in Figure 7.

Table 6. Relative densities of each species of sea cucumber on the reef crests.

Species	Common name	Relative density
Holothuria atra	Lollyfish	91.21
Actinopyga mauritiana	Surf redfish	4.67
Bohadschia vitiensis	Brown sandfish	1.48
Bohadschia similis	Brownspotted sandfish	1.11
Actinopyga echinites	Deep-water redfish	0.74
Bohadschia argus	Leopardfish	0.43
Holothuria coluber	Snakefish	0.18
Holothuria fuscogilva	White teatfish	0.06
Holothuria scabra	Sandfish	0.06
Holothuria whitmaei	Black teatfish	0.06
Total		**100**

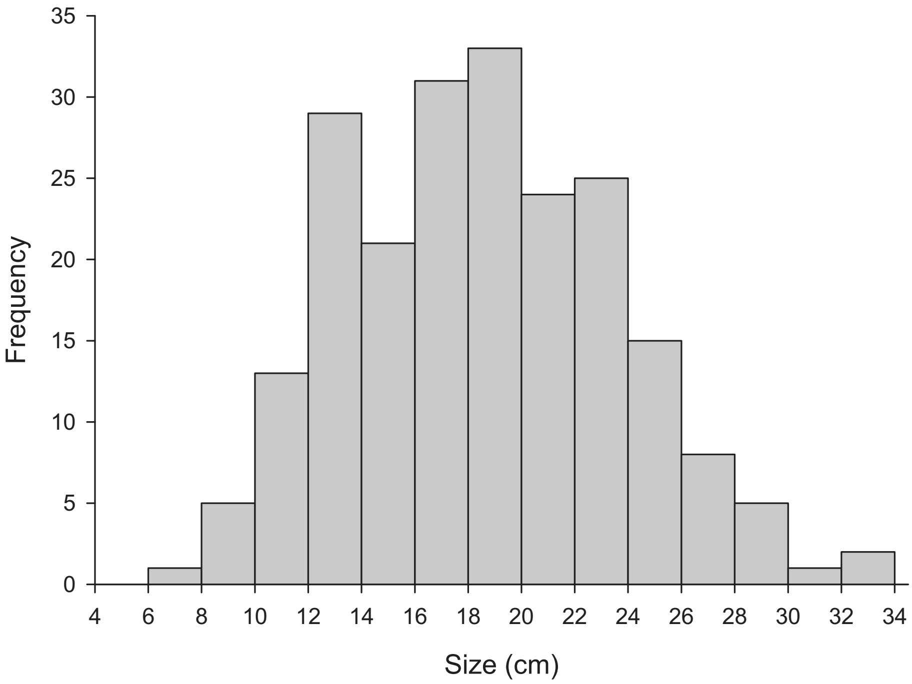

Figure 7. Size-frequency distribution of *H. atra* on reef crests (n=213). Mean size = 18.1 cm (standard deviation = 5.1 cm).

The mean density of all sea cucumbers at each site is shown in Figure 8. Site 7 in the Tinputz had mean sea cucumber densities that far exceeded of all other sites. These high densities were due to high abundances of *H. atra* (1339) recorded at this site in 10 transects. Site 7 (directly outside of Tinputz station) is closed to fishing under a customary tambu.

A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean densities of sea cucumbers on reef crests were significantly different between the four regions surveyed ($P<0.001$). A Dunn's Multiple Pairwise Comparison test revealed that Pororan had a significantly higher densities of sea cucumbers than Saposa or Buka Town ($P<0.05$).

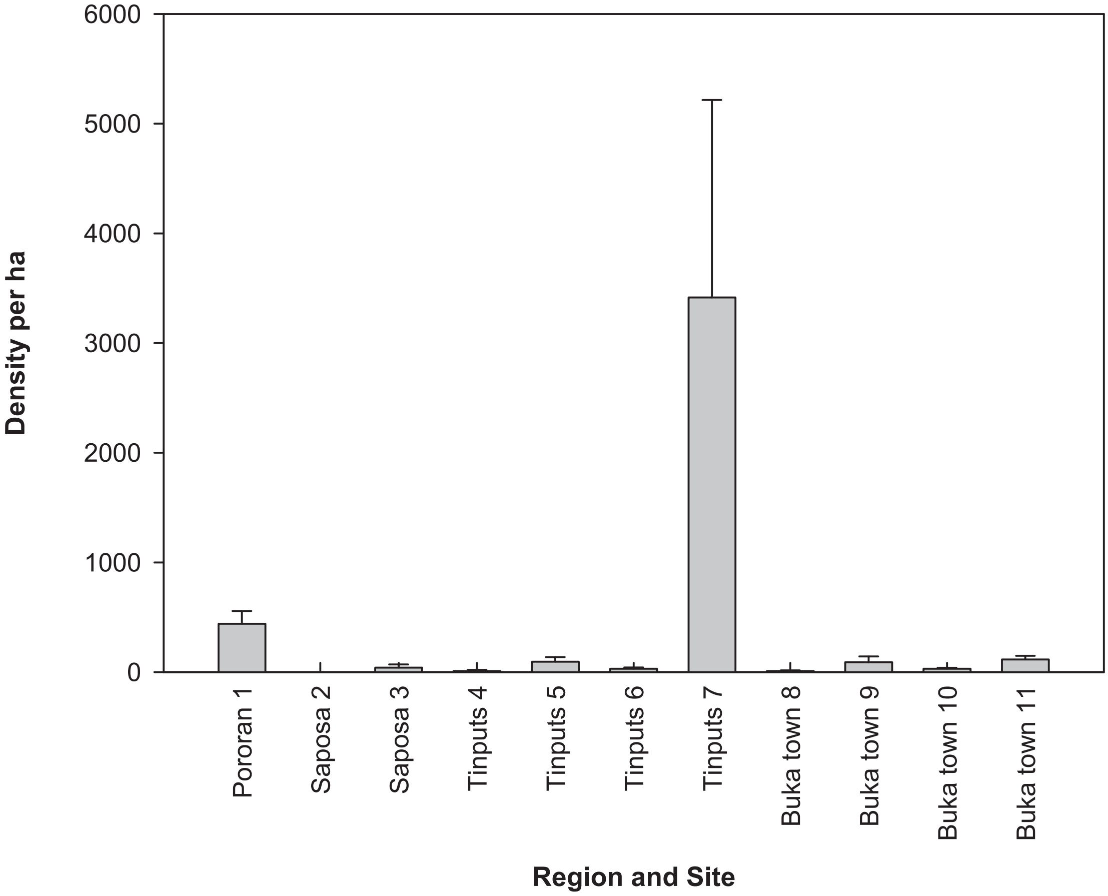

Figure 8. Mean sea cucumber densities (+ 1SE) on reef crests.

The mean densities of sea cucumbers on the reef crests in the four regions surveyed are shown in Table 7. *H. atra* mean densities were highest in the Tinputz, but high value species such as *A. mauritiana* and *B. vitiensis* were only sighted in reasonable abundances in the Pororan region. However caution needs to be taken when interpreting these results since only one reef crest site was sampled in Pororan.

Table 7. Sea cucumber densities on reef crests in the four regions surveyed.

Species	Region	Density (ind. $ha^{-1)}$	Standard deviation (ha^{-1})
Low value species			
Actinopyga echinites	Pororan	0	0
	Saposa	0	0
	Tinputz	11	30.7
	Buka town	2	6.9
B. similis	Pororan	45	68.5
	Saposa	0	0
	Tinputz	0	0
	Buka town	0	0
Holothuria atra	Pororan	177.5	110.2
	Saposa	15	39.5
	Tinputz	1362	3854.3
	Buka town	55	74
H. coluber	Pororan	0	0
	Saposa	2.5	7.9
	Tinputz	1	5
	Buka town	1	5
High value species			
A. mauritiana	Pororan	177.5	202.2
	Saposa	2.5	7.9
	Tinputz	4	20
	Buka town	0	0
Bohadschia argus	Pororan	5	10.6
	Saposa	0	0
	Tinputz	2	10
	Buka town	3	8.3
B. vitiensis	Pororan	32.5	35.5
	Saposa	0	0
	Tinputz	11	55
	Buka town	0	0
Holothuria fuscogilva	Pororan	0	0
	Saposa	0	0
	Tinputz	1	5
	Buka town	0	0
Holothuria whitmaei	Pororan	0	0
	Saposa	0	0
	Tinputz	1	5
	Buka town	0	0
H. scabra	Pororan	2.5	7.9
	Saposa	0	0
	Tinputz	0	0
	Buka town	0	0

3.2.3. Shallow outer reef slope

3.2.3.1. Sea cucumbers

A total of 202 sea cucumbers (made up of eight different species) were recorded at the 26 reef flat sites surveyed (Figure 9).

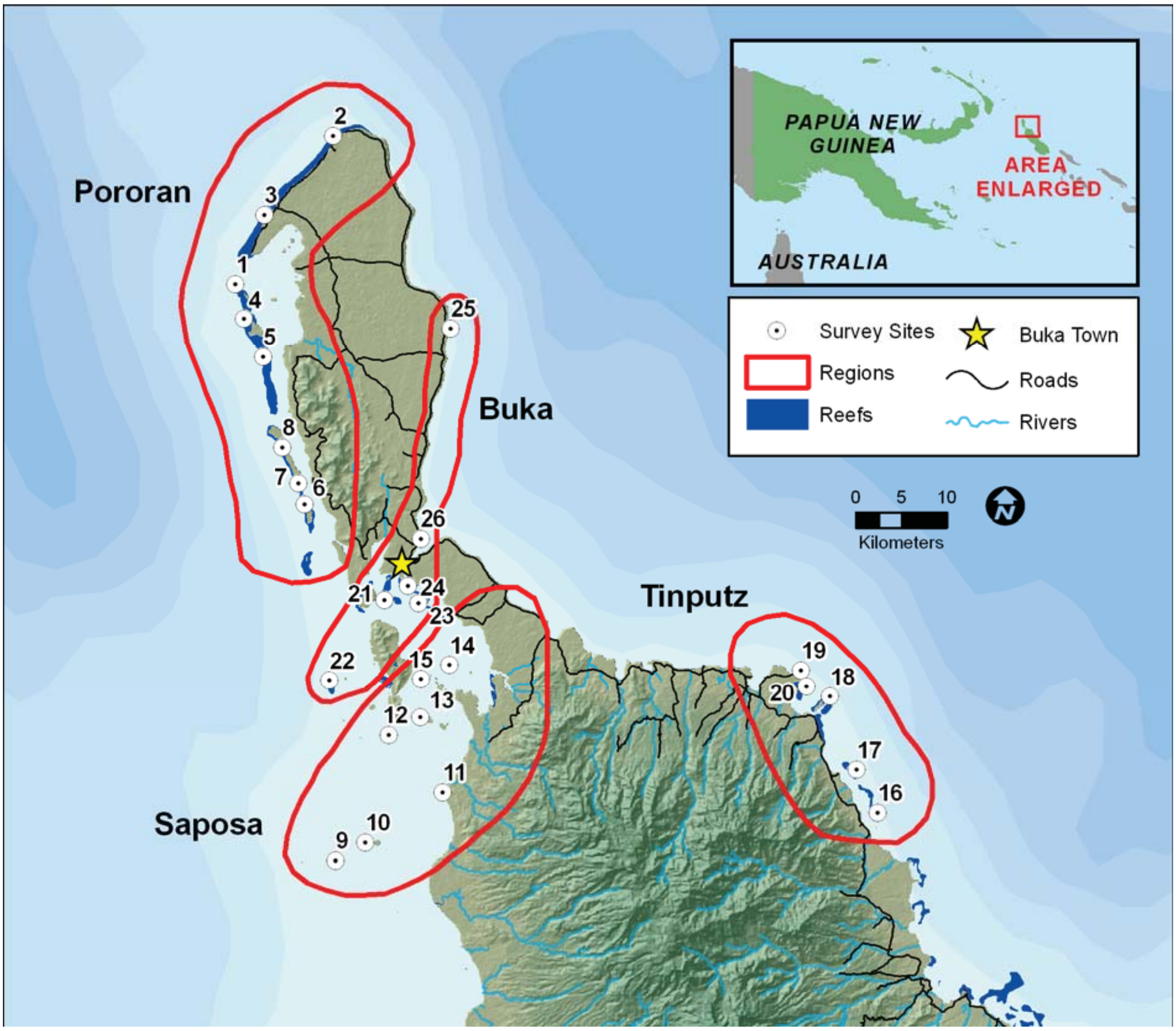

Figure 9. Locations of the 26 shallow reef slope sites surveyed.

The relative density of each of the species recorded on transects is shown in Table 8. The shallow reef slope had low species diversity with only eight species of sea cucumber sighted. *P. graeffei* accounted for 54% (109) of all sea cucumbers recorded on shallow slopes. The second most abundant species was *H. edulis* which made up 20% of the sea cucumbers sighted. The size-frequency distributions of *P. graeffei* and *H. edulis* are shown in Figure 10 and 11.

Table 8. Relative densities of each species of sea cucumber on the shallow reef slopes.

Species	**Common name**	**Relative density**
Pearsonothuria graeffei	Flowerfish	53.96
Holothuria edulis	Pinkfish	20.3
Holothuria atra	Lollyfish	8.91
Thelenota anax	Amberfish	5.45
Holothuria whitmaei	Black teatfish	4.46
Bohadschia argus	Leopardfish	3.96
Thelenota ananas	Prickly redfish	2.48
Holothuria coluber	Snakefish	0.5
Total		**100**

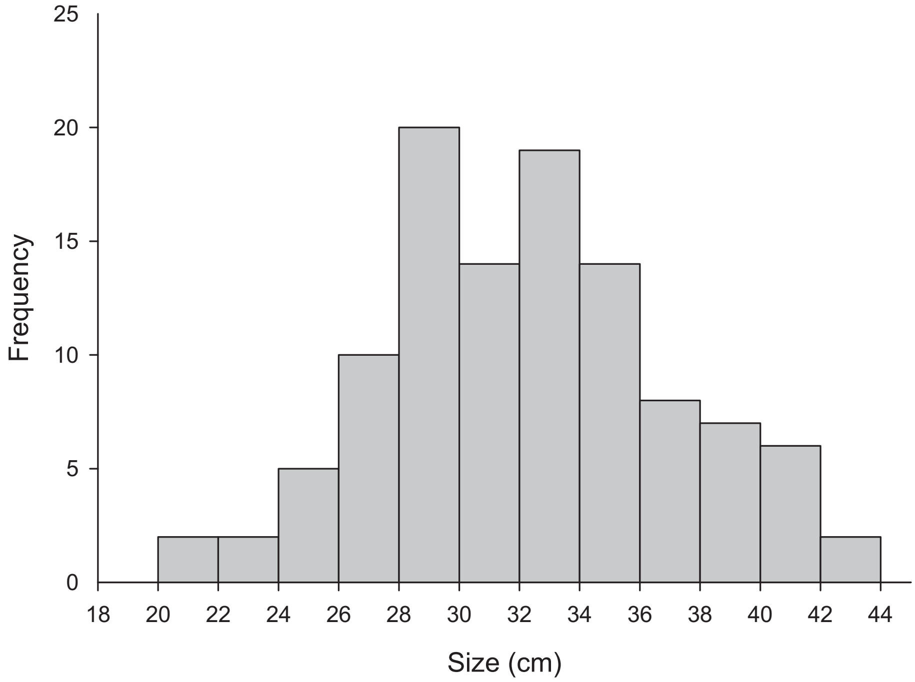

Figure 10. Size-frequency distribution of *P. graeffei* on shallow reef slopes (n=109). Mean size = 31.7 cm (standard deviation = 4.8 cm).

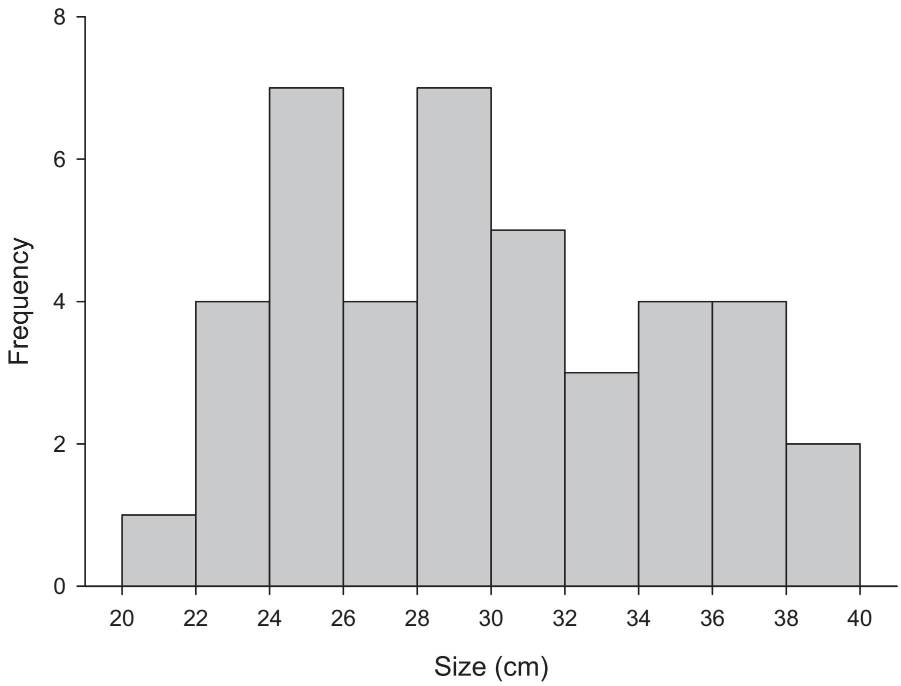

Figure 11. Size-frequency distribution of *H. edulis* on shallow reef slopes (n=41). Mean size = 20.1 cm (standard deviation = 4.9 cm).

The mean density of all sea cucumbers at each site is shown in Figure 12. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean densities of sea cucumbers on shallow reef slopes were not significantly different between the four regions surveyed (P=0.418).

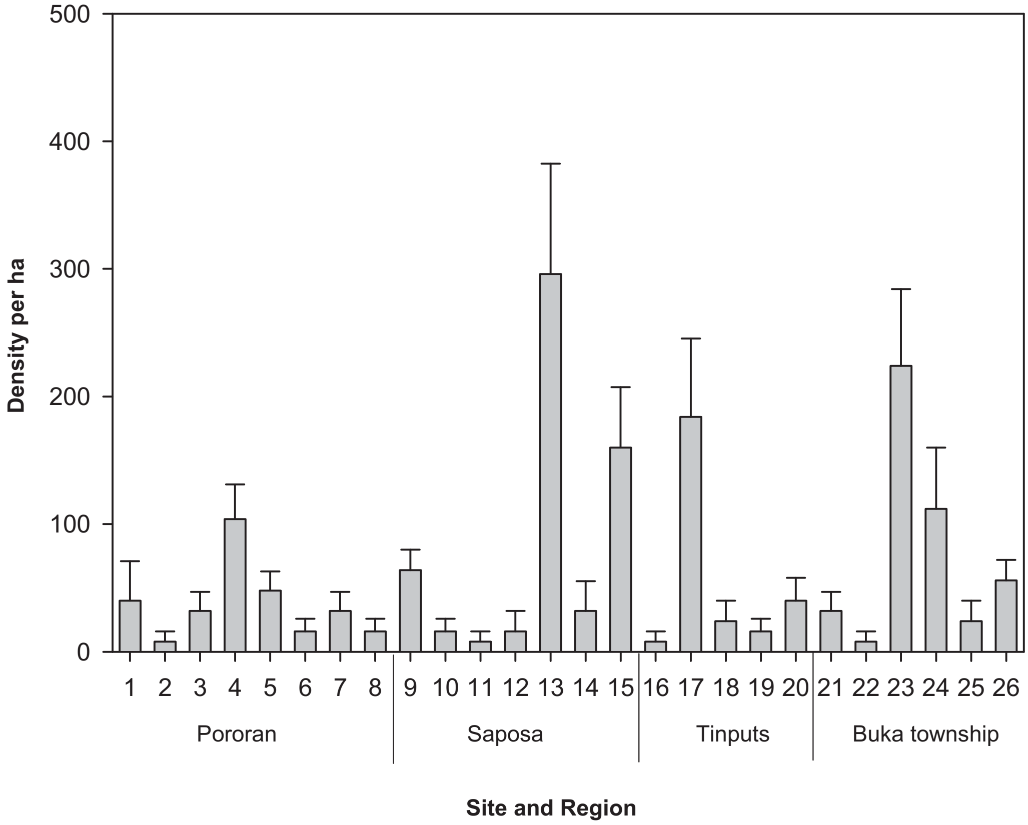

Figure 12. Mean sea cucumber densities (+ 1SE) on shallow (8-10m) reef slopes

The mean densities of sea cucumbers on shallow reef slopes in the four regions surveyed are shown in Table 9. *P. graeffei* was the only species present in moderate densities in all regions surveyed. The second most abundant species was *H. edulis*, but this species was only seen in Saposa and Buka town regions.

Table 9. Sea cucumber densities on shallow slopes in the four regions surveyed.

Species	Region	Density (ind. $ha^{-1)}$	Standard deviation (ha^{-1})
Low value species			
Holothuria atra	Pororan	1	6.3
	Saposa	14.8	52.3
	Tinputz	0	0
	Buka town	5.3	22.8
H. coluber	Pororan	0	0
	Saposa	1.1	6.8
	Tinputz	0	0
	Buka town	0	0
H. edulis	Pororan	0	0
	Saposa	33.2	68.2
	Tinputz	0	0
	Buka town	16	52.1
Pearsonothuria graeffei	Pororan	31	47.5
	Saposa	16	26
	Tinputz	48	87.2
	Buka town	45.3	62.8
Thelenota anax	Pororan	0	0
	Saposa	10.3	26.3
	Tinputz	0	0
	Buka town	2.7	10.2
High value species			
Bohadschia argus	Pororan	1	6.3
	Saposa	4.6	16.2
	Tinputz	0	0
	Buka town	4	16.1
Holothuria whitmaei	Pororan	3	14
	Saposa	1.1	6.8
	Tinputz	6.4	24.9
	Buka town	1.3	7.3
Thelenota ananas	Pororan	1	6.3
	Saposa	3.4	11.4
	Tinputz	0	0
	Buka town	1.3	7.3

3.2.3.2. Trochus

29 Trochus (*Trochus niloticus*) were recorded on the shallow slope transects. The size-frequency distribution of trochus is shown in Figure 13.

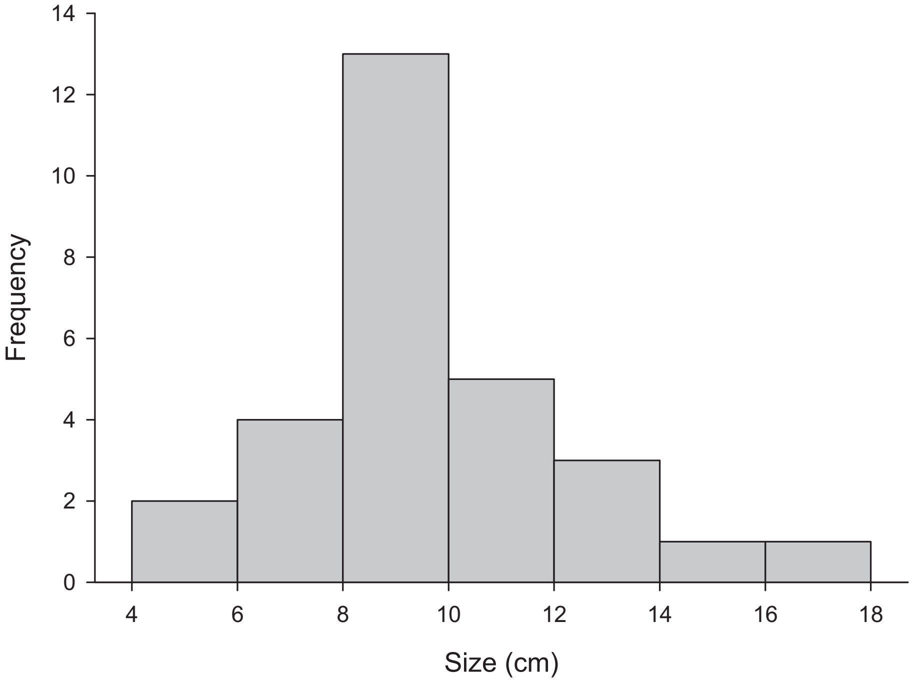

Figure 13. Size-frequency distribution of *Trochus niloticus* on shallow reef slopes (n=29). Mean size = 9 cm (standard deviation = 2.7 cm).

The mean densities of trochus per site are shown in Figure 14. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean densities of trochus on shallow reef slopes were significantly different between the four regions surveyed (P=0.001). Pororan had higher densities of trochus than the other three regions surveyed.

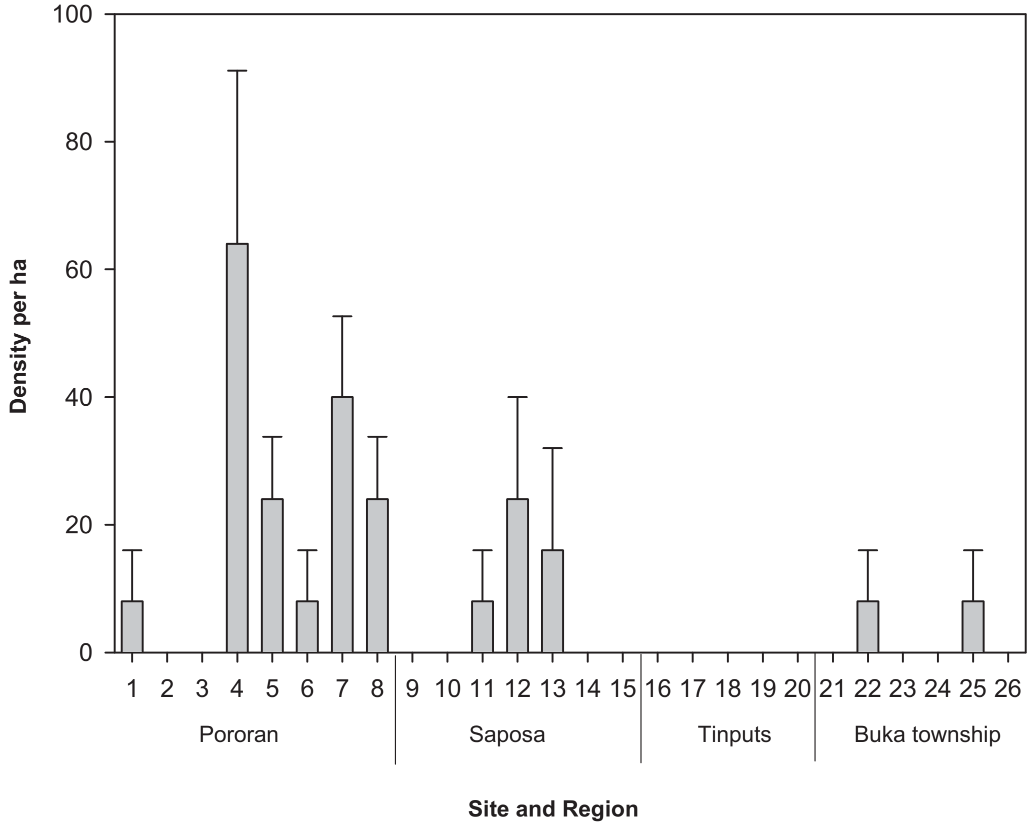

Figure 14. Mean trochus densities (+ 1SE) on shallow reef slopes.

3.2.4. Deep Slope

A total of 142 sea cucumbers (made up of twelve different species) were recorded at the 14 deep reef slope sites surveyed (Figure 15).

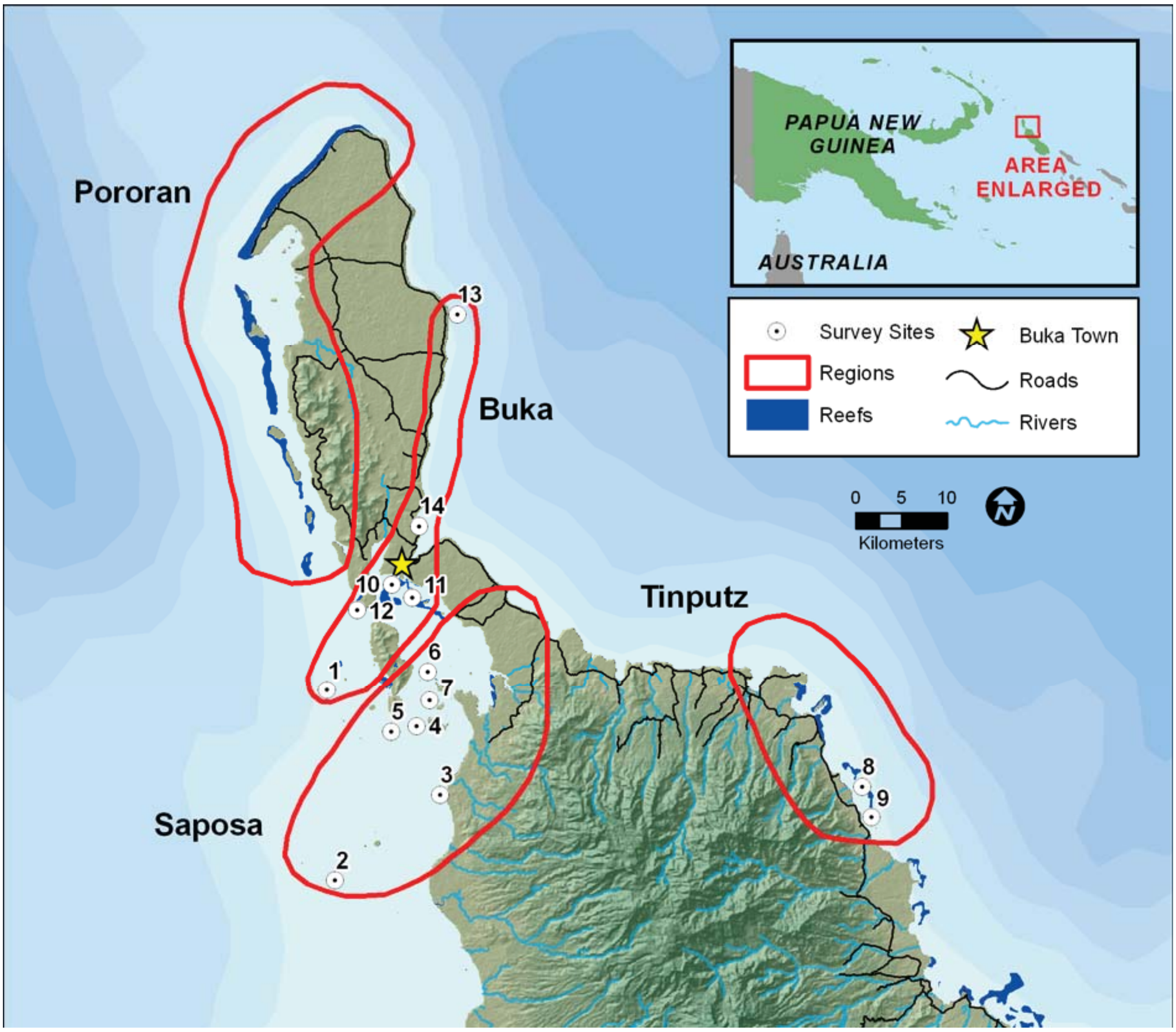

Figure 15. Locations of the 14 deep reef slope sites surveyed.

The relative density of each of the species recorded on transects is shown in Table 10. The deep reef slope had the highest species diversity of the five habitats surveyed. *H. edulis* account for 26% (37) of all sea cucumbers sighted on deep reef slopes followed by *T. anax* 17.6% (25) and then *H. fuscogilva* 11.97% (17). The size-frequency distributions of *T. anax* and *H. fuscogilva* are shown in Figure 16 and 17. Size-frequency distribution of *H. edulis* is not shown as only a few individuals had their sizes recorded.

Table 10. Relative densities of each species of sea cucumber on the deep reef slopes.

Species	**Common name**	**Relative density**
Holothuria edulis	Pinkfish	26.06
Thelenota anax	Amberfish	17.61
Holothuria fuscogilva	White teatfish	11.97
Thelenota rubralineata	Candy-cane	9.86
Pearsonothuria graeffei	Flowerfish	9.15
Stichopus horrens	Dragonfish	5.63
Bohadschia vitiensis	Brown sandfish	4.23
Bohadschia argus	Tigerfish	4.23
Holothuria fuscopunctata	Elephant trunkfish	3.52
Thelenota ananas	Prickly redfish	3.52
Holothuria atra	Lollyfish	2.82
Holothuria whitmaei	Black teatfish	1.41
Total		**100**

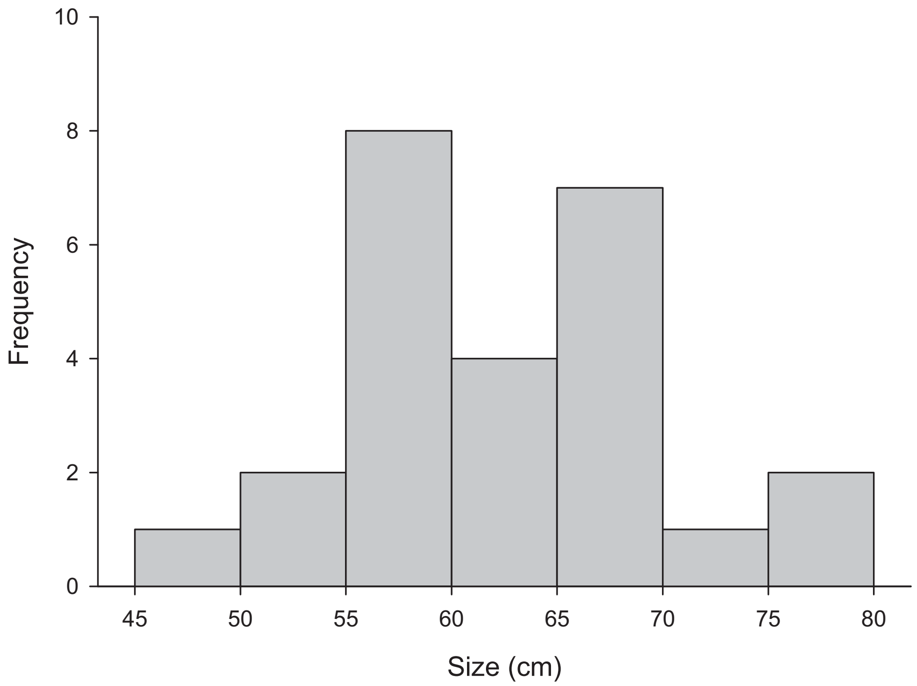

Figure 16. Size-frequency distribution of *T. anax* on deep reef slopes (n=25). Mean size = 61.6 cm (standard deviation = 7.3 cm).

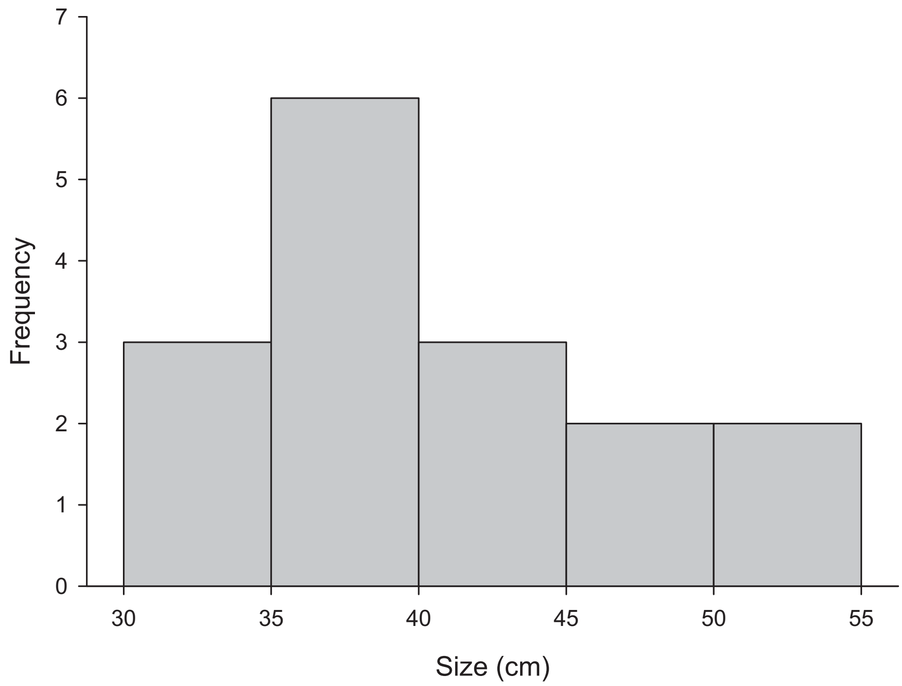

Figure 17. Size-frequency distribution of *H. fuscogilva* on deep reef slopes (n=16). Mean size = 40.1 cm (standard deviation = 6.3 cm).

The mean densities of all sea cucumbers per site is shown in Figure 18. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean densities of sea cucumbers on deep reef slopes were significantly different between the three regions surveyed ($P=0.002$). A Dunn's Multiple Pairwise Comparison test revealed that Saposa had significantly higher densities of sea cucumbers than Tinputz ($P<0.05$).

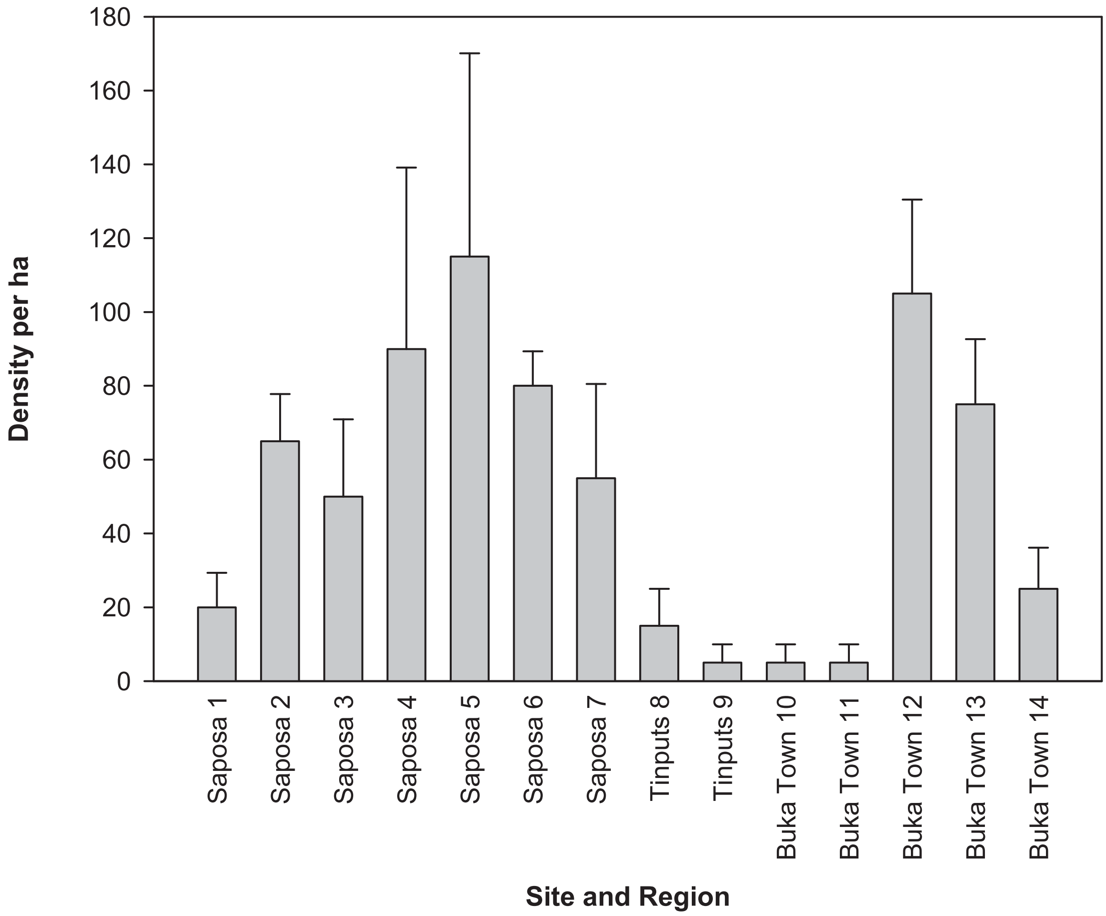

Figure 18. Mean sea cucumber densities (+ 1SE) on deep reef slopes

The mean densities of sea cucumbers on deep reef slopes in the four regions surveyed are shown in Table 11. Densities of all species were low in all regions surveyed.

Table 11. Mean sea cucumber densities on deep reef slopes in the four regions surveyed.

Species	Region	Density (ind. ha^{-1})	Standard deviation (ha^{-1})
Low value species			
Holothuria atra	Saposa	2.85	10.1
	Tinputz	0	0
	Buka town	0	0
H. edulis	Saposa	19.3	34.4
	Tinputz	0	0
	Buka town	0.4	1.6
H. fuscopunctata	Saposa	2.1	9.3
	Tinputz	0	0
	Buka town	2	10
Pearsonothuria graeffei	Saposa	8.6	29
	Tinputz	0	0
	Buka town	1	5
S. horrens	Saposa	5.7	33.8
	Tinputz	0	0
	Buka town	0	0
Thelenota anax	Saposa	12.9	26
	Tinputz	2.5	7.9
	Buka town	6	13.1
High value species			
Bohadschia argus	Saposa	0.7	4.2
	Tinputz	0	0
	Buka town	5	12.5
B. vitiensis	Saposa	2.1	9.3
	Tinputz	7.5	16.9
	Buka town	0	0
H. fuscogilva	Saposa	10	26.6
	Tinputz	0	0
	Buka town	3	8.3
H. whitmaei	Saposa	1.4	5.9
	Tinputz	0	0
	Buka town	0	0
Thelenota ananas	Saposa	2.1	7.1
	Tinputz	0	0
	Buka town	2	6.9
T. rubralineata	Saposa	0	0
	Tinputz	0	0
	Buka town	14	33.1

3.2.5. Lagoon.

A total of 52 sea cucumbers (made up of eight different species) were recorded at the 10 lagoon sites surveyed (Figure 19).

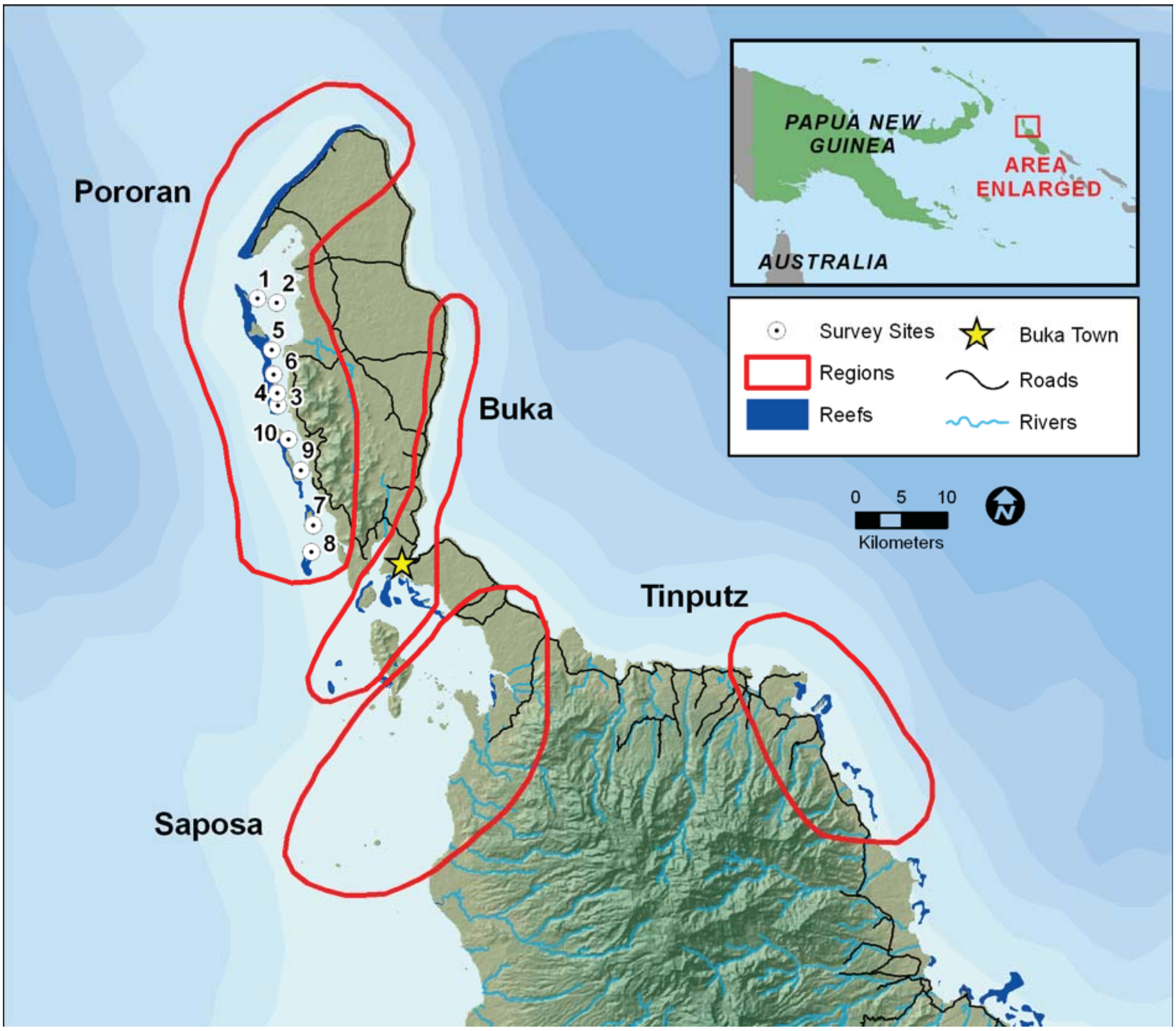

Figure 19. Locations of the 10 Lagoon sites surveyed.

The relative density of each of the species recorded on transects is shown in Table 12. *H. edulis* account for 53.85% (28) of all sea cucumbers sighted in the lagoon followed by *B .argus* 11.54 % (6) and *T. anax* 11.54% (6). The size-frequency distribution of *H. edulis* is shown in Figure 20.

Table 12. Relative densities of each species of sea cucumber in the lagoon.

Species	Common name	Relative density
Holothuria edulis	Pinkfish	53.85
Bohadschia argus	Leopardfish	11.54
Thelenota anax	Amberfish	11.54
Holothuria fuscogilva	White teatfish	7.69
Bohadschia vitiensis	Brown sandfish	5.77
Stichopus hermanni	Curryfish	5.77
Holothuria atra	Lollyfish	1.92
Thelenota ananas	Prickly redfish	1.92
Total		**100**

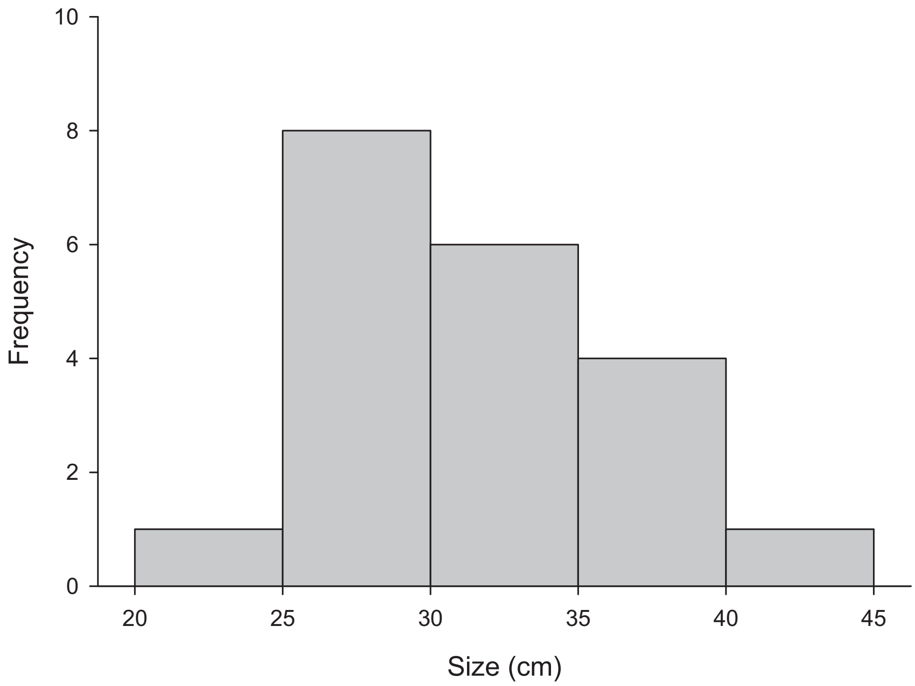

Figure 20. Size-frequency distribution of *H. edulis* in the lagoon (n=20). Mean size = 31.3 cm (standard deviation = 4.4 cm).

The mean densities of sea cucumbers at each lagoon site are shown in Figure 21.

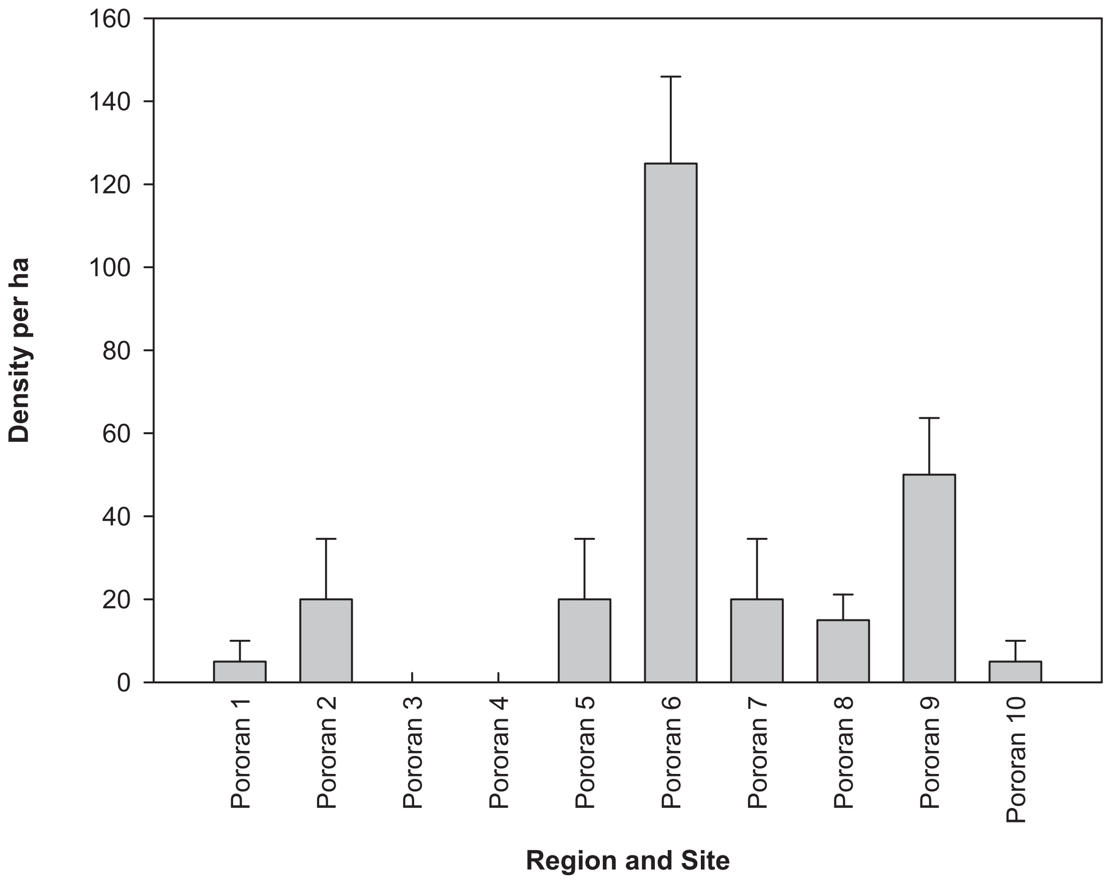

Figure 21. Mean sea cucumber densities (+ 1SE) in the lagoon.

The mean density of each species sighted within the lagoon is shown in Table 13. All species sighted in the lagoon were in very low densities.

Table 13. Mean densities of species sighted in the lagoon.

Species	Density (ind. ha^{-1})	Standard deviation (ha^{-1})
Low value species		
Holothuria atra	0.5	3.5
Holothuria edulis	14	38.9
Thelenota anax	3	8.2
High value species		
Bohadschia vitiensis	1.5	6
Stichopus hermanni	1.5	10.6
Holothuria fuscogilva	2	8.5
Thelenota ananas	0.5	3.5
Bohadschia argus	3	12

3.3. CHANGES IN THE FISHERY SINCE 1992

In 1992 one of the authors on this report (Paul Lokani) surveyed three reef flat sites in the Pororan region (Lokani, unpublished data 1992). The three sites were located near Pororan and Yaparu villages, Pororan Island. These sites are in close proximity to the reef flat sites 4 and 8 that were surveyed in 2008 (Figure 2). Four transects that averaged 600 m^2 were sampled at each site. Lokani's 1992 data is presented here and compared with the data from 2008 Pororan reef flat surveys data to provide a quantitative assessment of changes that have occurred in the fishery. In 1992 the three most common species on reef flats were Sandfish, Lollyfish and Brownspotted sandfish (Table 14). These were also the three species most commonly sighted at Pororan reef flats region in 2008.

Table 14. Relative density of each species of sea cucumber sighted on the Pororan reef flats in 1992

Species	Common name	Relative density
H. scabra	Sandfish	39.96
B. similis	Lollyfish	32.28
Holothuria atra	Brownspotted sandfish	20.35
Actinopyga echinites	Deep-water redfish	5.24
A. miliaris	Hairy blackfish	1.02
H. coluber	Snakefish	0.96
S. hermanni	Curryfish	0.16
Bohadschia argus	Leopardfish	0.03
Total		**100**

By 2008 the densities of Sandfish, Lollyfish and Brownspotted sandfish on Pororan reef flats were only a fraction of their former abundances (Figure 22).

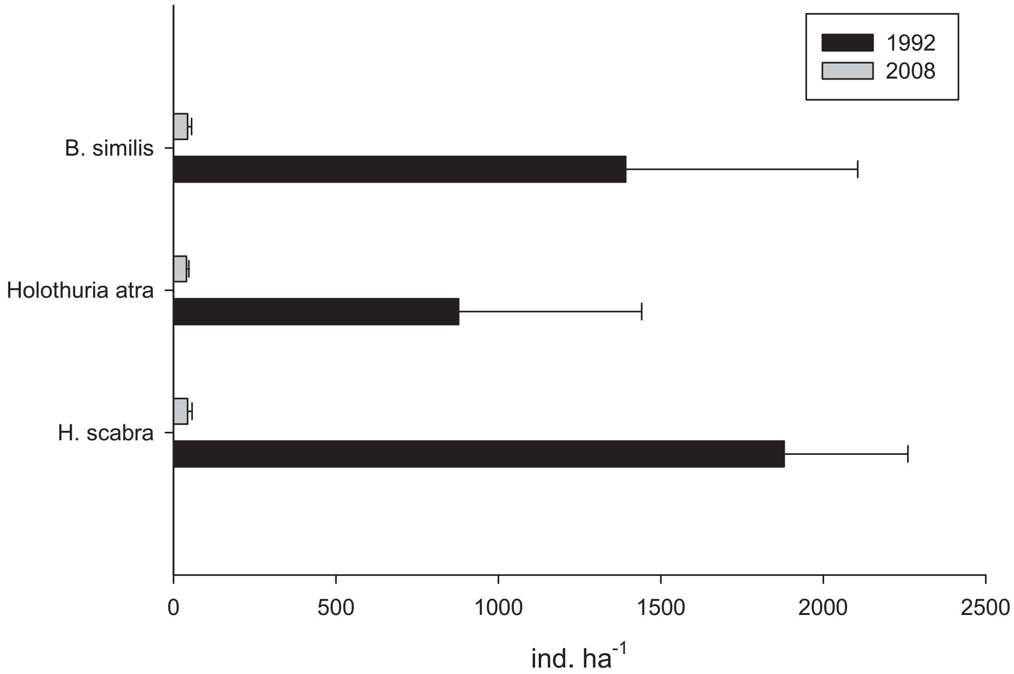

Figure 22. Mean density (ind. ha $^{-1}$) of the three sea cucumber species that were most commonly sighted in transects on the Pororan reef flats in 1992 (n=12) and 2008 (n=90).

Of the eight species that were sighted on reef flats in both the 1992 and 2008 survey, all declined to 1%-40% of their former abundance. By 2008 six of the eight species that were sighted in both surveys showed reductions in abundance of 95% to 99% of 1992 levels (Table 15).

Table 15. Mean densities of sea cucumber species that were seen on the Pororan reef flats in both the 1992 and 2008 survey. The percentage of each species that still remained on the Pororan reef flats in 2008 is also shown.

Species	1992 (ind. ha^{-1})	2008 (ind. ha^{-1})	Percentage remaining since 1992	Difference significant?
H. scabra	1879.51	48.33	3%	Yes (P < 0.001)
B. similis	1392.36	43.83	3%	Yes (P < 0.001)
Holothuria atra	877.78	40	5%	Yes (P = 0.004)
Actinopyga echinites	226	1.95	1%	Yes (P < 0.001)
A. miliaris	44.1	2.22	5%	No (P = 0.069)
H. coluber	41.32	1.11	3%	Yes (P < 0.001)
S. hermanni	6.94	1.39	20%	Yes (P = 0.002)
Bohadschia argus	1.39	0.55	40%	No (P = 0.220)

4.0. DISCUSSION

In nearly all habitats and all regions surveyed sea cucumbers were present in low or very low densities. A comparison of historical 1992 survey data from the Pororan region with results from this survey provide compelling quantitative evidence that the sea cucumber fishery has been severely overfished. All species recorded in both the 1992 and 2008 survey on the Pororan reef flats showed major reductions in abundance over this 16 year period. These changes were typically extreme, with 6 of the eight species declining to between 1% and 5% of 1992 levels.

Although the densities of sea cucumbers on reef flats declined significantly between 1992 and 2008, the relative species composition on the reef flats did not change that markedly. The three most commonly sighted sea cucumbers on reef flats in 1992 (Sandfish, Lollyfish and Brown sandfish) were also the three most commonly sighted sea cucumbers on reef flats in 2008. While no historical quantitative data is available for the other habitats surveyed in 2008, it is highly likely that 2008 sea cucumber densities on the reef crest, reef slope and lagoon habitats are also only a fraction of their former 1992 abundances.

Indeed, it is possible that declines in other habitats may be even more extreme than what occurred on reef flats. A comparison of sea cucumber densities in 1992 and 2006 in New Ireland Province showed that sea cucumber densities in reef flat environments declined less than in other habitats such as lagoons (National Fisheries Authority, 2007). Sea cucumber abundances in the Pororan lagoon were historically very high (Lokani, personal observations) but in 2008 sea cucumbers were present in the lagoon in extremely low abundances. The size frequency distribution of high value species such as sandfish also support a conclusion that sea cucumber stocks have been overfished. Most of the sandfish sighted in this survey were juveniles; with the vast majority being below the minimum legal size of 22 cm. Furthermore, at most reef flat sites surveyed sandfish densities were bellow 100 ind. ha^{-1}, which is the density required to sustain breeding populations of this species (Friedman et al. 2008). It was only at sites in the Tinputz where densities of sandfish exceeded 100 ind. ha^{-1}.

In this 2008 survey three sea cucumber species that were not recorded in Lokani's 1992 survey were sighted on Pororan reef flats, they were *A. Mauritiana, B. vitiensis* and *H. whitmaei*. The higher species diversity sighted on Pororan reef flats in 2008 may be related to the fact that the 2008 survey covered a much larger geographical area and sampled five times more sites than Lokani's 1992 survey. A close examination of the 2008 data reveals that nearly all *A. Mauritiana* recorded were sighted at two sites located just north of the sites surveyed in 1992. These two sites are located on a narrow reef flat, and transects placed here intersected the surf zone. This was not the case for the three 1992 sites, which were located on wider reef flats. This explains the relative dominance of *A. Mauritiana* in the 2008 surveys, since this species is typically found in the surf zone.

The only site in this survey that had a high density of sea cucumbers was a reef crest site in the Tinputz (Site 7). The high densities at this site were due to high abundances of *H. atra*, and it is noteworthy that this site is closed to fishing under a customary tambu. The fact that a tambu had been placed on this site was unknown to the survey team at the time they began sampling. It was only when traditional reef owners approached them on the reef that they learnt they were sampling within an area that was closed to fishing. The much higher than average densities of *H. atra* at this site provide evidence for the positive impact that protection can have for this species.

In a recent survey of sea cucumbers in New Ireland, sea cucumber densities in two customary protected "control' sites were compared with densities from 40 other sites around New Ireland that are open to fishing. Similar to this study, the New Ireland survey revealed that at one of the two 'control' sites abundances of *H. atra* (but not other species) were in far greater abundances on inter tidal habitats than at surrounding sites that were open to fishing (National Fisheries Authority, 2007). Research in the Solomon Islands has also shown that sea cucumber densities on reef flats within a Marine Protected Area (MPA) improved rapidly following MPA establishment (Hamilton et al. 2007).

Traditionally many regions in Bougainville placed tambus on reefs in order to allow stocks to recover (Lokani, 1995; Hamilton 2003). Encouraging the reestablishment of such practices would be one means of allowing sea cucumber stocks the chance to recover. The three year PNG wide closure of the sea cucumber fishery that was put in place in December 2009 should also allow stocks the chance to recover. In the future the data collected in this survey could be used as a baseline to evaluate the effectiveness of this closure in Northern Bougainville.

As expected, in this survey significant habitat related differences existed, with some species predominantly found in one habitat over another. For example, sandfish were almost exclusively located on reef flats, whereas white teatfish were predominantly located at deep reef slopes and deep lagoon habitats. Lollyfish were found in all habitats, with densities highest in reef flat and reef crest zones. Similar to earlier studies, the highest densities of sandfish were seen at sites that had seagrass cover (Long and Skewes, 1997; National Fisheries Authority, 2007).

Within habitat regional differences also existed. For example, on the deep reef slopes, the Saposa region had significantly higher densities of sea cucumbers than the Tinputz region, yet Saposa had lower densities of sea cucumbers on reef flats than all other regions. Such finding must be interpreted with caution, given the low level of sampling within each region for many of the habitats compared. For the Saposa region, the significantly lower level of sea cucumbers on the reef flats is due to the absence of sandfish in this region, a finding that no doubt in part reflects the fact that no seagrass covered reef flats were sampled in the Saposa region. The shallow reef slope habitat was the most extensively sampled habitat in this survey, and in this habitat the mean sea cucumber densities did not differ significantly among regions.

5.0. REFERENCES

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CHAPTER 2: FOOD FISH SURVEY

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1.0 INTRODUCTION

Reef finfish are the mainstay of the subsistence and artisanal fisheries in Bougainville and comprise a major component of the protein in the diet of coastal communities. Ensuring the persistence of healthy reef fisheries is critical for the food security and prosperity of coastal communities in Bougainville. However in recent years growing coastal population along with an increasing move towards artisanal and commercial fishing appears to have resulted in depletion of some marine resources' (Lokani 1995). Valuable macro invertebrates' such as sea cucumbers are severely overfished (see Chapter 1) and many grouper spawning aggregations are reported to be in decline (Hamilton 2003a). The abundances of large rare species such as the bumphead parrotfish (*Bolbometopon muricatum*) have also declined markedly in recent decades following the commencement of night spearfishing (Lokani, personal observations).

The purpose of this survey was to collect quantitative baseline data on reef fishes of importance to local fisheries. This baseline data can be compared to similar studies in other regions in Melanesia, and will highlight species and areas of concern. Such information can be used to inform better management of these resources in the future.

2.0. METHODS

2.1. STUDY SITES

In total 26 sites around Buka were surveyed for food fishes. 4 regions were surveyed in the Northern Bougainville area. 8 sites were surveyed in the Pororan area, 7 sites were surveyed in the Saposa area, 5 sites were surveyed in the Tinputz area and 6 sites were surveyed around the Buka township area (Figure 1). Exposed reef slopes (both fringing and barrier reefs) were the most common habitats surveyed although several sheltered sites in Saposa were also surveyed.

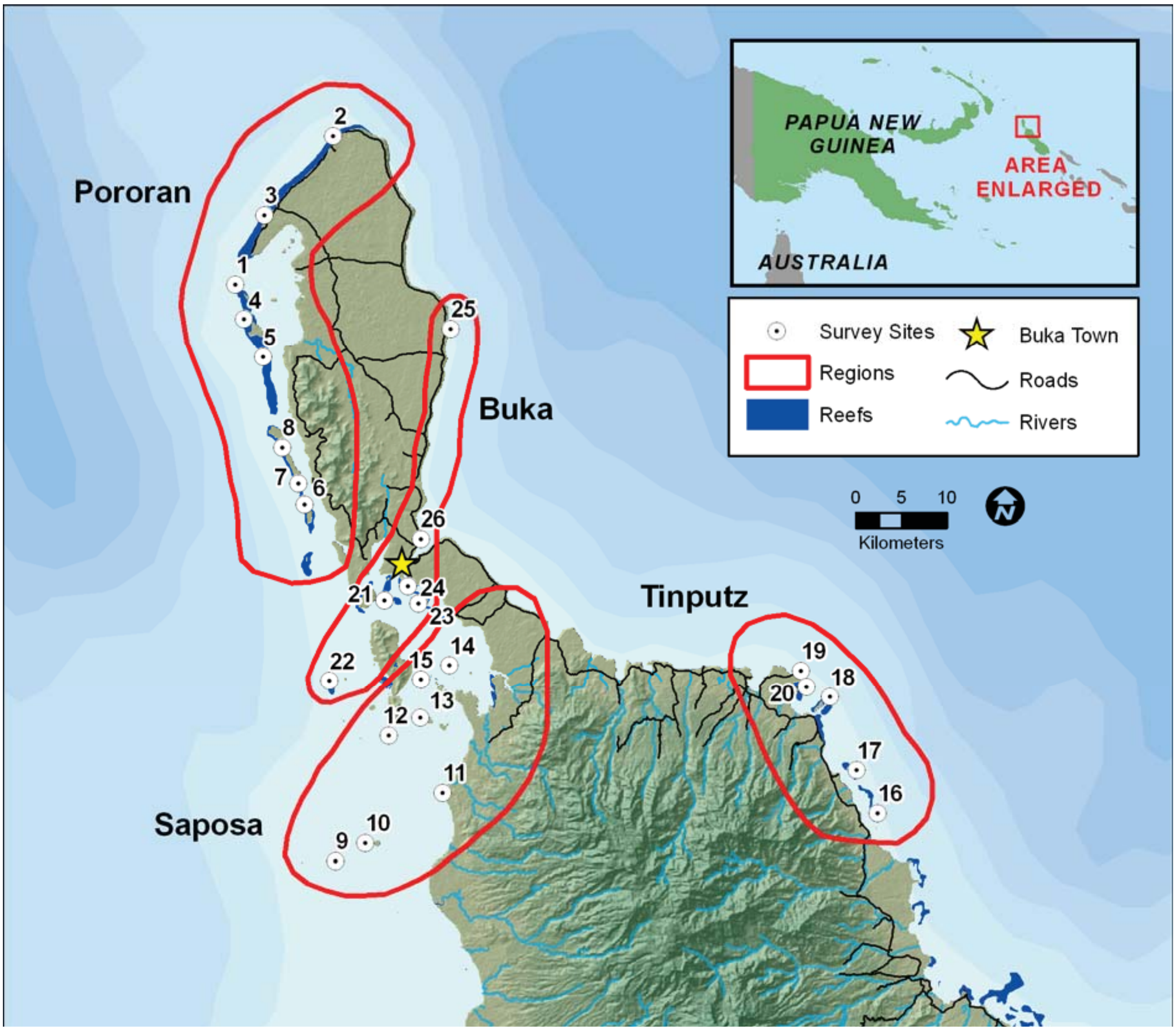

Figure 1. Locations of the 26 reef slope sites surveyed for reef fish and coral cover and the four regions they were surveyed in (circled in red).

2.2. TARGET SPECIES

The list of key fishery species that were surveyed is shown in Table 1. For consistency and comparison purposes we adopted the list of key food fish species used in the Solomon Island 2004 Rapid Ecological Assessment (REA) (Green et al. 2006).

Table 1. Key species of food fishes surveyed

Taxa/Family	Species	Common Name
Sharks	*All species*	Sharks
Mobulidae (manta rays)	*Manta spp.*	Manta rays
Myliobatidae (eagle rays)	*Aetobatus narinari*	Spotted eagle ray
Labridae (wrasses)	*Cheilinus undulatus*	Humphead wrasse
	Cheilinus fasciatus	Redbreasted wrasse
Scaridae (parrotfishes)	*Bolbometopon muricatum*	Bumphead parrotfish
	Hipposcarus longiceps	Pacific longnose parrotfish
	Chlorurus microrhinos	Steephead parrotfish
Serranidae (groupers)	*Plectropomus areolatus*	Squaretail coral grouper
	Plectropomus laevis	Blacksaddle coral grouper
	Plectropomus oligacanthus	Highfin coral grouper
	Plectropomus leopardus	Leopard coral grouper
	Epinephelus fuscoguttatus	Brown-marbled grouper
	Epinephelus polyphekadion	Camouflage grouper
	Epinephelus lanceolatus	Giant grouper
	Cromileptes altivelis	Barramundi cod
	Variola louti	Yellow-edged lyretail
	Variola albimarginata	White-edged lyretail
	Epinephelus merra/quoyanus	Honeycomb groupers
	Cephalopholis argus	Peacock grouper
	Cephalopholis cyanostigma	Bluespotted grouper
	Cephalopholis miniata	Coral grouper
Haemulidae (sweetlips)	*Plectorhinchus albovittatus*	Giant sweetlips
	Plectorhinchus vittatus	Oriental sweetlips
	Plectorhinchus lineatus	Diagonal-banded sweetlips
	Plectorhinchus chaetodonoides	Many-spotted sweelips
Lutjanidae (snappers)	*Aprion virescens*	Green jobfish
	Lutjanus gibbus	Humpback snapper
	Lutjanus bohar	Red snapper
	Lutjanus argentimaculatus	Mangrove red snapper
	Macolor niger	Black snapper
	Macolor macularis	Midnight snapper
	Symphorichthys spilurus	Sailfin snapper
	Small yellow and spot (= L. monostigma, L. fulviflamma, L. ehrenbergii etc)	Longspot/blackspot/onespot snapper
	Small & yellow lines (= L. quinquelineatus, L. kasmira)	Five-lined/bluestripe snapper
Lethrinidae (emperors)	*Lethrinus olivaceus*	Longface emperor
	Lethrinus erythropterus	Longfin emperor
	Lethrinus rubrioperculatus	Spotcheek emperor
	Lethrinus xanthochilus	Yellowlip emperor
	Monotaxis grandoculis	Humpnose bigeye bream
	Small lethrinids (Lethrinus spp.)	Small emperors
Acanthuridae (surgeonfishes)	*Naso hexacanthus*	Sleek unicornfish
	Naso lituratus	Orangespine unicornfish
	Naso unicornis	Bluespine unicornfish
	Naso brevirostris	Spotted unicornfish
	Large ringtails (Acanthurus xanthopterus, A. mata, A. nigricauda A. dussumieri, A. blochi, A. fowleri etc)	Ringtails
	Small surgeonfish: Acanthurus lineatus and Ctenochaetus species	Lined surgeonfish and Bristletooth
Siganidae (rabbitfishes)	*Siganus lineatus*	Lined rabbitfish
	Siganus vermiculatus	Vermiculate rabbitfish
	Siganus fuscescens	Dusky rabbitfish
	Siganus puellus	Masked rabbitfish
Mullidae (goatfishes)	*Parupeneus bifasciatus/trifasciatus*	Doublebar/Indian doublebar

		goatfish
	Parupeneus cyclostomus	Goldsaddle goatfish
	Parupeneus barberinus	Dash-dot goatfish
	Parupeneus vanicolensis	Yellowfin goatfish
Kyphosidae (drummers)	*Kyphosus spp.*	Drummer
Ostracidae (boxfishes)	*Ostracion cubicus*	Yellow boxfish
Caesionidae (fusiliers)	*Caesio cuning*	Yellowtail fusilier
Balistidae (triggerfishes)	*Balistoides viridescens*	Titan triggerfish
	Pseudobalistes flavimarginatus	Yellowmargin triggerfish
	Balistapus undulatus	Orange-lined triggerfish
Chanidae (milkfishes)	*Channos channos*	Milkfish
Holocentridae (soldierfishes and squirrelfishes)	*Sargocentron spiniferum*	Sabre squirrelfish
Carangidae (trevally)	*Caranx ignobilis*	Giant trevally
	Caranx sexfasciatus	Bigeye trevally
	Caranx papuensis	Brassy trevally
	Caranx melampygus	Bluefin trevally
Sphyraenidae (barracudas)	*Sphyraena* spp.	Barracuda

2.3. SURVEY METHODS

Key food fish species were surveyed using underwater visual census techniques that consisted of a combination of transect counts and long swims, based on methods in the Solomon Islands REA (Green et al., 2006).

2.3.1. Transect counts

Five replicate transects were surveyed at each site. Each transect was 50 m long and 10 m wide, giving a total area surveyed of 500 m^2 per transect. Transect lengths were measured using 50 m tapes, and transect widths were visually estimated. Transect tapes were laid by an assistant following the observer to minimize disturbance to the fish communities being counted. The tapes then remained in situ until all surveys were completed at that site. Benthic communities were surveyed along the same transects after the fish counts were completed (See Chapter 3). In each pass of a transect the number of individuals of each fish species was counted and recorded onto underwater paper. The size of each individual (length in cm) was also estimated and recorded. Fish identifications were based on (Allen, et al. 2003).

2.3.2. Long swim surveys

Key fisheries species of food fish that are large and particularly vulnerable to overfishing were also counted (and their size estimated) using long swim methods specifically developed for this purpose (Choat and Pears 2003). This method was developed to improve estimates of the abundance of these species, since they tend to be uncommon and clumped in distribution, so smaller transects dimensions (e.g., 50 m x 10 m) are not suitable for obtaining reasonable estimates of their abundance. In this method, the observer surveyed a 20 m wide area during a single pass of the reef slope over a set time period (20 minutes) scanning the reef slope for these species. Average swim speeds for an observer were calculated such that the average distance covered in a timed swim could be estimated. Long swims covered an average area of 8000 m^2.

The species surveyed using the long swim method were:

- Humphead wrasse (*Cheilinus undulatus*);
- Bumphead parrotfish (*Bolbometopon muricatum*) and steephead parrotfish (*Chlorurus microrhinos*);
- Large groupers (*Epinephelus fuscoguttatus, Epinephelus polyphekadion, Epinephelus lanceolatus, Cromileptes altivelis, Plectropomus areolatus, Plectropomus laevis, Plectropomus leopardus, Plectropomus oligacanthus Variola louti* and *Variola albimarginata*);
- Giant trevally (*Caranx ignobilis*); and
- Large and uncommon emperors (*Lethrinus olivaceus, Lethrinus erythropterus, Lethrinus rubrioperculatus* and *Lethrinus xanthochilus*).

2.4. DATA ANALYSIS

Key fisheries species were compared among the four regions based on the density and biomass of all species and key families. Fish density estimates per transect and per long swim were converted to the number of individuals per hectare (ha). Fish density estimates per transect were converted to the number of individuals per hectare (ha). Fish biomass was calculated by converting estimated fish lengths to weights (Appendix 1) using the allometric length-weight conversion formulae W=aLb where a and b are constants for each species. Fish biomass per transect was converted to the biomass of fish per hectare (ha). Most constants were obtained from Fishbase (www.fishbase.org).

Typically the median value for a species was used, or when no species-specific information was available, the constants for a closely related species or the constants of the overall mean values of a genus were used Differences in fish densities and biomass between the four regions were investigated using Kruskal-Wallis One Way Analysis of Variance on Ranks (SigmaStat) since data was non-normal. A Multiple Pairwise Comparison Procedure (Dunn's Method) was used to identify where the significant difference between regions existed.

3.0. RESULTS

3.1. FISH DENSITY

Bony fishes were most abundant, accounting for 99.93% of the fish counted (Table 2). The most abundant families were snappers, surgeonfishes and fusiliers, followed by drummers, emperors and goatfishes. Sharks and rays were uncommon, accounting for 0.07% of the fishes counted (Table 2).

Table 2. Relative densities and biomass of each fish family sighted around Buka

Family	Common name	Relative density	Relative biomass
LUTJANIDAE	Snappers	25.56	18.96
ACANTHURIDAE	Surgeonfishes	21.86	8.3
CAESIONIDAE	Fusiliers	14.04	0.3
KYPHOSIDAE	Drummers	8.48	17.26
LETHRINIDAE	Emperors	7.38	4.56
MULLIDAE	Goatfishes	6.7	0.93
SIGANIDAE	Rabbitfishes	6.07	1.39
BALISTIDAE	Triggerfishes	4.19	6.05
LABRIDAE	Wrasses	2.14	7.71
SERRANIDAE	Groupers	1.49	3.16
HAEMULLIDAE	Sweetlips	1.08	4.24
SCARIDAE	Parrotfishes	0.7	5.8
CARANGIDAE	Trevally	0.19	0.15
SHARKS	Sharks	0.07	21.14
HOLOCENTRIDAE	Squirrelfishes	0.03	0.02
OSTRADICIDAE	Boxfishes	0.02	0.03
RAYS	Rays	0	0
SPHYRAENIDAE	Barracudas	0	0
Total		**100**	**100**

3.1.1. Density of total fish assemblage

The density of all bony food fishes at each site is shown in Figure 2. A Kruskal-Wallis One Way Analysis of Variance on Ranks on density shows that mean densities were significantly different between the four regions surveyed (P=0.026). A Dunn's Multiple Pairwise Comparison test revealed that Tinputz had significantly higher densities of fish than both Pororan and Saposa (P<0.05).

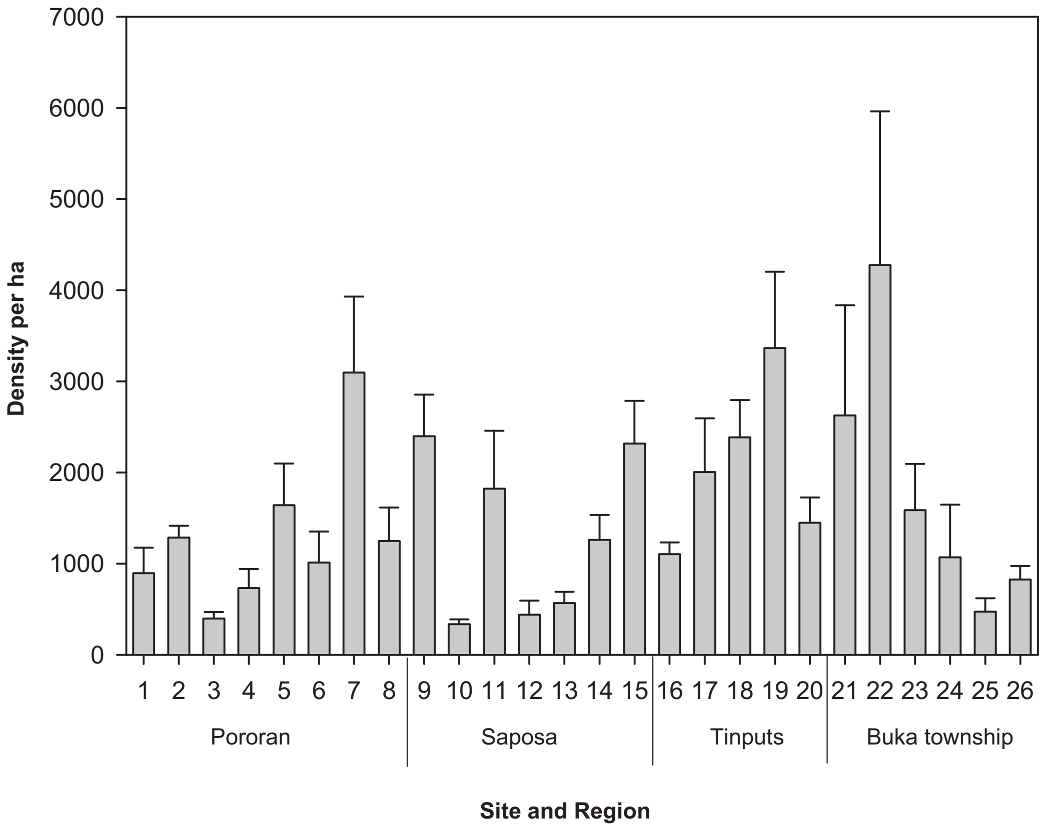

Figure 2. Mean densities (+ 1SE) of food fishes sighted.

3.1.2. Densities of the key families of fishes

To examine if densities of key families of fishes differed significantly between the four regions surveyed we compared the total densities of snappers, surgeonfishes, emperors, and groupers. These families were chosen in order to allow comparisons between mean densities around northern Bougainville with other regions in the Solomon Sea, since these four families were investigated in detail in the Solomon Islands 2004 Rapid Ecological Assessment (REA). Unlike the Solomon Islands REA parrotfishes were not examined in detail in this survey because they made up a very low proportion (0.7%) of total fish density sighted (Table 2).

3.1.2.1. Snappers

Snappers made up 25.56% of the total fish density sighted in this survey. The density of snapper at each site in shown in Figure 3. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean total densities were significantly different between the four regions surveyed ($P=0.012$). A Dunn's Multiple Pairwise Comparison test revealed that Tinputz had significantly higher mean densities of snapper than Buka Town ($P<0.05$).

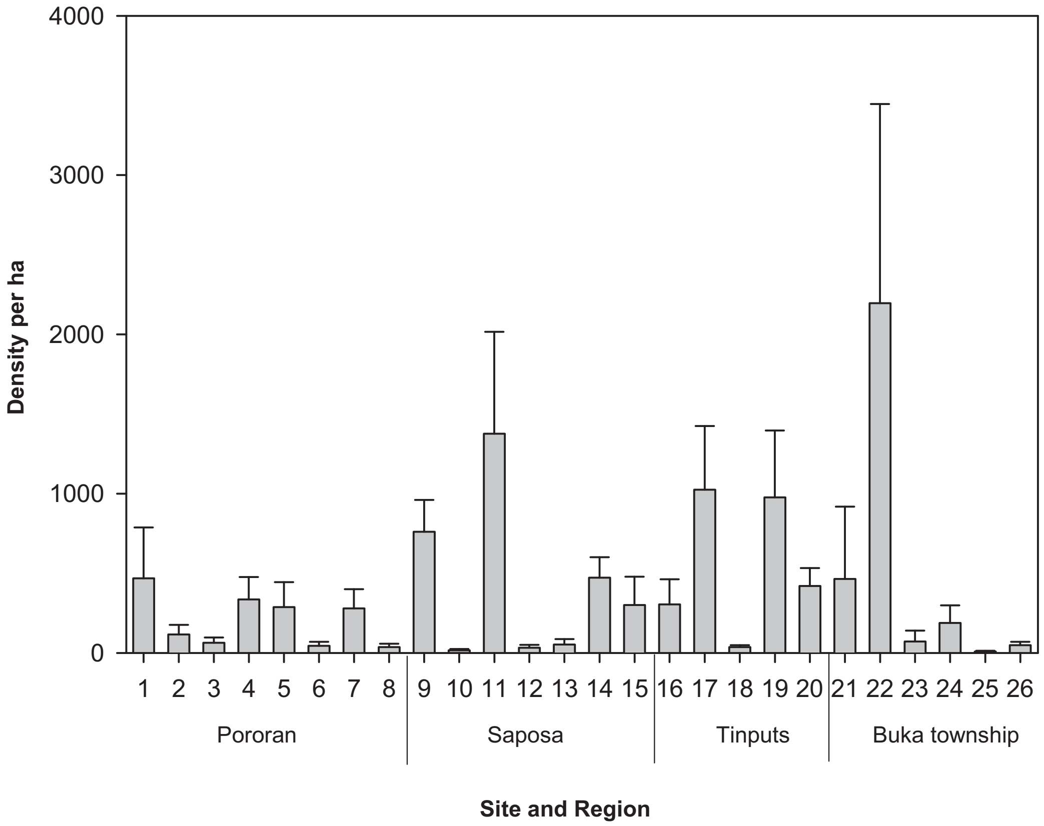

Figure 3. Mean density (+ 1SE) of Snappers sighted.

3.1.2.2. Surgeonfishes

Surgeonfishes made up 21.86% of the total fish density sighted in this survey. The density of surgeonfishes at each site in shown in Figure 4. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean total densities were significantly different between the four regions surveyed (P=0.002). A Dunn's Multiple Pairwise Comparison test revealed that Tinputz had significantly higher mean densities of surgeonfish than Buka Town (P<0.05).

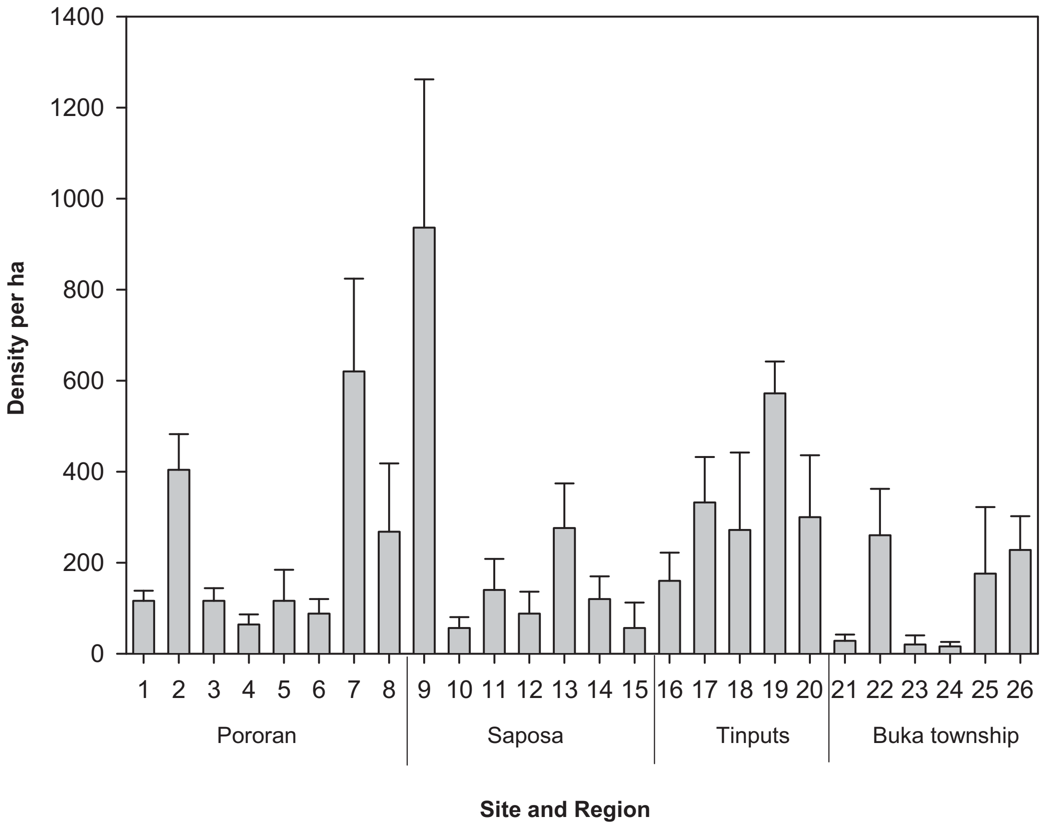

Figure 4. Mean density (+ 1SE) of Surgeonfishes sighted.

3.1.2.3. Emperors

Emperors made up 7.38% of the total fish density sighted in this survey. The density of emperors at each site in shown in Figure 5. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean total densities were not significantly different between the four regions surveyed (P=0.074).

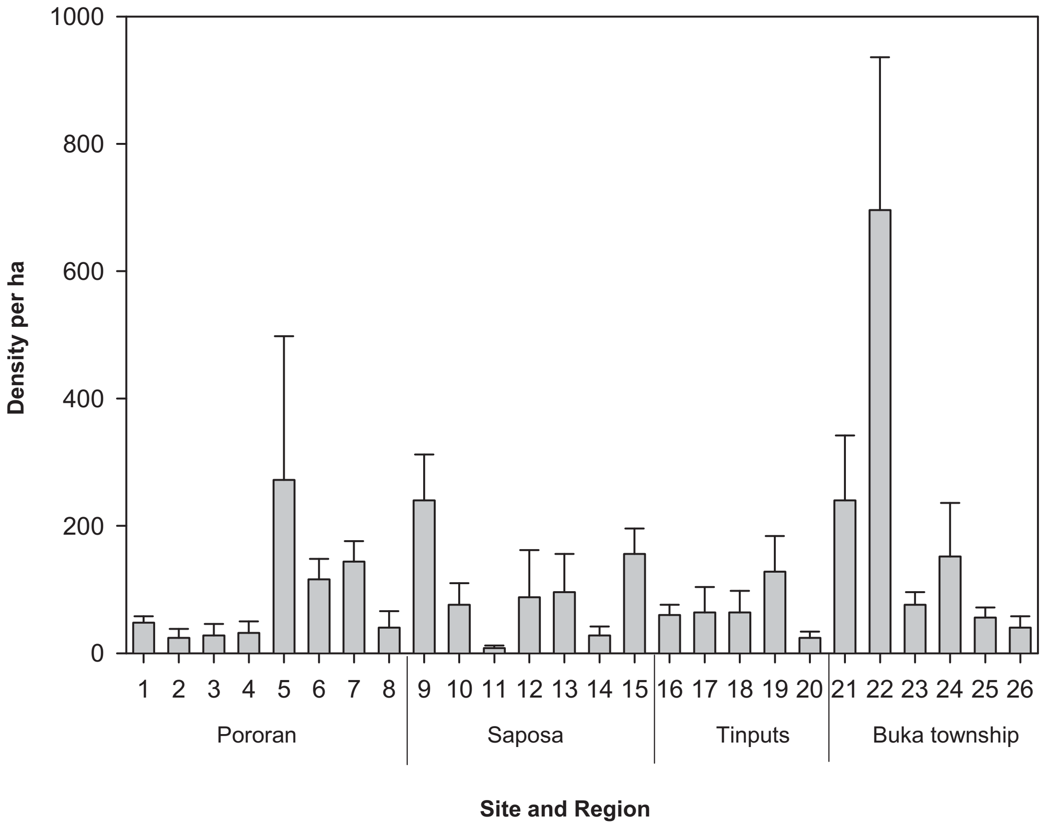

Figure 5. Mean density (+ 1SE) of Emperors sighted.

3.1.2.4.Groupers

Groupers made up 1.49% of the total fish density sighted in this survey. The density of groupers at each site in shown in Figure 6. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean total densities were not significantly different between the four regions surveyed (P=0.261).

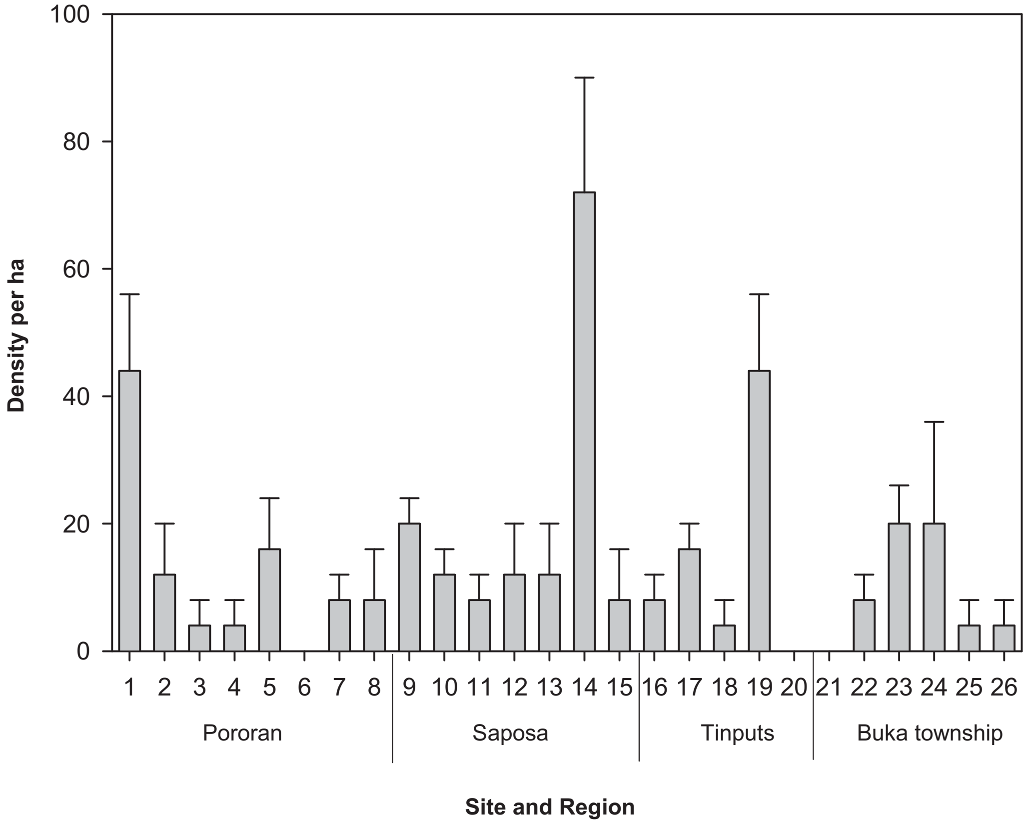

Figure 6. Mean density (+ 1SE) of Groupers sighted.

3.2. FISH BIOMASS

Bony fishes made up 79.86% of the total biomass of fish surveyed, with sharks accounting for the remaining 21.14% of biomass (Table 2). Families that made up the largest proportion of biomass were sharks, snappers, drummers, surgeonfishes and wrasse (Table 2). The biomass of all bony food fishes at each site is shown in Figure 7. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean biomasses were significantly different between the four regions surveyed (P=0.003). A Dunn's Multiple Pairwise Comparison test revealed that Tinputz had significantly higher biomass of fish than Pororan, Saposa and Buka township (P<0.05).

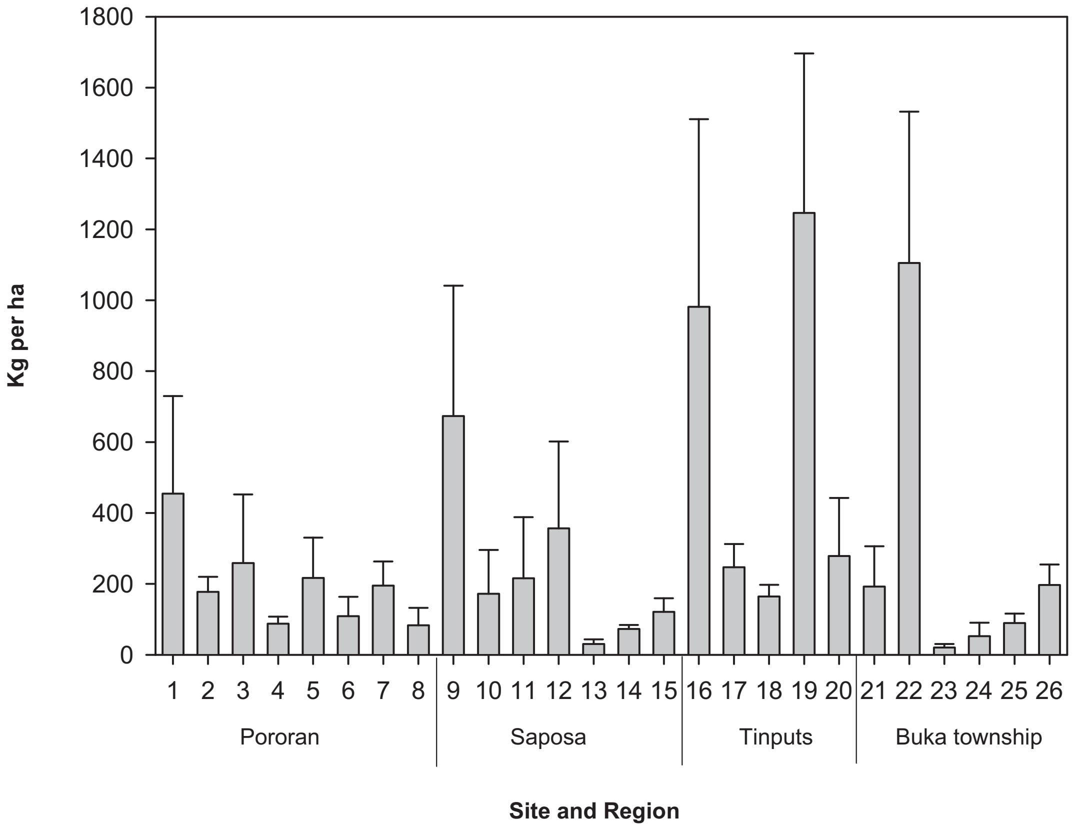

Figure 7. Mean biomass of food fishes (+ 1SE) sighted.

3.2.1. Biomasses of the key families of fishes

To examine if biomass of key families of fishes differed significantly between the four regions surveyed we compared the total biomass of snappers, surgeonfishes, emperors and groupers. These being the same four families whose relative densities were compared between the four regions.

3.2.1.1. Snappers

Snappers made up 18.96% of the total fish biomass in this survey. The biomass of snapper at each site in shown in Figure 8. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean biomass was significantly different between the four regions surveyed (P=0.004). A Dunn's Multiple Pairwise Comparison test revealed that Tinputz had significantly higher mean biomasses of snapper than Buka Town (P<0.05).

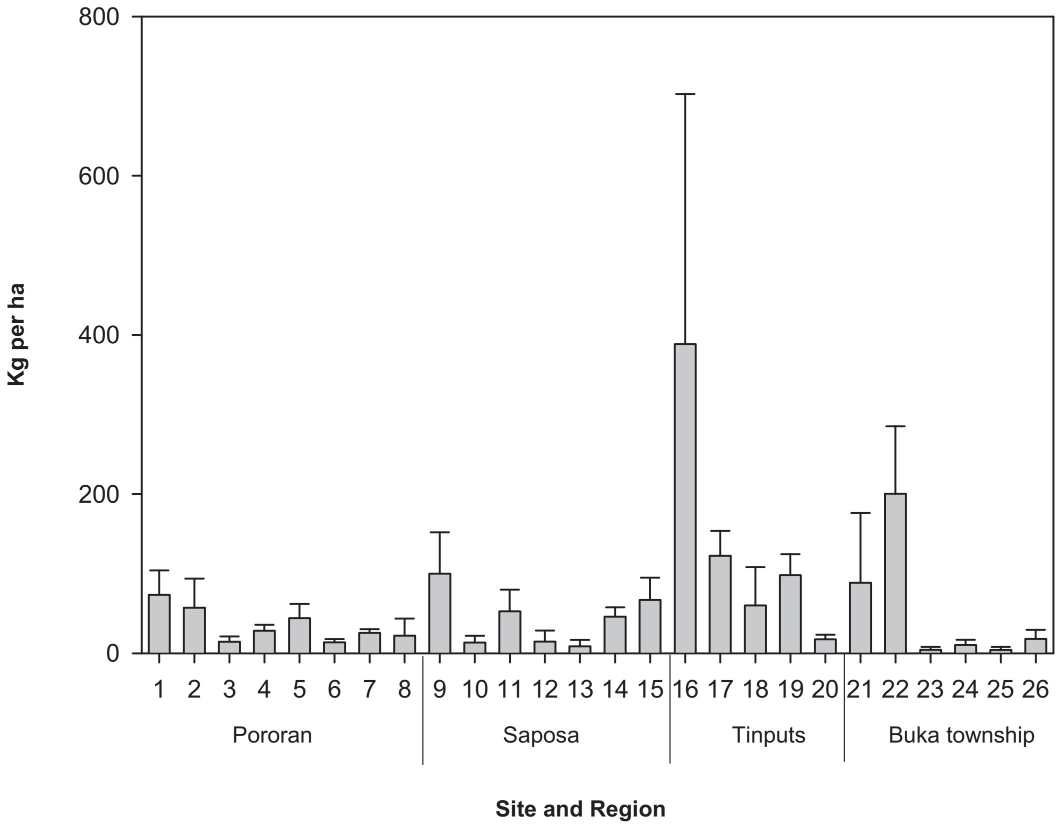

Figure 8. Mean biomass (+ 1SE) of Snappers sighted.

3.2.1.2. Surgeonfishes

Surgeonfishes made up 8.3% of the total fish biomass in this survey. The biomass of surgeonfishes at each site in shown in Figure 9. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean total biomasses were significantly different between the four regions surveyed (P=0.001). A Dunn's Multiple Pairwise Comparison test revealed that Tinputz had significantly higher mean biomasses of surgeonfish than Pororan, Saposa and Buka township (P<0.05).

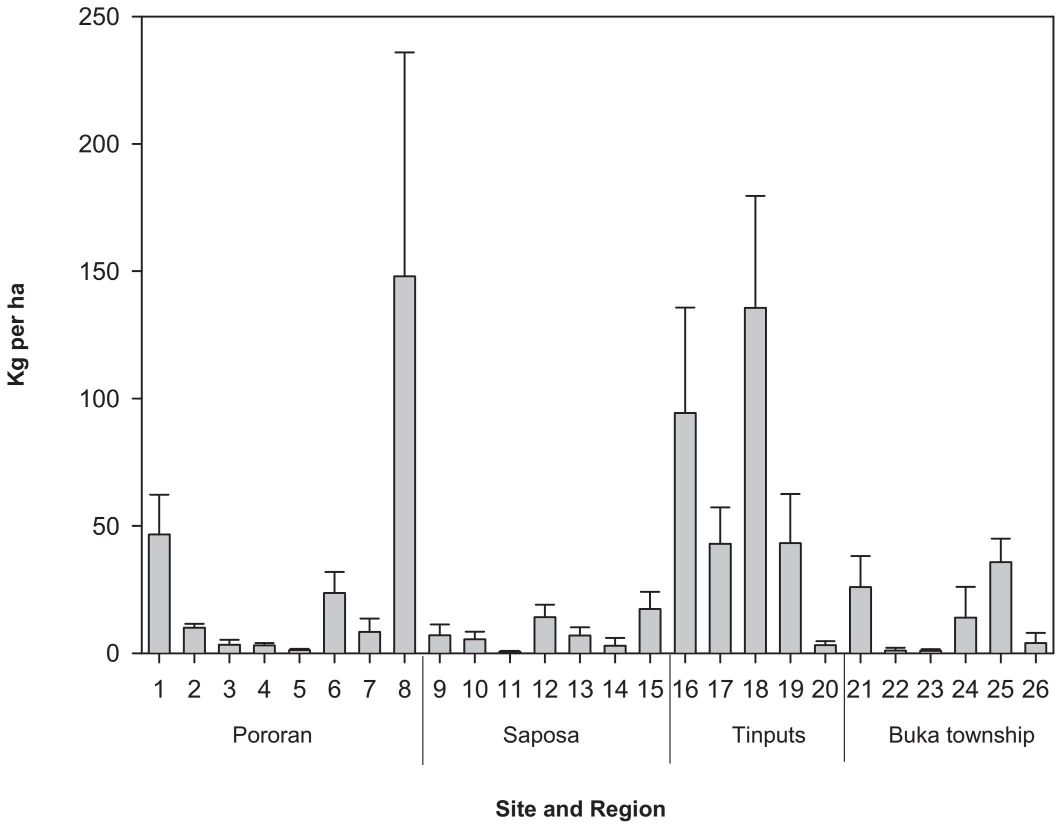

Figure 9. Mean biomass (+ 1SE) of Surgeonfishes sighted.

3.2.1.3. Emperors

Emperors made up 4.56% of the total fish biomass in this survey. The biomass of emperors at each site in shown in Figure 10. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean total biomasses were significantly different between the four regions surveyed (P=0.015). A Dunn's Multiple Pairwise Comparison test revealed that Buka town had significantly higher biomasses of emperors than Saposa (P<0.05).

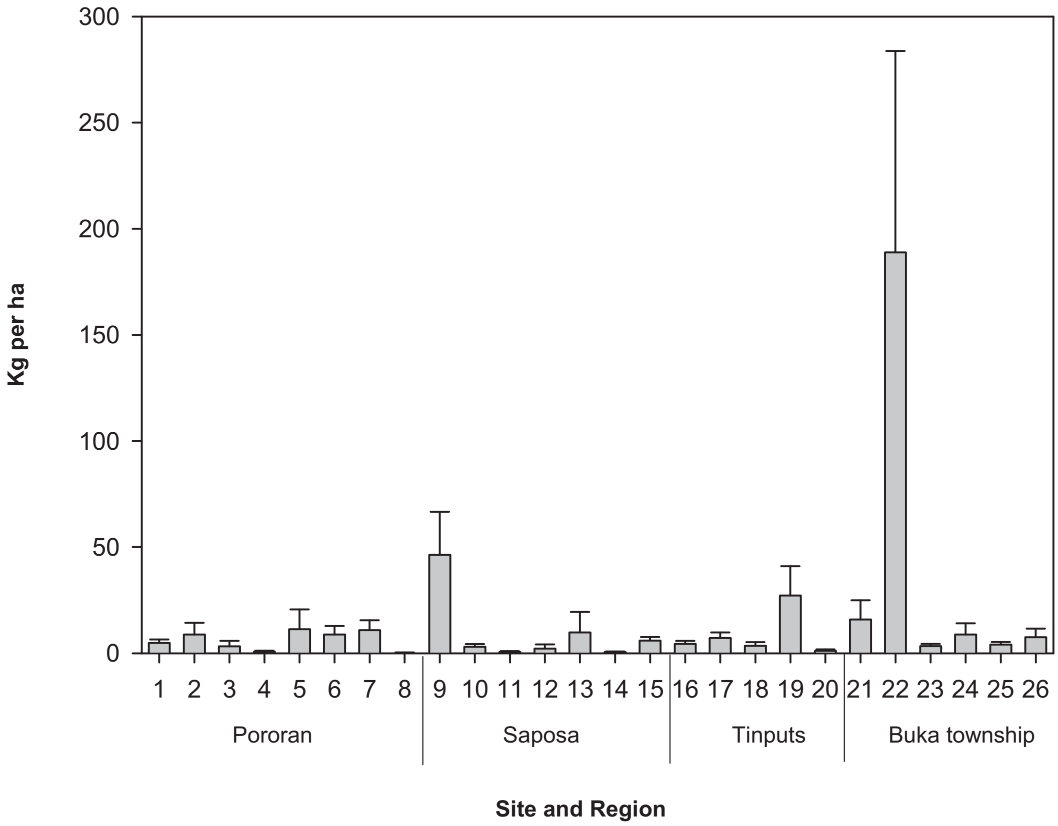

Figure 10. Mean biomass (+ 1SE) of Emperors sighted.

3.2.1.4. Groupers

Groupers made up 3.16% of the total fish biomass in this survey. The biomass of groupers at each site in shown in Figure 11. A Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean total biomasses of groupers were not significantly different between the four regions surveyed (P=0.295).

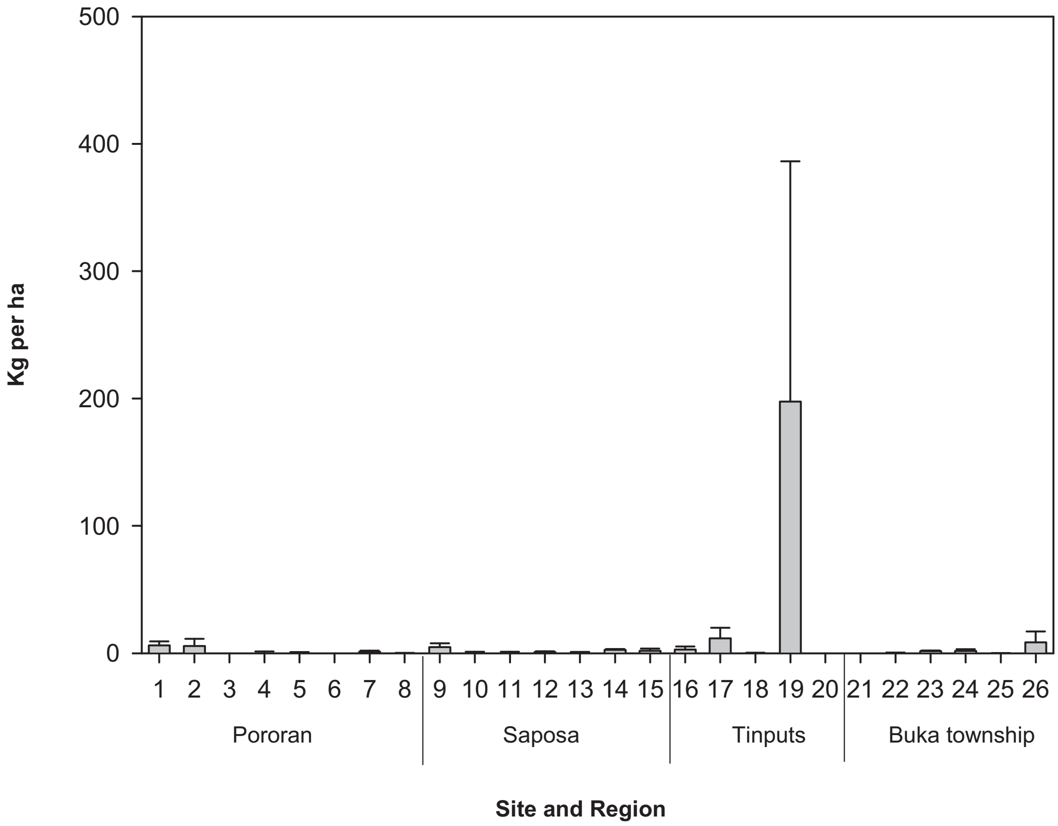

Figure 11. Mean biomass (+ 1SE) of Groupers sighted.

3.3. FOOD FISHES SIGHTED ON LONG SWIMS

The density and biomass of large vulnerable food fishes sighted on long swims is shown in Figure 12 and 13. Kruskal-Wallis One Way Analysis of Variance on Ranks shows that mean densities and biomasses of fish sighted on long swims were not significantly different between the four regions surveyed (P=0.295 and P=0.069 respectively).

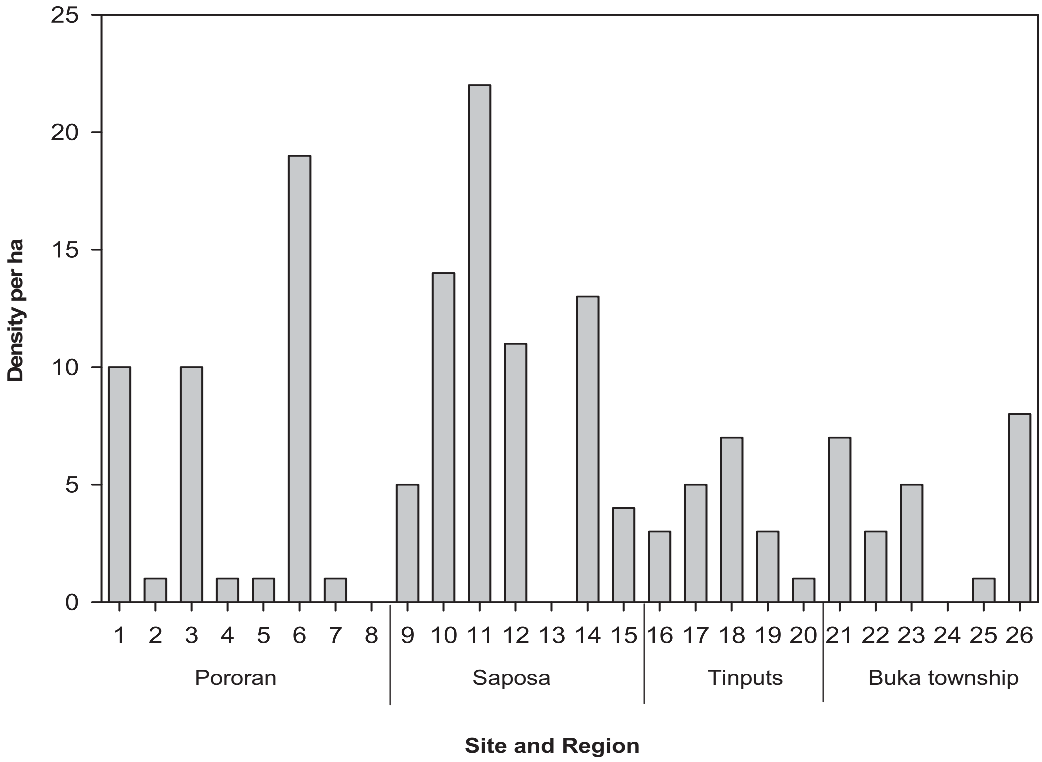

Figure 12. Density of large vulnerable fish sighted.

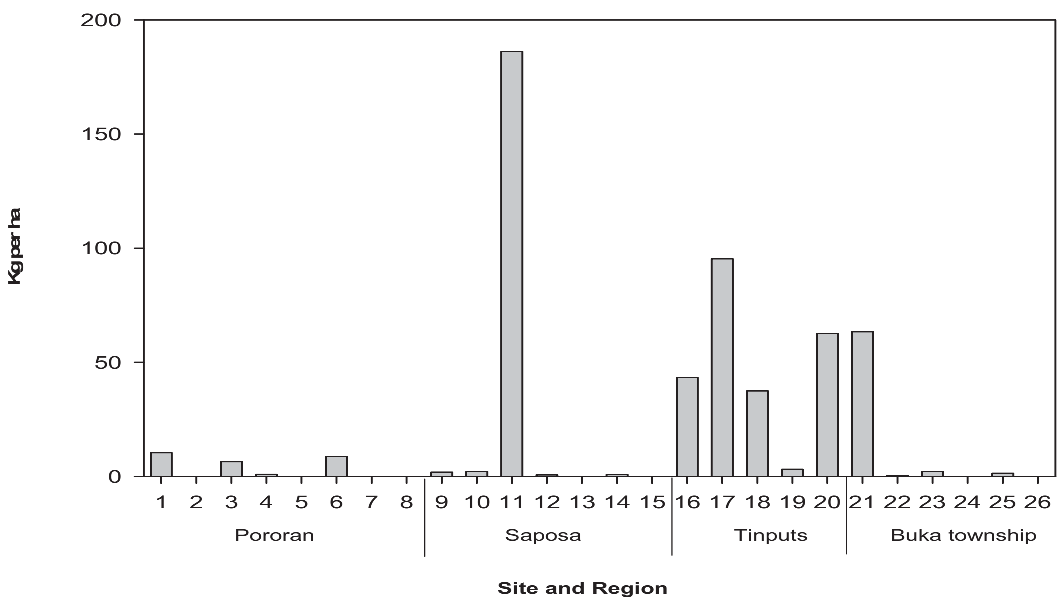

Figure 13. Biomass of large vulnerable fish sighed

Table 3 and 4 shows a comparison of the mean densities and biomass of all large vulnerable fish, Humphead wrasse and Bumphead parrotfish that were sighted on long swims in Bougainville and four other nearby regions in the Solomon and Bismarck Sea; that being Western and Choiseul province in the Solomon Islands and Manus and New Ireland province in Papua New Guinea . Mean densities and biomasses of all vulnerable reef fishes in Bougainville are very low relative to densities in Western, Choiseul and Manus province. Densities of vulnerable reef fish were similar in Bougainville and New Ireland, with Bougainville having higher mean biomass of vulnerable reef fish than that seen in the New Ireland survey.

Table 3. Mean densities of all vulnerable fishes, Humphead wrasse and Bumphead parrotfish sighted in Bougainville with comparisons from other regions in Solomon Sea and Bismarck Sea

	Solomon Sea			Bismarck Sea	
Mean density per ha	Bougainville	Western Province, Solomon Islands	Choiseul Province, Solomon Islands	Manus Province	New Ireland Province
All vulnerable fish	7.45	18	25	22	6
Humphead wrasse	0.43	2.2	3.4	1.71	0.69
Bumphead parrotfish	0	7	1.2	4.21	0.35

Table 4. Mean biomass of all vulnerable fishes, Humphead wrasse and Bumphead parrotfish sighted in Bougainville with comparisons from other regions in Solomon Sea and Bismarck Sea

	Solomon Sea			Bismarck Sea	
Mean biomass (kg per ha)	Bougainville	Western Province, Solomon Islands	Choiseul Province, Solomon Islands	Manus Province, PNG	New Ireland Province, PNG
All vulnerable fish	21.53	170	45	64.5	6.8
Humphead wrasse	1.62	10.42	23.9	3.08	0.54
Bumphead parrotfish	0	103.02	10.58	52.22	0.54

4.0. DISCUSSION

The densities and biomass of all fish species surveyed on transects were very low compared to other regions in the Solomon Sea that were surveyed using identical methods (and indeed, the same observer, Michael Giningele) during the Solomon Islands REA (Green et al. 2006). For example, the maximum densities of reef food fishes seen in this survey were around 4000 food fishes per hectare. In the Solomon REA the maximum densities of food fishes per ha were 37,000 per ha (Western Province) and in 5 of the 7 provinces surveyed, it was not uncommon to see over 20,000 fish per ha on transects. It is noteworthy that most provinces in the Solomon Islands have much lower human population densities than Bougainville, and it was the two provinces with the highest human populations (Malaita and Guadalcanal) that had the lowest fish densities in the Solomon Islands.

Analysis of the data revealed the densities and biomass of a reef fishes were significantly higher in the Tinputz than in all other regions surveyed. At a family level, the Tinputz had significantly higher densities and biomass of both snappers and surgeonfishes than some of the other regions surveyed. The higher densities and biomass of reef fishes in the Tinputz correlates positively with the live hard coral cover, which was significantly higher in the Tinputz and Pororan region than in the Saposa or Buka town region (see Chapter 3). Although the higher densities and biomass of reef fishes in the Tinputz region is no doubt partially due in good coral reef health, it also possibly reflects lower levels of historical fishing pressure in the Tinputz region. Tinputz is the furthest distance from Buka town of all four regions surveyed. Factors such as geographical variability, recruitment variability can also not be ruled out.

Of particular concern in this survey was the very low abundance of parrotfish. The densities and biomass of the parrotfish species surveyed were so low that it was meaningless to do an analysis on this family. In this study parrotfishes made up only 0.7% of the total fish density and 5.8% of the biomass of all fish sighted. In comparison, in the Solomon Island REA parrotfish made up 5.14% of the total fish density and 14.25% of the total biomass (Green et al. 2006). Parrotfishes are extremely vulnerable to overexploitation by night divers, and in areas where night spearfishing is practiced their densities and biomass tends to drop rapidly once cash markets for parrotfishes develop (Gillett and Moy 2006; Hamilton 2003b). This is a concern given that parrotfishes are ecologically important elements of the coral reef fish fauna that have profound effects on the dynamics of reef growth and sedimentation (Bellwood, et al. 2003). Herbivorous coral reef fish such surgeonfishes, parrotfishes, rabittfishes and drummers all play a critical role in coral reef resilience in the Indo-pacific by limiting the establishment and growth of algal communities that impede coral recruitment (Green and Bellwood 2009). These families of herbivorous were in very low abundances in this survey, and may explain why some reefs have shifted from a coral dominated system to an algal dominated system following recent outbreaks of crown-of-thorns starfish (see Chapter 3).

The densities of large vulnerable reef fishes sighted on long swims were low at all sites surveyed, again indicating overfishing in many regions. The large Humphead wrasse was rarely seen in this survey and the Bumphead parrotfish was never sighted. These two species are considered key indicators of general reef fisheries health, and their low densities or complete absence from long swim surveys strongly point to overfishing, particularly by night spear fishers with flashlights. Night spearing commenced in the Buka region in the early 1980s, and initially resulted in very large catches of Bumphead parrotfish and other parrotfishes (Paul Lokani, personal observations). The densities of Humphead wrasse and Bumphead parrotfish in northern Bougainville were much lower than in other regions of the Western Solomon Islands and the Bismarck Sea that were surveyed in 2004 and 2006 using identical methods (Green et al. 2006; Hamilton et al. 2009). Other large vulnerable species such as the Humphead wrasse were also in low densities in this survey, and sharks were rarely recorded in food fish surveys. On coral reefs sharks are apex predators that play a key role in maintaining healthy reef ecosystems. The low numbers of reef sharks sighted in Bougainville are also indicative of overfishing by the shark fin trade. In general total fish densities and biomasses were low to moderate, indicating that this region has already been fairly heavily fished by subsistence and artisanal fisheries. The implication of this is that it is very unlikely that the current coral reef fish populations can support further commercial fisheries developments and management is clearly desirable.

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6.0. APPENDIX 1. FISH BIOMASS CONSTANTS FOR EACH FOOD FISH SPECIES

Family	Genus and species	Biomass constant a	Biomass constant b	Source
ACANTHURIDAE	Large ringtails	0.0210	2.9435	Mean value for Genus, Fishbase
	Naso brevirostris	0.0136	3.1280	Median value, Fishbase
	N. hexacanthus	0.0202	2.9558	Median value, Fishbase
	N. lituratus	0.0487	2.8390	Median value, Fishbase
	N. unicornis	0.0228	2.9220	Median value, Fishbase
BALISTIDAE	*Balistapus undulatus*	0.0058	3.5540	Median value, Fishbase
	Balistoides viridescens	0.0244	3.0180	Median value, Fishbase
	Pseudo. flavimarginatus	0.0244	3.0180	As for *B. viridescens*
CARANGIDAE	*Caranx ignoblis*	0.0296	2.9780	Median value, Fishbase
	C. melampygus	0.0211	2.9410	Median value, Fishbase
	C. papuensis	0.0249	2.9100	Median value, Fishbase
	C. sexfasiatus	0.0318	2.9300	Median value, Fishbase
KYPHOSIDAE	*Kyphosus sps.*	0.0218	3.0053	Mean value for Genus, Fishbase
HAEMULLIDAE	*Plectorhinchus albovittatus*	0.0270	2.8848	Median value, Fishbase
	P. chaetodontoides	0.0148	3.0830	Median value, Fishbase
	P. lineatus	0.0131	3.0663	Median value, Fishbase
	P. vittatus	0.0209	2.9474	Mean value for Genus, Fishbase
HOLOCENTRIDAE	*Sargocentron spiniferum*	0.0154	3.1188	Median value, Fishbase
LABRIDAE	*Cheilinus fasiatus*	0.0318	3.0000	Median value, Fishbase
	Cheilinus undulatus	0.0123	3.1123	Median value, Fishbase
LETHRINIDAE	*L. erythropterus*	0.0219	2.9471	Mean value for Genus, Fishbase
	L. olivaceous	0.0297	2.8187	Median value, Fishbase
	L. rubrioperculatus	0.0201	2.9694	Median value, Fishbase
	L. xanthochilus	0.0219	2.9395	Median value, Fishbase
	Small Lethrinus spp.	0.0219	2.9471	Mean value for Genus, Fishbase
	Monotaxis grandoculis	0.0239	3.0110	Median value, Fishbase
LUTJANIDAE	*Aprion virescens*	0.0162	2.9050	Median value, Fishbase
	L. argentimaculatus	0.0071	3.1800	Median value,

				Fishbase
	L. bohar	0.0156	3.0587	Median value, Fishbase
	L. gibbus	0.0131	3.1375	Median value, Fishbase
	Small and yellow lines	0.0111	3.1540	L.kasmira Median value,Fishbase
	Small yellow and spot	0.0184	2.9700	L. mono Median value, Fishbase
	Macolor macularis	0.0211	3.0000	Mean value for Genus, Fishbase
	Macolor niger	0.0211	3.0000	Median value, Fishbase
	Symphorichthys spilurus	0.0189	2.9349	Mean value for Genus, Fishbase
MULLIDAE	*Mulloidichthys vanicolensis*	0.0099	3.0150	Median value, Fishbase
	Parupeneus bifasciatus/trifasciatus	0.0036	3.4510	Median value, Fishbase
	P. barberinus	0.0151	3.0780	Median value, Fishbase
	P. cyclostomus	0.0243	3.0000	Median value, Fishbase
OSTRADICIDAE	*Ostracion cubicus*	0.1010	2.5880	Median value, Fishbase
SCARIDAE	*Bolbometapon muricatum*	0.0098	3.1329	Hamilton (2004)
	Chlorurus microrhinos	0.0179	3.0448	Median value, Fishbase
	Hipposcarus longiceps	0.0198	3.0000	Mean value for Genus, Fishbase
SIGANIDAE	*S. fuscescens*	0.0137	3.0682	Median value, Fishbase
	S. lineatus	0.0219	2.9983	Median value, Fishbase
	S. puellus	0.0246	3.0000	Median value, Fishbase
	S. vermiculatus	0.0168	3.0326	Median value, Fishbase
SPYYRAENIDAE	*Sphyraena spp.*	0.0267	2.9200	Medain value, Fishbase, S. barracuda
SERRANIDAE	*Cephalopholis argus*	0.0093	3.1807	Median value, Fishbase
	C. cyanostigma	0.0164	3.0303	Mean value for Genus, Fishbase
	C. miniata			
	Cromileptes altivelis	0.0962	2.4893	Median value, Fishbase
	Epinephelus fuscoguttatus	0.0134	3.0572	Median value, Fishbase
	E. lanceolatus	0.0173	3.0000	Median value, Fishbase
	E. merra	0.0096	3.1960	Median value, Fishbase
	E. polyphekaidon	0.0124	3.0570	Median value, Fishbase
	Plectropomus areolatus	0.0079	3.1570	As for *P. leopardus*
	P. laevis	0.0059	3.2377	Median value, Fishbase
	P. leopardus	0.0079	3.1570	Median value, Fishbase
	P. oligocanthus	0.0132	3.0000	Median value, Fishbase
	Variola albimarginata	0.0139	3.0424	Mean value for Genus,

				Fishbase
	V. louti	0.0122	3.0791	Median value, Fishbase
SHARKS	*Carcharhinus amblyrhynchos*	0.0023	3.3727	Median value - fish base
	Triaenodon obesus	0.0014	3.3820	Median value - fish base
	Carcharhinus melanopterus	0.0033	3.6490	Median value, Fishbase
RAYS	*Aetobatus narinari*	0.0059	3.1300	Median value - fish base

Chapter 3. Benthic Survey

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1.0. INTRODUCTION

The Autonomous Region of Bougainville is situated between Solomon Islands to its southeast and Papua New Guinea to its northwest. It is located in the Solomon Sea in a region that forms the eastern portion of the global centre of marine diversity, known as the Coral Triangle (Figure 1). The Coral Triangle includes all or part of the Philippines, Indonesia, Malaysia, Timor Leste, Papua New Guinea and Solomon Islands. The Coral Triangle comprises 76% of the world's corals and 37% of the world's coral reef fish species in an area that covers less than 2% of the planet's oceans (Veron et al. 2009).

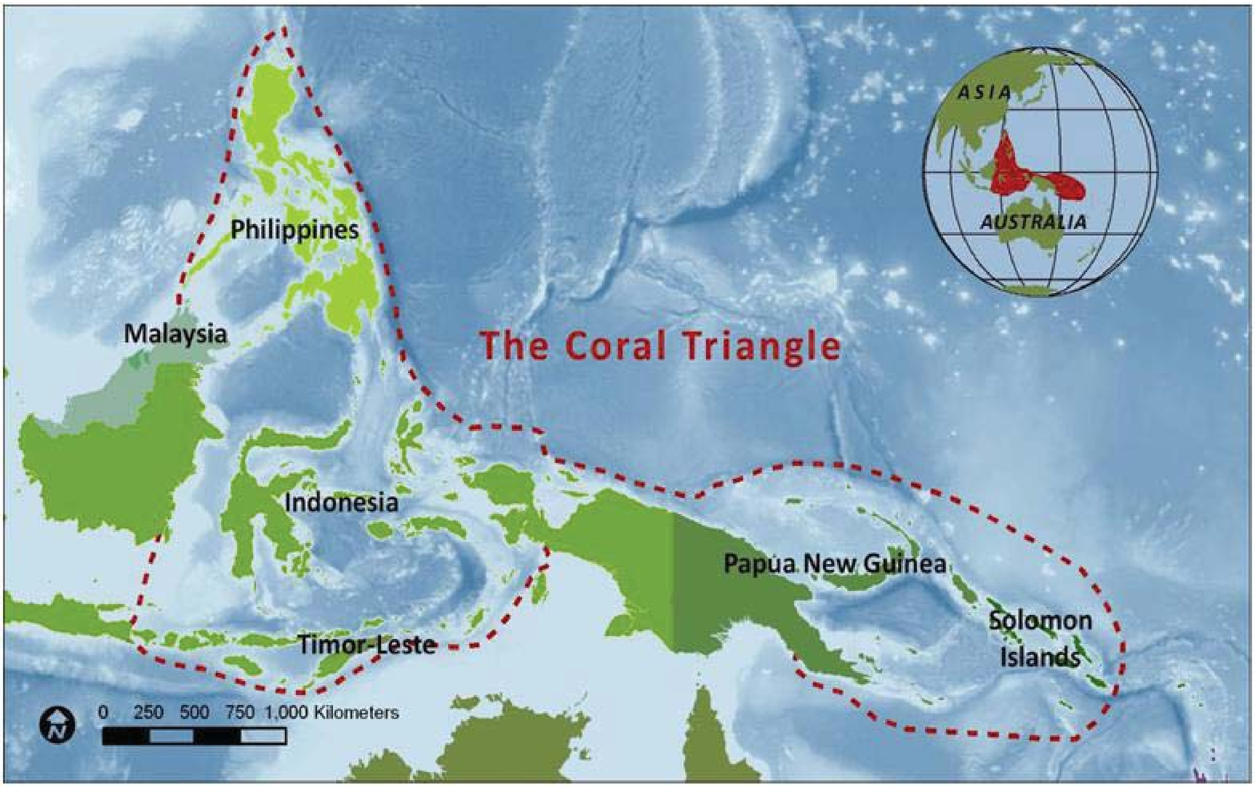

Figure 1. The Coral Triangle (Veron et al. 2009)

As well as the harbouring a remarkable diversity of life, Bougainville's coral reefs also support thousands of subsistence and artisanal fishers, whose livelihoods and prosperity is integrally linked to the ecosystem services that coral reefs provide. Coral reefs also provide a natural form of defence to extreme weather events such as storms or cyclones, by buffering their impacts on nearby coastal areas and communities. Clearly, ensuring the ongoing health of coral reefs is critical for maintaining food security, preserving biodiversity and in order for coastal communities to maximize their resilience to increasingly severe and frequently storms that will arise in the future as a consequence of climate change. The aim of this report is to provide baseline information on the general substrate composition and current conduction of the coral reefs in Northern Bougainville. This will assist in building a more complete picture of reef status and in providing recommendations for managers.

2.0. METHODS

2.1. STUDY SITES

Benthic cover was surveyed at the same sites that were surveyed for food fishes. In total 26 sites around northern Bougainville were surveyed for benthic cover. 8 sites were surveyed in the Pororan area, 7 sites were surveyed in the Saposa area, 5 sites were surveyed in the Tinputz area and 6 sites were surveyed around the Buka township area (Figure 2).

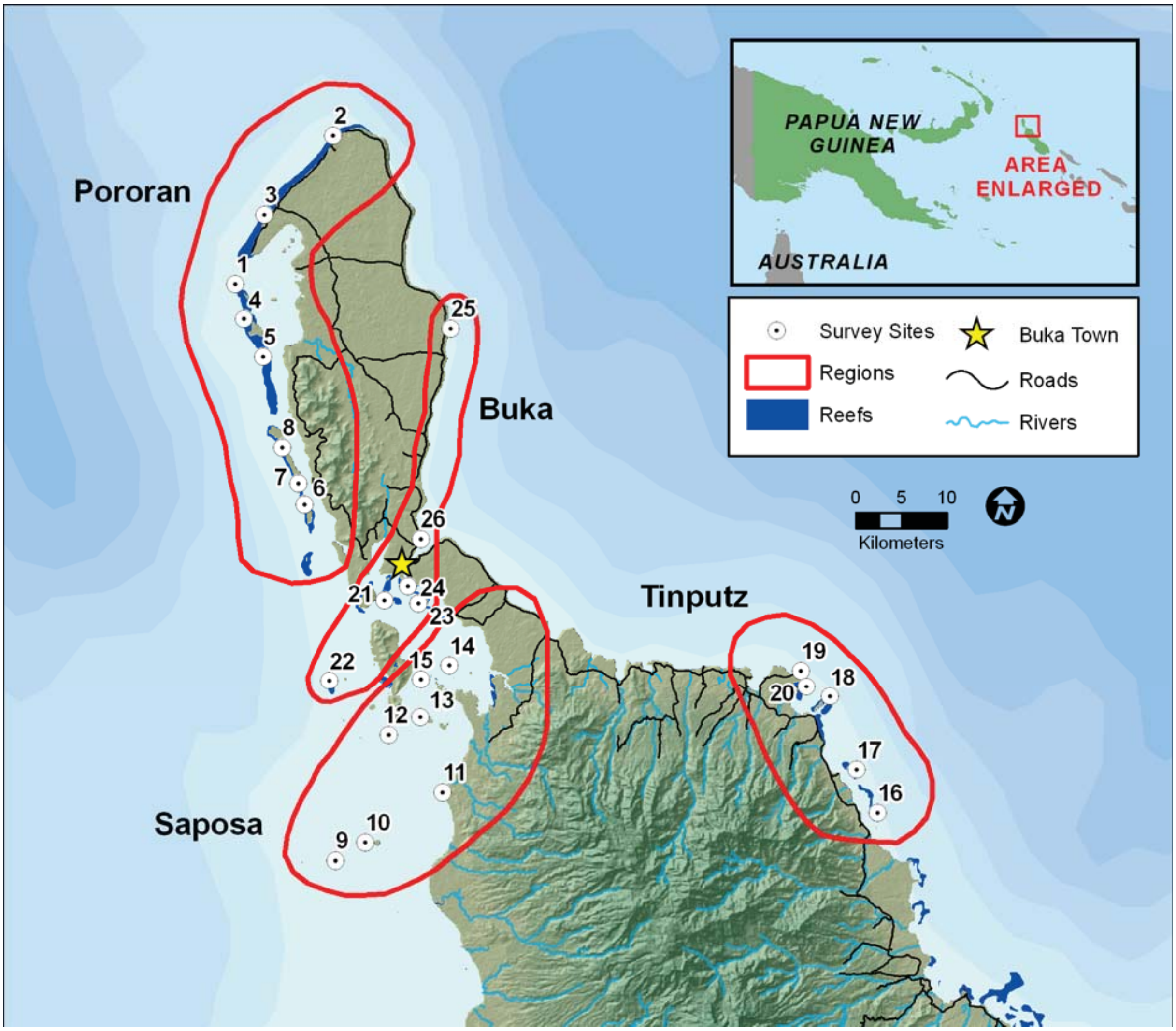

Figure 2. Locations of the 26 reef slope sites surveyed for reef fish and coral cover and the four regions they were surveyed in (circled in red).

2.2. SURVEY METHODS

Benthic data were collected using a modified version of the Point Intercept Method (Hill and Wilkinson 2004; Hughes, 2006). Benthic data were collected from three points every 2 m along a 50 m transect tape. Two points were located 1 metre on either side of the transect line and the third was below the transect. A total of five 50 m transects were laid at a depth profile of 8-10 m at each site. This resulted in a total collection of 75 data points for each transect, and a total of 375 data points for each site. Benthic composition was recorded based on lifeforms consistent with the categories provided by (English, et al.

1997). For ease of presentation, these were further grouped into four major categories: Corals, Macroalgae, Non-living and Others (Table 1). One of the observers who conducted long swims along the 8-10 m reef slopes to record abundances of large vulnerable fishes (see Chapter 2) also made counts of the number of crown-of-thorns starfish (*Acanthaster planci*), since densities of crown-of-thorns starfish are considered to be a key indicator of coral reef health. Counts of crown-of-thorns starfish were converted to densities estimates per ha for each site.

Table 1. Lifeform categories and Major categories

Code	**Lifeform**	**Major category**
ACB	*Acropora* Branching	Coral
ACE	*Acropora* Encrusting	Coral
ACD	*Acropora* Digitate	Coral
ACT	*Acropora* Tabular	Coral
ACS	*Acropora* Submassive	Coral
CB	Coral Branching	Coral
CE	Coral Encrusting	Coral
CF	Coral Foliose	Coral
CM	Coral Massive	Coral
CS	Coral Submassive	Coral
CMR	Mushroom Coral	Coral
CHL	Blue Coral	Coral
CME	Fire Coral	Coral
CTU	Organ Pipe Coral	Coral
DCA	Dead Coral with Algae	Macroalgae
AA	Algae Assemblage	Macroalgae
CA	Coralline Algae	Macroalgae
HA	*Halimeda* Algae	Macroalgae
MA	Macroalgae	Macroalgae
TA	Turf Algae	Macroalgae
S	Sand	Non-living
R	Rubble	Non-living
Si	Silt	Non-living
DC 1	Dead Coral	Non-living
RCK	Rock	Non-living
SC	Soft Coral	Others
SP	Sponge	Others
ZO	Zoanthid	Others
OT	Others (Ascidians, anemones, gorgonians etc)	Others

2.2.1. Data analysis

Data was grouped at the major lifeform category for the purpose of graphing and analysis. One way ANOVAs (SigmaStat) were carried out to investigate if the mean Coral, Macroalgae, Non-living and Other major lifeforms were significantly different between the four regions surveyed.

3.0. RESULTS

The mean percentage of each major lifeform sighted at 26 sites in the benthic survey is shown in Table 2. Macroalage made up the highest percentage cover, followed by Coral, Non-living and Other lifeforms.

Table 2. Relative percentage of each major lifeform.

Major Lifeform	Percentage cover
Macroalage	40.6 %
Coral	37.8 %
Non-living	18.5 %
Other	3.3 %

In this survey considerable variability existed in the health and condition of coral reefs surveyed. To investigate differences further we plotted each major life form by region.

3.1. CORAL COVER

The mean percentage of Coral cover at each site is shown in Figure 3. Coral cover was highly variable between sites, ranging from 1.9% (Site 24, Buka town) to 83.7% (Site 16, Tinputs). A One-way Analysis of Variance shows that the mean percentage of Coral cover was significantly different between the four regions surveyed ($P<0.001$), with a Holm-Sidak Multiple Pairwise Comparison test revealing that Tinputs and Pororan had significantly higher live coral cover than Saposa and Buka Town ($P<0.001$).

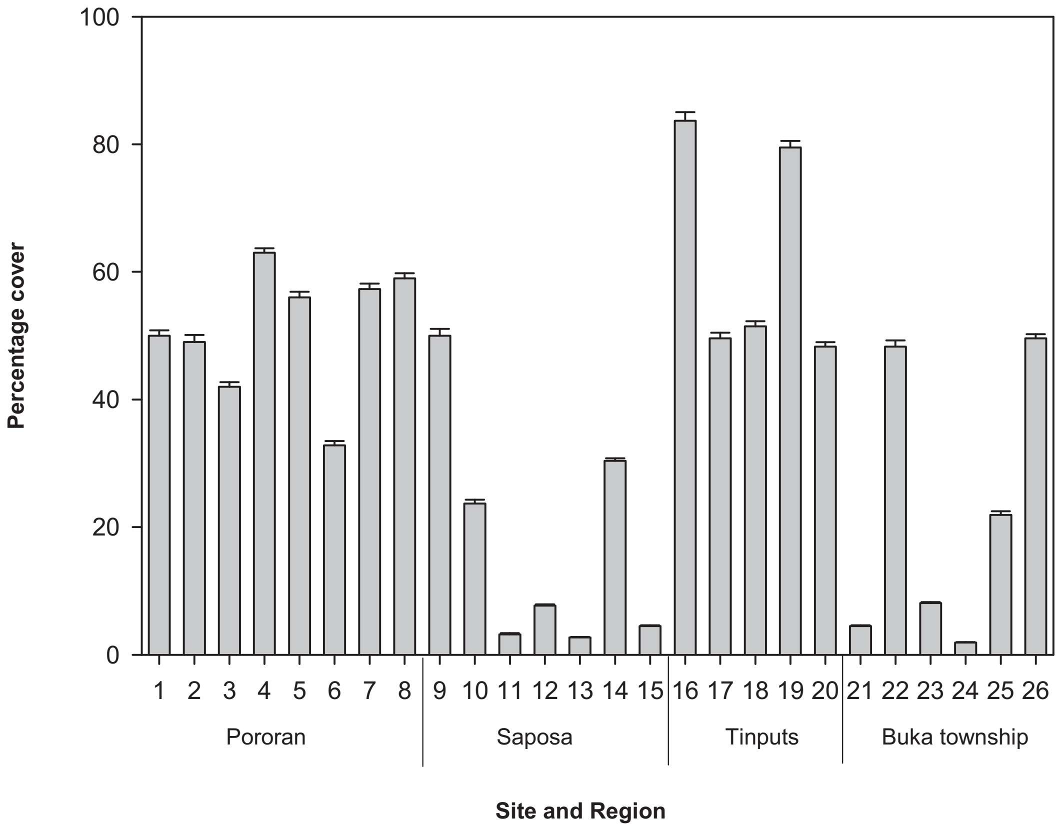

Figure 3. The mean percentage of Coral cover (+ 1SE) at each site.

Coral reefs were in extremely poor condition and life hard coral cover was very low in the majority of reefs that are located southwest of Buka town and are in close proximity to Bougainville Island (Sites 11,12, 13, 15, 21, 23 and 24). At these sites extensive areas of complex reef systems were dead and covered in algae, from what appear to be a combination of crown-of-thorns starfish outbreaks, disease and bleaching events (Figure 4-7). This contrasted markedly with sites in Pororan and Tinputs and some outer reef sites in the Saposa region which had healthy coral reefs and high live coral cover (Figure 8).

Figure 4. Dead branching coral covered with macroalage in the Saposa region.

Figure 5. Dead coral reef complex in the Buka town region.

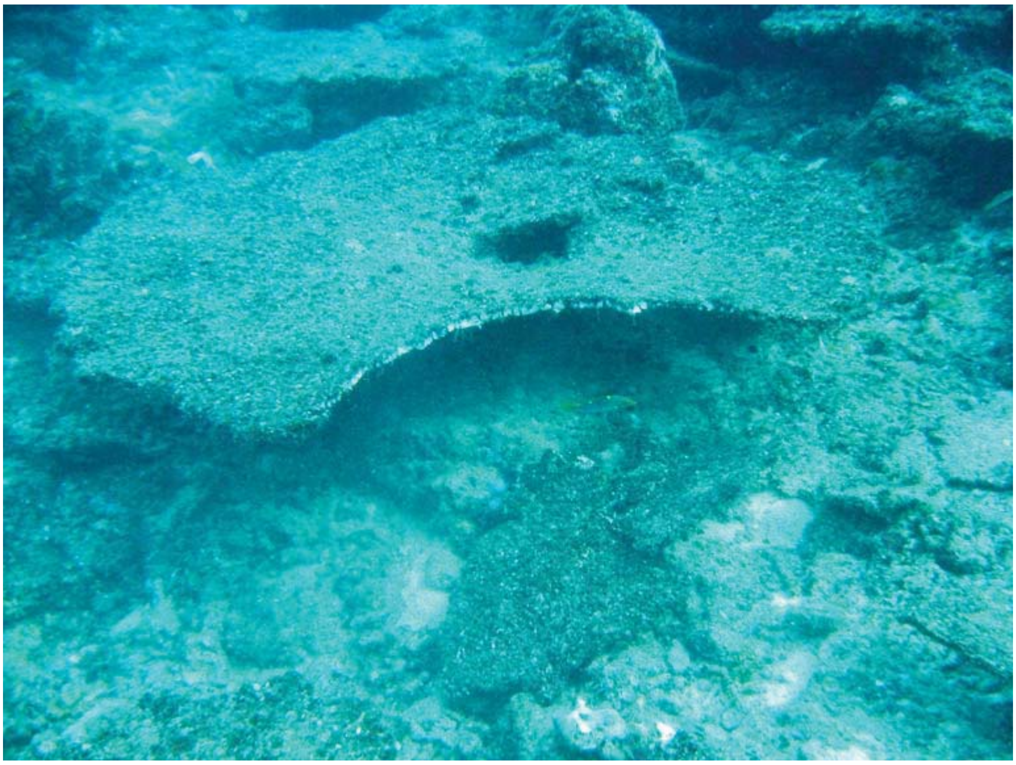

Figure 6. Dead tabular corals were brittle and broke when a diver placed a hand on the coral and applied slight pressure.

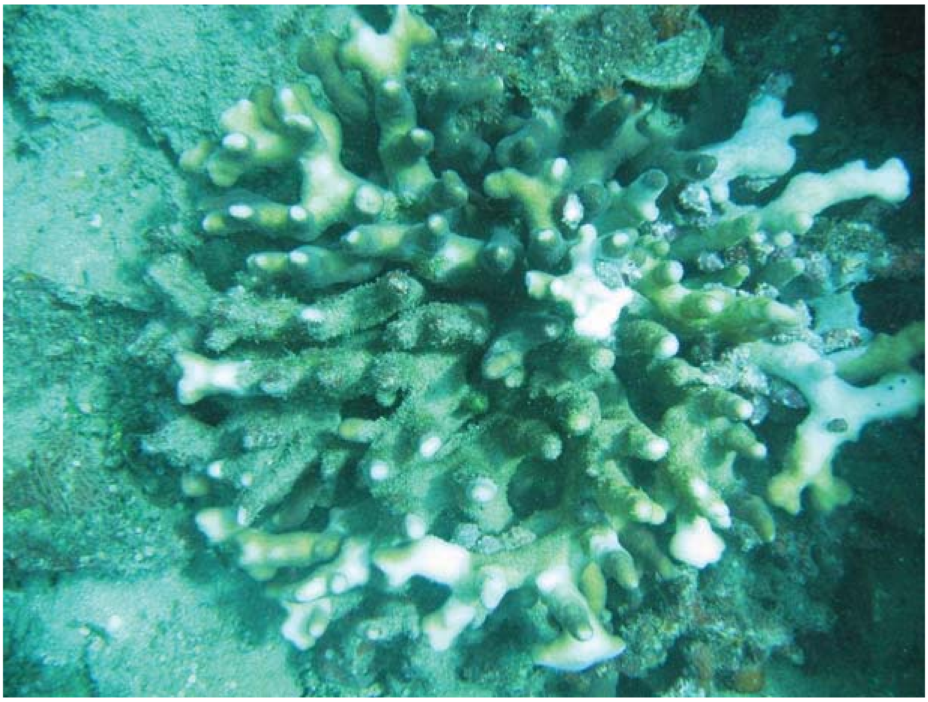

Figure 7. Dead, diseased and/or partially bleached coral.

Figure 8. Healthy reef fringing outer islands in the Saposa region

3.2. MACROALGAE

The mean percentage of algal cover at each site is shown in Figure 9. Macroalgae cover was high in the majority of sites surveyed, ranging from 8.3% (Site 10, Saposa) to 70.7% (Site 21, Buka Town). Highest Macroalgae cover was seen at sites within the Saposa and Buka town region (e.g. Sites 11 , 15, 21, 23), with dead coral covered in algae being dominant. A One-way Analysis of Variance shows that the mean percentage of Macroalgae cover was not significantly different between the four regions surveyed (P=0.250).

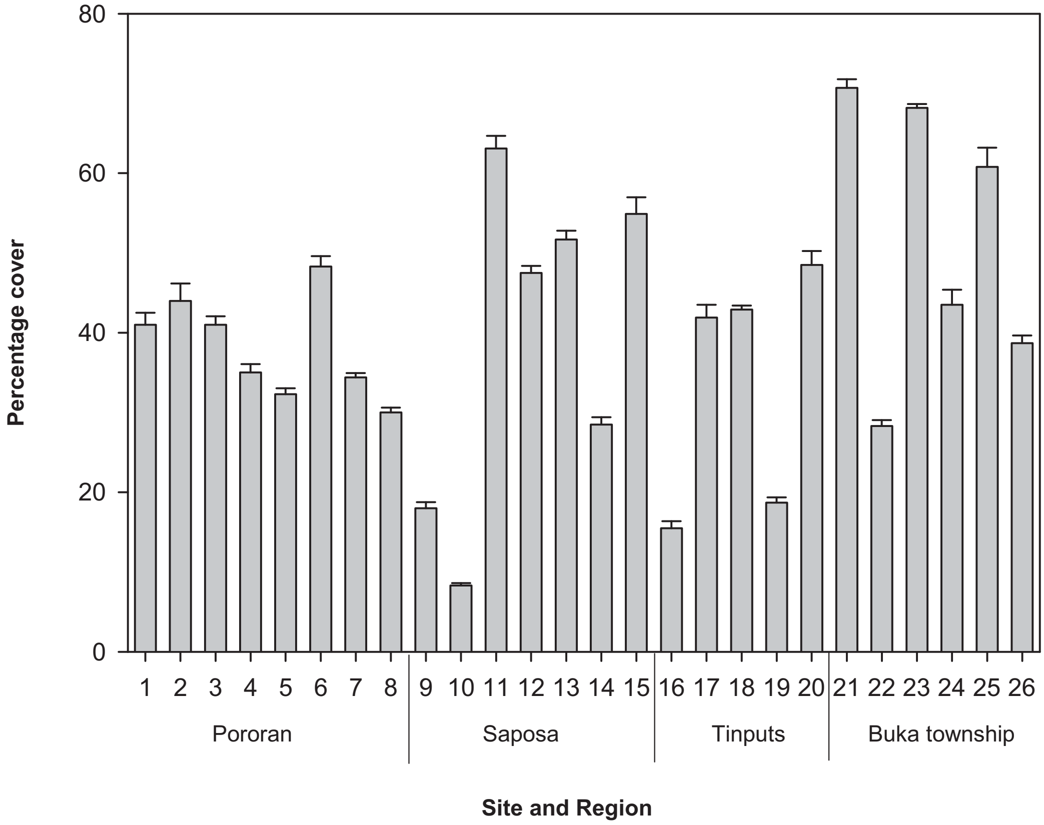

Figure 9. The mean percentage of Macroalgae cover (+ 1SE) at each site

3.3. NON-LIVING

The mean percentage of Non-living cover at each site in each year is shown in Figure 10. Non-living cover ranged from 0.5% (Site 20) to 67.7% (Site 10). A One-way Analysis of Variance shows that the mean percentage of Non-living cover was significantly different between the four regions surveyed (P<0.001). A Dunn's Multiple Pairwise Comparison test revealing that the Saposa region had had significantly higher non-living coral cover than Pororan and Tinputs (P<0.05).

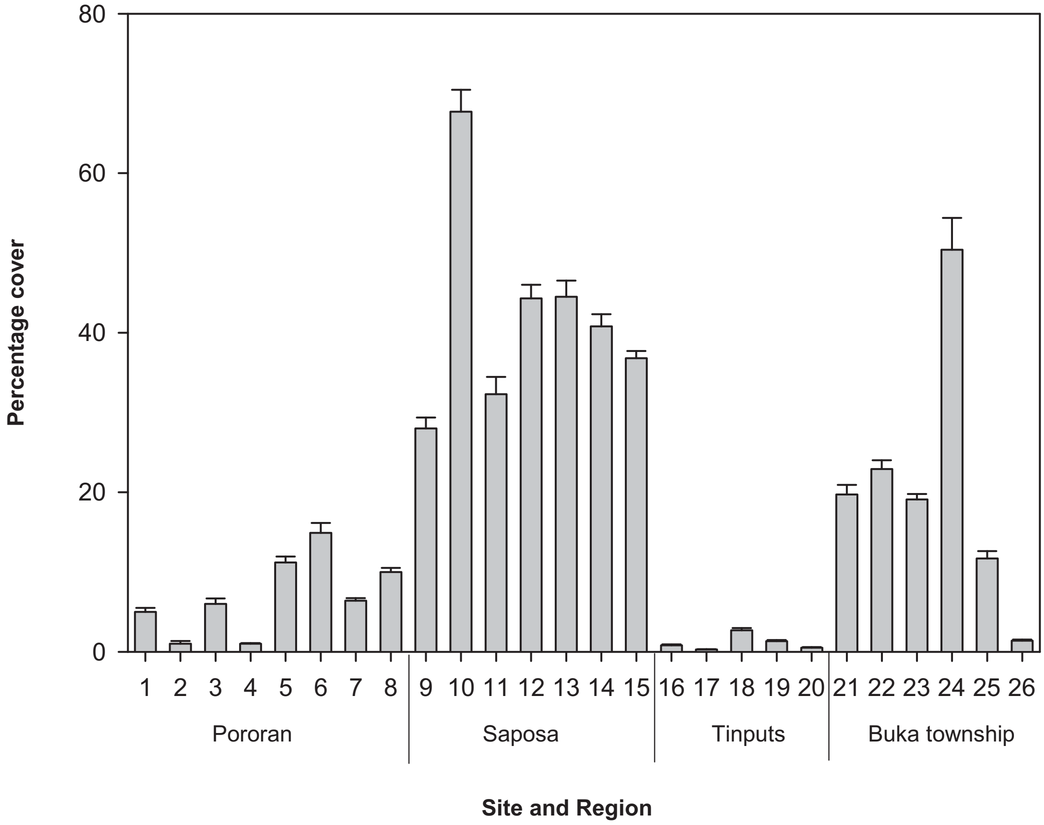

Figure 10. The mean percentage of Non-living cover (+ 1SE) at each site

3.4. OTHER

The mean percentage of Other cover at each site is shown in Figure 11. Other cover ranged from 0% (Site 16) to 11% (Site 3). A One-way Analysis of Variance shows that the mean percentage of Other cover was not significantly different between the four regions surveyed (P=0.159).

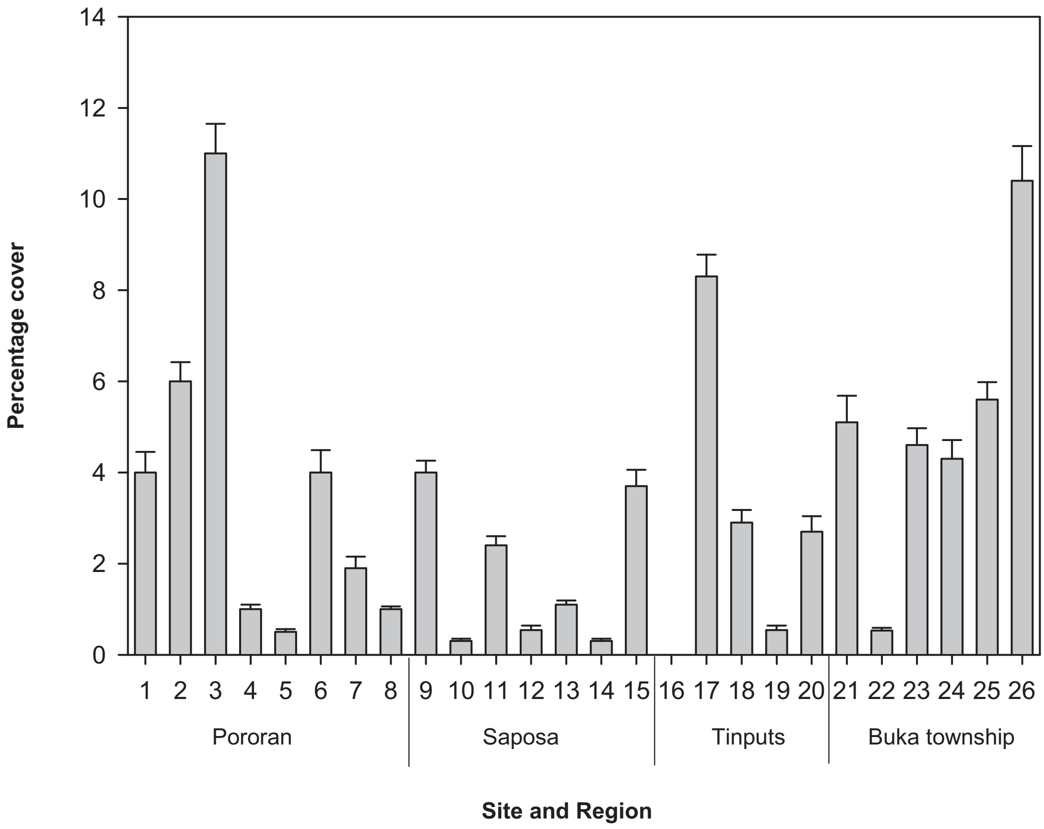

Figure 11. The mean percentage of Other cover (+ 1SE) at each site

3.5. CROWN-OF-THORNS STARFISH

At the time of this survey all four regions surveyed in Northern Buka had chronic problems with crown-of-thorns starfish (Figure 12). 35% of the reefs surveyed had adult crown-of-thorns starfish densities that were high enough (>6 per hectare) to be considered as developing outbreaks of crown-of-thorns starfish, while one site in Buka town (Site 22) was experiencing an active outbreak of crown-of-thorns starfish (Figure 13). At Site 5 in Pororan the reef had extensive recent damage from crown-of-thorns starfish, with the majority of tabular corals bleached white.

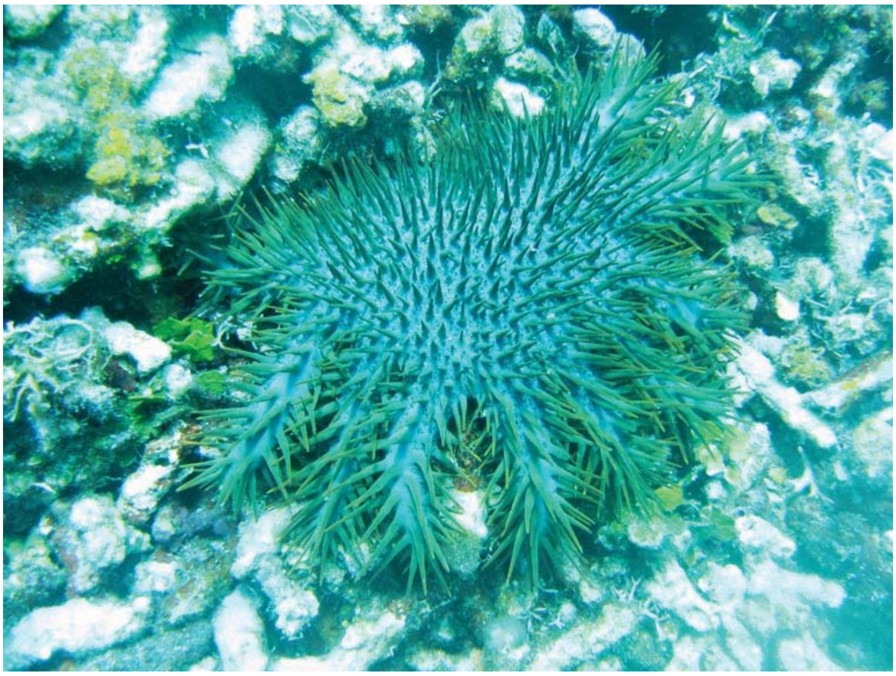

Figure 12. A crown-of-thorns starfish on extensity damaged reef in the Saposa region

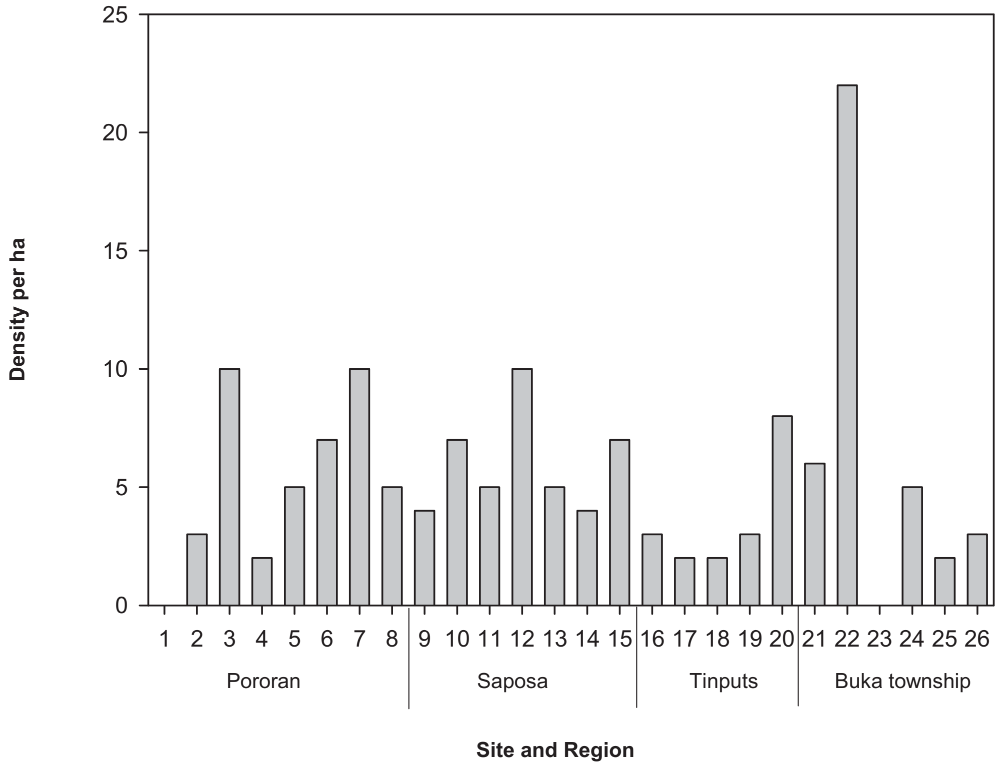

Figure 13. Number of crown-of-thorns starfish per hectare on exposed outer reef slopes in Bougainville.

4.0. DISCUSSION

The general reef condition and extent of live hard coral cover varied considerably between the sites and regions surveyed. In the Tinputs several sites had very healthy reefs that had coral cover approaching or exceeding 80%. This is a remarkably high live coral cover, and indeed, exceeds the maximum live coral cover seen at 66 sites surveyed throughout the Solomon Islands in 2004 (Hughes 2006). Starkly contrasting this was many sites in the Saposa and Buka town region which had devastated reefs with less than 5% live coral cover. Unfortunately in these regions extensive areas of complex coral reef have shifted from a coral dominated system to an algal dominated system. Sohano reef (Site 11) in the Saposa region is an example of this. Clearly this complex reef once had a high percentage of live coral cover, but at the time of this survey this reef was almost completely dead and covered in algae, with crown-of-thorns starfish outbreaks, disease and possibly also coral bleaching the likely causes of this devastation.

A coral reef expert, who examined photos of corals from the Saposa region that had partially survived, estimated that new growth rates relative to dead patches indicate that this extensive coral mortality occurred approximately two years prior to this 2008 survey (Lyndon DeVantier, Pers. comm., November 2008). At the Sohano reef and many like it in the Saposa and Buka town region the dead reef structure was still intact; however it was fragile and is likely to erode into rubble in the next decade if there is not a significant level of new coral recruits to this reef. At the time of this survey there was very limited evidence of any new coral recruitment at many of the sites that had experienced mass mortality.

In approximately a third of sites surveyed the numbers of crown-of-thorns starfish seen were high enough to indicate developing outbreaks, and at one site in the Buka town region an active outbreak was occurring. Large outbreaks of crown-of-thorns starfish have also occurred in New Ireland Province in the past five years (Hamilton et al. 2009). It is plausible that the onset of crown-of-thorns starfish outbreaks was linked to anthropogenic factors that had already reduced the health of surveyed reefs. Two of the theories to explain crown-of-thorns starfish outbreaks are; 1) overfishing of crown-of-thorns starfish natural predators, and 2) Human development of the coastal zone results in increased nutrients flowing to the sea, which results in an increase in planktonic food for larvae of crown-of-thorns starfish and greater adult survival rates. In this survey the most extensively damaged reefs were southwest of Buka town and in close proximity to Bougainville Island, where one may expect to see the most severe impacts of both land based run off and overfishing.

Similarly, it is likely that historical overfishing prior to crown-of-thorns starfish outbreaks or bleaching events had already reduced the resilience of many of the coral reefs surveyed, and hence inhibited their ability to recover. Herbivorous coral reef fish such surgeonfishes, parrotfishes, rabittfishes and drummers all play a critical role in coral reef resilience in the Indo-pacific by limiting the establishment and growth of algal communities that impede coral recruitment (Green and Bellwood, 2009). These families of herbivorous were in very low abundances in this survey, and yet regions which had healthy coral reefs such as the Tinputs had significantly greater abundances of herbivorous fish (surgeonfishes) than the reefs in Buka town which were generally in very poor condition (See Chapter 2).

At several sites surveyed rubble and dead coral fragments provided evidence of previous incidences of blast fishing, and non-biodegradable rubbish such as bottles and plastic were seen around Sohano, Madias and Hahila reefs which were in close proximity to Buka town. In Buka, Kokopau and Sohano areas coral is frequently used for building, suggesting that the demand for the removal of corals in these regions is high.

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AUTONOMOUS BOUGAINVILLE GOVERNMENT

NATIONAL FISHERIES AUTHORITY