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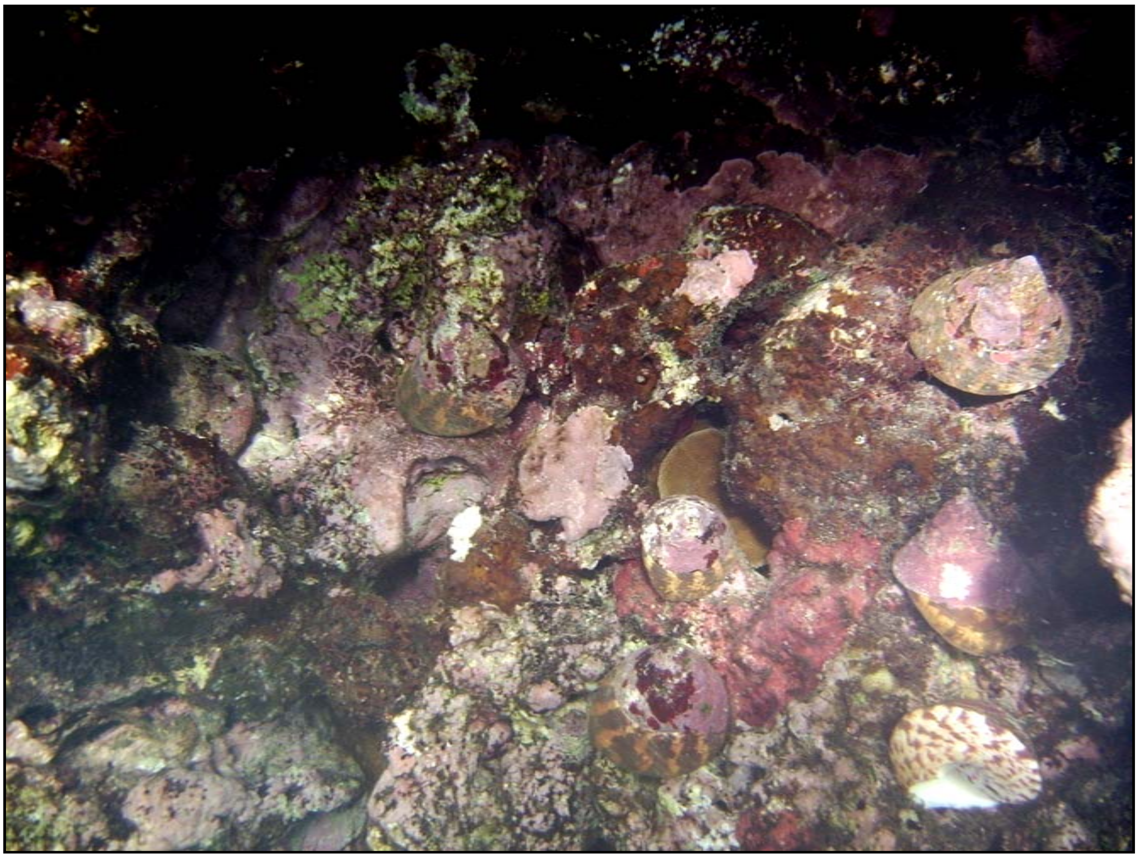
Kalo Pakoa[1], Kim Friedman[1], Emmanuel Tardy[1], Ferral Lasi[1]
December 2008



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Executive summary

Trochus and sea cucumber have been important fisheries for the people of Epi Island for many years, but the resources have never been assessed in the past and resource information needed for management is not available. Traditional management is an important regime for managing trochus and sea cucumber on Epi and in other parts of Vanuatu. However, increasing fishing pressures, population and economic demand are a challenge to the effective implementation of community based management systems. The purpose of this assessment survey was to collect baseline resource information to describe the status of the resource and provide recommendations for management.

The trochus and sea cucumber resource surveys at the five Epi sites of Lamen Bay, Mapuna Bay, Bonkovio-Brisbane, Burumba and Mavelao-Valesdir were conducted from 30 March to 21 April 2008 by staff members of the Secretariat of the Pacific Community (SPC), The Pacific Regional Oceanic and Coastal Fisheries (PROCFish) project team and the Vanuatu Fisheries Department (VFD). A total of 68 stations of shallow reef transects, scuba dive transects and timed swims were completed at the five sites covering over 35,000 m² of reef area. The reef systems on Epi are not extensive and lack the full range of conditions that are needed to support a large diversity of invertebrate resources. The reef slope generally lacks suitable habitat for invertebrates. A total of 40 invertebrate species were recorded on Epi, dominated by smaller gastropods (24 species), 9 species of sea cucumber, 2 of bivalve, 1 crustacean, 1 octopus, and 3 species each of starfish and urchins.

Trochus was commonly distributed on the reef at all the sites assessed on Epi. More aggregations were present in shallow waters on the reef platform that can be accessed by reef walk and shallow snorkeling. Trochus densities vary at the sites from low at Mapuna Bay to high in Burumba, but overall density was below the minimum sustainable level of 500 per ha. However, active recruitment indicates that the fishery has the potential to recover to this level if stronger management is practiced. A small proportion of large trochus were above the new upper size limit of 13 cm, indicating that the new upper size limit may not be effective in protecting larger breeding stocks.

A total of nine species of sea cucumbers were recorded on Epi; surf redfish, black teatfish, greenfish and tiger or leopardfish were the main commercial species and greenfish was the most abundant species. Two species of giant clams were present on Epi: *Tridacna maxima* and *T. crocea*—*T. maxima* being the most important species present but at relatively low density across all sites. The reefs on the east side of Epi were very impacted by an active crown-of-thorns starfish outbreak. Low live coral cover and a correspondingly high proportion of dead substratum were recorded. In addition, reefs near river mouths were impacted by siltation.

The chiefs and village elders of the five communities that represent 80% of the island's trochus fishing grounds were concerned about the declining state of their trochus fisheries. They claimed their traditional 'taboo' management system has been weakened by continuous buying of shells on the island. The chiefs do not have the power anymore to control their people's fishing and do not have any power to control the shell buyers. They wanted the government, through VFD, to take necessary step to control the fishery and the industry to ensure total compliance. They specifically want VFD to ban trochus fishing for Epi Island or for the whole country to stop all harvesting and selling of trochus.

1. Introduction

1.1 General overview

The island of Epi, with a total land area of 444 km², is the second largest island in Vanuatu's central province of Shefa. Epi is volcanic in origin, a remnant of a larger island known as Kuwae. Around the year 1400, eruptions of Kuwae volcano destroyed much of the southern part of the island, leaving behind the islands of Tongoa, Tongariki, Buninga, Ewose and Valea—the remaining pieces of the southern part of Kuwae (Hoffmann 2006). Coral reef development is concentrated on the northern and western parts of the island, which were not affected by this volcanic action. The people of Epi suffered a great deal during the early contact period with Europeans. The population fell from 7000 people to 1000 in only 70 years. This decline was caused mainly by diseases but also mistreatment by traders and black birding (O'byrne and Harcombe 1999). The population of South Epi was only 300 people in the early 1980s, but has increased with immigration from the nearby Shepherds Islands and Paama. The present population of Epi stands at 4554 people, of which Moriu (Mapuna Bay) accounts for 2.9 per cent (130), Lamen Bay 5.6 per cent (256), Bonkovio-Brisbane 4.7 per cent (213), Burumba 3.9 per cent (179) and Mavelao-Valesdir for 3.5 per cent (159) (National Statistics Office 2000).

During the days of the condominium administration of the New Hebrides, large French-owned coconut plantations were developed on the island's fertile west coast from Lamen Bay all the way to Votlo. Copra and beef were the island's main products. These plantations were abundant when all land was repossessed by the native owners after independence. Valesdir is the only remaining large plantation actively producing copra and beef. The island's principal economic today is agriculture in the form of subsistence farming of cash and root crops and fishing. Crops such as root crops, kava, peanuts and domesticated livestock are exported to Port Vila markets.

As in other parts of the country, harvesting of trochus shell (troka) and bêche-de-mer were the first commercial fisheries activities known to Epians. Deep-bottom fishing for snapper was developed in the 1980s, but these activities ceased at the end of the project funding. Much of the fishing now is for subsistence use for food security. Tourism is a growing activity on Epi, especially in Lamen Bay, which has created some local demand for garden crops and fish. Trochus fishing is still an active income-producing activity at open seasons, although recent catches are much smaller than they used to be. The island's gross domestic product (GDP) is $457.00 per capita.

1.2 Trochus fisheries in Vanuatu

1.2.1 Biology and ecology

The average life span for trochus is 15–20 years, but most animals reach reproductive maturity by 2 years of age in the wild and 12 months in captivity. Trochus first become sexually mature at 5.0–6.5 cm in basal diameter. Trochus is a dioecious (separate male and female) broadcast spawner and fertilization takes place in the water column. Spawning is initiated by the males, and females spawn in response to the presence of sperm in the water. Females generally spawn for 5–10 minutes, with individuals releasing more than one million eggs (Nash 1985).

Spawning often occurs in synchrony with lunar or tidal conditions, generally occurring at night and within one or two nights of either a full or new moon. Spawning occurs throughout the year in low latitudes and only during the warmer months in high latitudes (Nash 1985). In the central Great Barrier Reef region, spawning occurs throughout the year. Subsequent to fertilization, the eggs hatch into trochophore larvae (planktonic phase) after approximately 12 hours. The larval phase lasts approximately 3 to 5 days, and the veliger then settle to the bottom and begin grazing on fine filamentous algae and microorganisms. Adult trochus are largely non-selective herbivores, grazing the epibenthos of a wide variety of biotic and abiotic materials, including algae, foraminifera, mollusks and crustaceans (Asano 1944). Small to medium sized trochus are cryptic (small and well camouflaged), while larger specimens are easily visible on the bottom.

1.2.2 Trochus fishery

Invertebrates, in particular trochus, green snail, giant clam, lobster and finfish, are an important part of the diet of the Melanesian people of Vanuatu. Collection of trochus and green snail for their protein-rich flesh is a traditional activity in Vanuatu. Commercial harvesting of trochus for its shell is likely to have begun in the 1900s during the rise in bêche-de-mer trading in the Asia-Pacific region. French settlers were reported to have harvested trochus shells in Vanuatu at the beginning of the 20th century (Bell and Amos 1994). Production figures for these early years are not available except for a total of 60 metric tonnes (mt) in 1921 (Dunbar 1981). Wading, snorkeling and shallow skin diving are still the main trochus fishing methods. Trochus is an important cash crop for remote areas, the sale of trochus shell was estimated at VUT25 million annually to the communities in the 1990s (Wright 2000) and an important fisheries export commodity worth VUT107 million of foreign exchange in 2000 (ADB 2002).

1.2.3 Production and marketing

Export figures are available only from 1969 to the present (see Figure 1 and Appendix 1). Production figures above 100 mt occur only twice: in the mid 1970s and the early 1990s. Otherwise, production for most years was below 100 mt. In the late 1980s to mid 1990s, 6 processing factories were established in Port Vila and Santo to utilize the local raw materials. Overcapacity due to limited resource resulted in the closing down of most of these factories that by 1999 only a processor was active in the country. The only operating factory, Hong Shell Product Ltd., imported raw trochus shells from Australia in 1999, which raised annual exports for that year to 498 mt. Raw shell importation from Australia was discontinued due to poor shell quality as compared to the local shells. Average annual exports over 16 years (1990–2006) reveal a major decline from 145 mt (1990–1994) to 45 mt (2002–2006). Furthermore, a decline in actual exports from 73 mt in 2001 to 36 mt in 2006 presents a continuous worsening trend as fishing is allowed to continue.

The marketing of trochus shell (buying and export) is currently protected for the local shell processing factories in the name of value adding. A review report of the shell industry in Vanuatu by Fisheries Department in 1990s highlighted the impact of this protection policy which unfortunately provided for a much lower economic return of raw shell. Fishermen have been precvented from receiving fair and competitive prices for their shell. Local shell price has been stagnant at US$1.80–$3.27 or (VUT200–370) per kg (Pakoa 2007). The price variation is based on distance from the origin of the product to Port Vila, taking into account freight and other costs. Field agents for instance can come around to buy products on the islands, or fishers freight produce to Port Vila themselve, where they would tend to get a fair price.

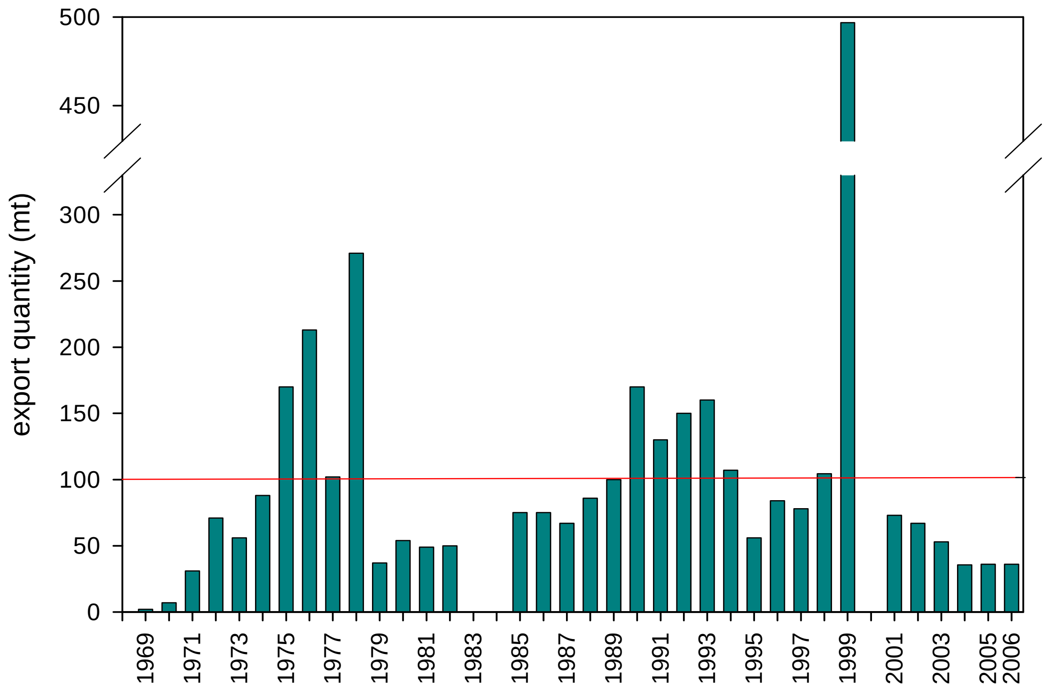

Figure 1: Historical trochus shell export production in Vanuatu

1.2.4 Management

The first moratorium ever implemented in the country was instituted by the Condominium of the New Hebrides from 1958 to 1962. Stock assessment surveys conducted in 1959 and 1961 in the areas of Aneityum, Cook Reef, Maskelynes and Tutuba Island indicated an increase in the number of shells in all the sites assessed (Devambez 1959, 1961). Fishing reopened in 1962 with a new annual export quota of 72 mt (whole dry shell weight). In 1983, a new policy was passed scrapping the 1962 quota system and replacing it with a ban on whole shell exports. The ban on whole shell exports was introduced by the new Vanuatu administration to promote value adding and create employment locally. Additional harvest regulations included a 9 cm size limit and an annual quota of 75 mt of raw shell to be processed per processing factory per year. The restriction on raw shell export created a burden on the responsible agency in monitoring and enforcing the policy. A new upper size limit of 130 mm was instituted in 2005 to protect larger breeders (the larger the shells, the more egg is produced) and prevent poor quality shells from being harvested.

The traditional management system of taboo is the principle mode of management practiced by communities based on the customary marine tenure system. The traditional resource management system was strengthened in the post-independence years through policies to empower local governments and communities. As a result, taboos were resurrected in many areas where the system had faded (Johannes 2004). Community based management became central in controlling time and length of open seasons, harvest quantities and enforcement of minimum harvest sizes. The VFD, on the other hand, directly controls the exporting of products through issuance of an exporting permit. In other words, communities have been relied upon to control harvests and to enforce existing harvest management measures. While many communities have established well managed marine areas to protect their resources, many are being faced with the increasing challenge of controlling fishing activities by community members in communally or individually own reefs against external market forces exerted mainly by shell buyers.

Many areas in the country have been depleted of their breeding stocks, and an increased number of resource owners have requested assistance from VFD to restock their reefs with trochus (Pakoa 2007). Some restocking activities have been carried out in the Shefa and Tafea provinces and recently on Malekula and Pentecost (Jimmy and Amos 2004), but lack of stocks has been a challenge to translocation activities. Reseeding with hatchery bred trochus has been promoted as a management tool, however this have largely remain experimental with little evidence for it's application as a management tool

Information on the status of this resource in most of the islands, other than at the sites assessed by PROCFish and this survey, is not available. Recent assessment reports (Marchandise 1991; Amos 1991) provided some information about the resource status but there are no follow-up surveys to provide recent information that can be used for management. Export figures remain the best available indicator for the status of the resource.

1.3 Trochus fishery on Epi Island

Trochus has been the main commercial fishery product on Epi for many years. A socio-economic survey conducted in the early 1980s found that 100% of fishers on Epi were engaged in trochus fishing (David 1985). The areas of Mavelao-Valesdir, Burumba, Bonkovio-Brisbane, and Lamen Bay on the west coast, and Mapuna Bay and Nikaura on the east coast are important trochus fishing areas. The relatively shallow reef platforms provide suitable habitat for trochus. Beyond the narrow reef edge, trochus habitat is limited, thus the animals are restricted to these shallow areas. Trochus fishing is known to be relatively well managed on Epi because of the traditional management system of taboo. This is attributed to the island's low population and subsistence lifestyle. Availability of other income sources such as copra and kava helps in alleviating pressure on trochus.

1.3.1 Trochus fishing and marketing

Fishing for trochus in each area is normally controlled by the village paramount chief. In some areas, clan-imposed taboos are also practiced, especially when the clan has moved away from the main village and settled on its own land. In this case, a clan can enforce its own taboo over its own reef area. Based on traditional knowledge each village decides the time and length of its own open season, which is usually very limited. Open seasons can happen once or twice a year and last from a few days to a few weeks. Fishing is conducted mostly by wading at low tide, shallow snorkeling and free diving at deeper reef areas beyond the reef edges. Trochus fishing during open season is open to all members of the community, including children, women, adults and elders. Dugout canoes are normally used for transporting shells ashore, but fishers can also walk ashore with their catch. Powered boats are used by those who own them.

Extraction of the meat is done the old fashion way after the shell has been boiled. The meat is normally consumed locally or shipped to relatives in Port Vila and other islands, while the shell is sold. Buyers are notified in advance of an open season so that an agent can be sent over to purchase the shells, or an arrangement is made for individual fishers to ship their catch to Port Vila. The VFD has not been part of or involved in the management or decision making of trochus open seasons since there are no centralized coordination system in place to oversee or control harvesting of trochus.

In the past, when there were several buyers in the country, buyers would compete to buy shells and prices would vary slightly between buyers. Buyers' agents normally came around to buy shells on the island and ship them to Port Vila; in this case, the shell price would be slightly lower to account for freight costs. On the other hand, the price offered per kilo would be slightly higher if fishers ship their produce themselves to the factory gate in Port Vila or Santo. Buyers and fishers have determined buying prices in different areas of the country.

Prior to 2005, all trochus above 9 cm were legally harvestable (only the minimum legal harvestable size existed) regardless of their quality. Epi Islanders knew very little about shell quality; all they knew was "the larger the shell, the heavier it is and the more value it has". In 2005, a maximum size of 13 cm was instituted to protect breeding stock, but dissemination of management information to the rural areas is a problem. In 1998, this lack of knowledge resulted in the harvesting of undersized trochus on Epi that were later confiscated by VFD (Vanuatu Fisheries Department 2004).

Fishing is done normally at the household level, and a share (normally a sac of shells) is often allocated to the community basket for community projects and expenses. The community share can also be determined by allocating a fishing day or by contribution of a number of shells per household. In other harvests, households retain all of their catch to help with major household expenses such as school fees. The catch can also be aggregated by a group of households or a clan for family projects such as buying a new boat or a new truck. This catch organization and distribution however, is becoming less important thus are being lost nowadays as catch diminishes due to resource depletion.

1.3.2 Trochus production from Epi

Information on trochus production by island was not collected in the past. But it is known that even up to the 1990s a village on Epi would easily collect around 10–20 mt of trochus shells per open season, equaling a total of around 60–120 mt of raw shells per open season for the whole island. Over time, Epi has contributed over 50% of the trochus supply from the Shefa Province. Recent data provided by Hong Shell Product Ltd, showed that from 2002 to 2007, Epi supplied an average of 8.5 mt of raw trochus shell per year, with the amount per year ranging from 0.2 to 18.9 mt (Table 1). Based on these data, each of the five communities produced an average of only two mt of trochus per year. Based on this seasonal estimates, the present annual production of 8 mt represents some 86% drop in production for the island of Epi.

Table 1: Trochus production from Epi Island

Year	Quantity kg
2002	2,883
2003	236
2004	18,972
2005	8,898
2006	5,012
2007	14,744
Average	***8,457***

1.3.3 Trochus management on Epi

Traditional management via the customary marine tenure system is central to the management of the trochus fishery on Epi. Traditional management systems on Epi are based on periodically-harvested reserves except in Nikaura (an area outside of the survey sites), where the only permanent reserve is located. The taboo system is implemented in the villages in two main ways: (a) by closing an area of the reef to fishing for all species, as is practiced in Nikaura, and (b) by closing fishing for trochus and sea cucumber while other fisheries remain open. The implementing institution for taboo is the traditional paramount chief of the village. Village councils have been created to back the work of traditional chiefs, but the chief makes the final decision. The power of taboo is weakening because clans can now impose their own taboo system in addition to the taboos imposed by the central village chief.

Instituting a village taboo requires agreement of all parties in the village who own different portions of the reef making up the community reef area. Once agreement is reached, the village paramount chief declares a taboo in a ceremony sealed by the ritual killing of a pig at the village *nakamal* or meeting house. The taboo system operates in a manner related to ‘pulse fishing’ (the fishery is closed indefinitely, with a short open season when the resource reaches a sustainable harvest level). In the past, two short open seasons could be called in a year; this, however, has been reduced to one every couple of years due to low trochus stocks.

Communities were advised by fisheries managers to close fishing areas for a minimum of three years before the next harvest, to allow for the buildup of sufficient harvestable stocks (trochus take 2.5 years to become sexually mature). At three years of age and 9.0 cm, trochus would have spawned and contributed to recruitment before being harvested. Communities however are normally left to make the final choice on these advices and in Epi not all communities implement their “taboo” based on this advice. The length of open season varies also between villages from a few days to weeks, once again determined by the communities themselves. Decisions to open the fishery and for how long are made without any advice from VFD on fishable stocks and allowable catches.

Once a taboo is activated, village members are responsible for policing their reef to maintain a no-take policy for all members of the community and outsiders. Anyone who contravenes this taboo is brought to village justice system and subject to a custom fine in the form of a live pig accompanied with food crops, mats and some money; confiscation of the catch; and seizure of gear.

1.4 Sea cucumber fishery

1.4.1 Sea cucumber fishery in Vanuatu

Sea cucumbers are not consumed locally in Vanuatu. Commercial trade began sometime in the earlier 19^{th} century during the rise in bêche-de-mer trading in the Asia-Pacific region. At the beginning of the 20th century, bêche-de-mer was one of the principal exports of Vanuatu. Fishing and processing of sea cucumber was abundant in the middle of the 20^{th} century. A brief revival was reported in 1973, but trade stopped again until the 1980s. Production was terminated in 1988 because of quality problems due to lack of processing skills by local fishers. Fishing resumed again in 1993 after several training sessions on processing were conducted for local fishers by SPC (Dalzell 1990).

1.4.2 Biology and ecology

Of the 1200 species of Holothuroidea that have been described, 18 species are commercially important in Vanuatu; *Actinopyga mauritiana, A. echinites, A. miliaris, Bohadschia argus, B. similis, B. vitiensis, Holothuria scabra, H. whitmaei, H. fuscogilva, H. atra, Stichopus chloronotus, S. herrmanni* and *Thelenota ananas*. Sea cucumbers are filter feeders, ingesting sand and detritus matter to digest bacteria and fungi on the sediment. They recycle nutrients in organic matter on the reef floor, making nutrients available to other organism and ensuring a healthy system. They breed by vegetative regeneration and spawning. Sexual maturity is reached at 3–4 years of age. Breeding occurs most often in summer months when sea water is warm. Fertilized eggs spend around 35–55 days as plankton before settling to the bottom to start a permanent sedentary life.

1.4.3 Fishing, production and marketing

Sea cucumber fishing and processing is conducted by local fishers, who then sell to local exporters who are mainly Asian nationals in joint venture arrangement with local interests. In the past, companies have participated in collection and processing by sponsoring fishing and supplying equipment, with an arrangement to buy dried bêche-de-mer in return. Pricing per species is always included in the equation in this kind of arrangement. Different prices are offered for different species (low, medium, high) and for different qualities. Products are classified in three grades—A, B and C—with A grade being the highest quality. The grade is dependent on both the processing technique and the size of the specimens depending on species. Some traders purchase raw and partly processed products for reprocessing to a higher quality product.

Export of bêche-de-mer picked up again in 1991, and from 1993 to 1997 annual production rose to an average of 45 mt, but rarely exceeded 50 mt. From this peak production period, exports have fallen continuously to an average of 11 mt in recent years. This continuous declining trend prompted the government to close down the fishery in 2008.

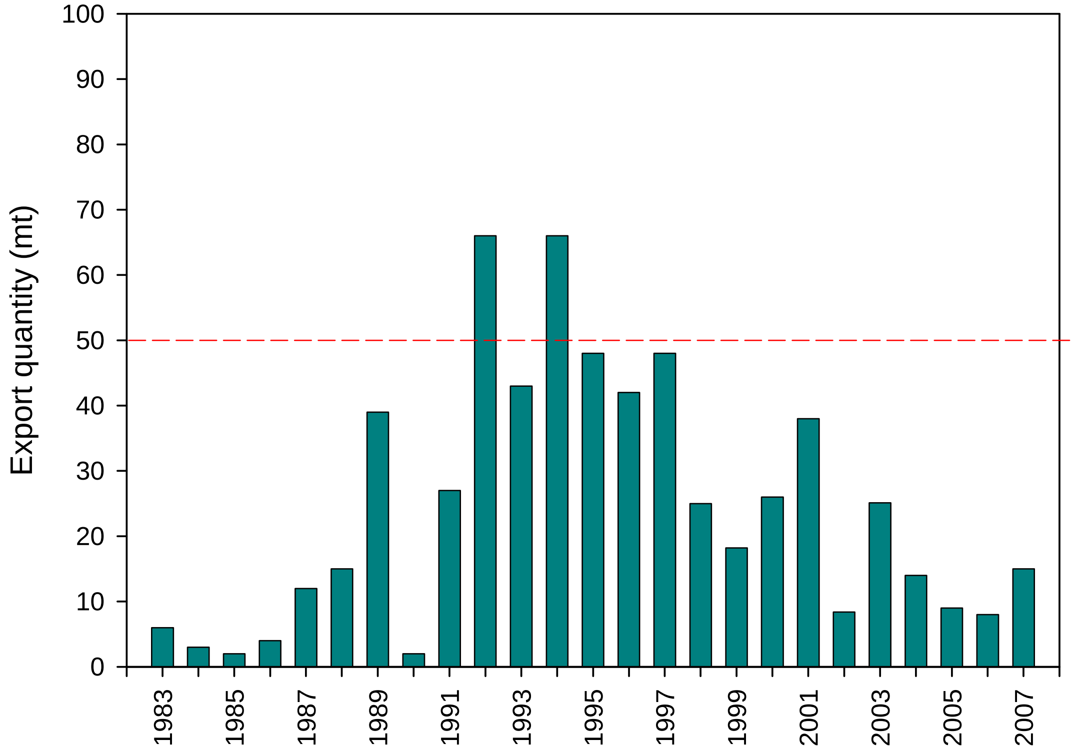

Figure 2: Historical sea cucumber export production in Vanuatu

1.4.4 Management

The sea cucumber industry in Vanuatu is characterized by periods of heavy exploitation followed by resting periods during which the fishery would be allowed to recover. The low- medium- and high-value species groups determine harvesting pressure, whereby the larger and highly priced species are targeted more than the smaller, low value species. Regulation to control the export of bêche-de-mer was instituted in 1988, and the ministerial order of 1991 set the total export quota at 35 mt, but this quota have rarely been enforced. Like trochus and other reef fisheries, community based taboo is the principle of management for sea cucumber. Past resource assessments (Chambers 1990; Gibbs et al. 1998; Lamont et al. 1999; Sounders et al. 2000) recorded high diversity (18 species), but densities are relatively low in most areas in the country. Falling export production indicated continued pressure on the resources, which signaled the need for management attention.

Restocking of cultured post larval (<10 mm) sea cucumbers imported from a Harvey Bay based sea cucumber farm in Australia has been conducted at some reefs in Efate and Malekula since 2004. While restocking of the natural population with hatchery bred sea cucumbers is still an unproven technique, the idea was soon accepted due to lack of local knowledge about this technology. Arrangements were made by the company (Bluefin Seafoods Ltd) with communities to provide juveniles in exchange for the harvest of wild stocks. This arrangement proved a failure when the wild sea cucumber stocks of the Maskelynes became depleted and none of the reseeded sandfish juveniles appeared to survive (Ropert Jimmy pers.com. 2008). According to PROCFish surveys in 2003, the Maskelynes held one of the best stocks of sandfish amongst the 17 Pacific Islands studied (Friedman et al. 2006), but this stock has now been depleted.

Regulations on maximum harvest size (dried product length) were instituted in 2005, but this alone was inadequate to stabilize the fishery. Therefore, a five-year moratorium on sea cucumber fishing was instituted for the first time in the country. A sea cucumber management plan must be developed with supporting regulations and community based management needs to be strengthened to control the fishery in the future.

1.5 Sea cucumber fishery on Epi Island

Epi is not an important area for sea cucumber, although some commercial species do exist and support a small fishery. The main species available on the island is greenfish (*S. chloronotus,* surf redfish *(A. mauritiana),* lollyfish *(H. atra),* prickly redfish *(Thelenota ananas)* and black teatfish *(H. whitmaei)* (Charly Valentine pers. com. 2004). Epi has been exporting small quantities of sea cucumber, but production figures are not available. An estimated 500 kilos of dried black teatfish, surf redfish, greenfish and prickly redfish were harvested at Mapuna Bay in early 2008 after the moratorium had been announced. The shipment was later confiscated from the buyer in Vila and destroyed (Jason Raubani pers. com. 2008).

The sea cucumber fishery was managed under the customary management system of taboo, as with other reef resources. Limited stocks make this fishery fragile in Epi. Harvest happened only when fishers themselves observed that there was sufficient stock to make a little bit of money. After fishing, there would be almost nothing left, which would indicate the need to close fishing again. In other words, decisions are made based on visual observation, historical knowledge of the fishery and recent local perceptions of what a sufficient stock of sea cucumber would mean. The length of an open season varies in each of the communities and normally lasts for a few weeks. Fishing is done mainly by men, while processing can involve women as well. As this is a small fishery, fishing is restricted to the few members of the community who are able to dive and know how to process the products. Catches are sold directly to exporters in Port Vila.

2. The aim of the survey

SPC technical assistance for the assessment of trochus and sea cucumber was officially requested by VFD in 2007. Trochus and sea cucumber are two of the most important commercial reef fisheries in Vanuatu and are in need for urgent management attention, but lack of resource information is a challenge for fisheries managers. In a new initiative by VFD, new management plans and regulations will be developed in the coming years to control these fisheries. Resource and socio-economic information are the baseline for developing these management measures and will be collected on an island by island basis when funds are available. This effort will also assess the level of community based management effectiveness in ensuring sustainability of resources. The first island to undertake this task was Epi, with funding support from the United Nations Food and Agriculture Organization (FAO).
SPC was asked to provide technical assistance in conducting an invertebrate resource survey at the five sites on Epi (Mapuna, Lamen Bay, Bonkovio-Brisbane, Burumba, and Mavelao-Valesdir) and to train the local staff in survey protocols.

Information from these surveys will used for decision-making to develop management and monitoring plans for trochus and sea cucumber fisheries. Specific objectives of these surveys therefore were to:

1) Collect information on presence, abundance and sizes for trochus and sea cucumber and other resources in the five sites.
2) Collect information about the reef habitat condition, including live coral coverage at the five sites.
3) Assess the status of trochus transplantation to Mapuna reef under the Australian Centre for International Agricultural Research (ACIAR)-funded trochus recruitment project.
4) Get the general feeling of the communities about their trochus and sea cucumber resources and management practices.
5) Train local fisheries staff on invertebrate survey techniques.

3. The survey sites

The island of Epi is partly surrounded by a series of coral reef systems which are present from the east coast at Nikaura to Mapuna Bay and Lamen Bay. A series of reefs interrupted by streams and rivers is found on along the west coast from Bonkovio-Brisbane all the way to Votlo at the southwest corner (Figure 6). In between reef systems, the shore is bordered by black or white sand beaches. Coral reef formations are narrow fringing reef platforms (50–100 m wide) that are partly exposed at low tide. The reef edge breaks off abruptly to approximately 5 meters of reef face that is inhabitable for trochus. Beyond the reef edges, a mix of sand and rubble habitat dominates the slopes; this is not suitable habitat for most invertebrates. The reef platform provides suitable conditions for trochus, which can be best assessed using a shallow water reef transect survey protocol. The western coast of Epi is sheltered and normally calm. Detailed backgrounds of the sites are presented in the following subsection.

3.1 Mapuna Bay

Mapuna Bay (owned by the community of Moriu) is exposed to southeast trade winds. Wind generated swells and currents are normal in the bay during most months of the year, and this can restrict in-water surveys. The northern entrance of the bay normally experiences large swells, making it unsafe for surveys. Mapuna Bay was involved in an ACIAR/VFD trochus transplantation and recruitment study from 2003 to 2006 (Jimmy and Amos 2004). Prior assessment recorded relatively low presence and sparsely distributed trochus stocks. Breeding in a sparsely distributed population reduces the success of fertilization of the gametes. The aim then was to revitalize natural recruitment by introducing new spawners. Wild adult trochus sourced from Lamen Bay reef (400 shells) were introduced to Mapuna Bay. These trochus were pre-conditioned in wire mesh cages placed on the reef for a month before they were set free.

The community of Moriu was a partner in the project. Its contribution was to administer the management of the introduced trochus during the study and after study's end. Preliminary results of the work indicated an increase in the recruitment of trochus at Mapuna Bay and that the community's commitment to enforce a taboo on trochus fishing was effective during the study period (Jimmy and Amos 2004).

In 2007, the community introduced a trochus open season without notifying VFD of its intension. Most of the introduced trochus were harvested during the open season (Yoan pers. com. 2008). The same community harvested sea cucumber early in 2008 without knowing a moratorium has been announced. About 500 kg of dry sea cucumber was sold to a buyer in Port Vila, but was confiscated and destroyed by VFD inspectors. Trochus fishing at Mapuna Bay was closed at the time of the survey. Further south of Mapuna Bay is Nikaura village, where a community ban on fishing of all reef species has been enforced since 2000 to support a village eco-tourism project.

3.2 Lamen Bay

Lamen Bay is a big community comprising both Lamen Island and part of the mainland. Previously, the community lived on Lamen Island, but some families have moved to the mainland. Lamen Bay is located at the sheltered side of the island, and sea conditions in the area are normally calm and very suitable for in-water work. The whole Lamen Bay community is governed by one paramount chief who also has the overall power to control reef taboo. Today however, although a village paramount chief still rules, his power to control the reef is no longer as strong as before. New settlements that have developed on the mainland have broken with the community and organized into smaller units or *clans* that now control portions of their own reef areas on both the mainland and Lamen Island (Tasso Welao pers. com 2008).

In 2003, Lamen Bay supported transplantation of 400 adult trochus to Mapuna Bay under the ACIAR/VFD trochus project (Jimmy and Amos 2004). A sales agent from the Hong Shell processing factory was stationed at Lamen Bay from 2003 to 2007 and continuously purchased shells all over the island. The presence of a buyer on the island has been linked to uncontrolled harvesting of trochus. Most village elders believe continuous buying has contributed to the disintegration of the centrally controlled taboo system and encouraged the rise in clan enforced taboos. Village unity and solidarity in enforcing taboo at Lamen Bay weakened because each clan now decides its own open and closed seasons. Fishing at Lamen Bay was closed at the time of the survey and buying of shells had stopped early in 2008.

3.3 Bonkovio-Brisbane

The Bonkovio-Brisbane community was formerly situated upland but moved to the coast in the 1970s. The fringing reef, stretch from Brisbane to just before Foland Point, supports the trochus fishery in the area. The reef is shallow and minimal effort is required to access trochus during harvest operations. A mark–recapture survey in 1996 collected 2000 trochus (sizes 5–9 cm basal diameter) by wading in front of ‘Les Charmettes’ plantation in a space of two hours and within 5000 m^2 (50 m x 100 m) (Vanuatu Fisheries Department 1996). Trochus aggregations (3–9 cm shells) were abundant under coral heads in very shallow water.

The purpose of that tag and release survey was to monitor growth rate of the shells, which appeared to be stunted. A 9.0 cm trochus shell from Bonkovio was heavier (249 g on average with a rounded base) than a normal shell of the same size (which weighs 179 g) (Vanuatu Fisheries Department 1996). The growth rate of the shells was normal (3 cm per year) as established for Vanuatu (Bour and Grandperrin 1985). Growth curves shows that Bonkovio shells would reach maximum size at 14 cm, while normal maximum sized for Vanuatu is 16 cm (Bour and Grandperrin 1985). Stunting of animals is caused by a shortage of grazing space resulting from congestion of the stock, which is normal in high density situations. The advice of fisheries managers was to thin these high aggregations down by moving shells to less congested reef areas, but this advice was not considered; instead the stunted shells were fished out. The problem no longer exists in the present stock (Mael pers. com. 2008). Trochus fishing in Bonkovio-Brisbane remained closed at the time of survey.

3.4 Burumba

Burumba is a large village with relatively strong chiefly control system. A village council provides extra support in maintaining order and enforcing council rules. Burumba reef extends from Foreland Point to Nelson Bay and is similar to those of Bonkovio and Lamen Bay, with a very shallow fringing reef platform that breaks off at the seaward edge (Figure 3). A few small patches of reef line the edge and provide a good habitat for trochus, but the main trochus habitat is the flat reef zone. Until the 1990s, the whole reef—up to a few meters off the beach—was littered with trochus, so that during harvest season, elders, women and children would fish along the near shore areas, while men would fish further away along the edges. The present stock is smaller than it used to be (Samuel pers. com. 2008). A village taboo on trochus fishing was enforced at the time of survey. While the taboo was effectively enforced, a member of the community who resided away from the main village was claiming a portion of the southern part of the reef. This friction was felt by the survey team during this survey.

3.5 Mavelao-Valesdir

Mavelao village is located between Rovoliu Bay and Valesdir Plantation. Fringing reefs (Figure 3) border the front of the village and extend all the way from Rovoliu to Valesdir, dissected by the Mavelao stream. Traditional village taboo was strong in the recent past, however a dispute over the title of the chief has led to total breakdown of the village structure. Ownership of the main village reef used to be controlled by the main village chief, but a small portion of the northern part is controlled by a clan that lives in a settlement near Rovoliu. Village solidarity in maintaining taboo was weakened by this disturbance. In 2003, Mavelao-Valesdir supplied 1000 adult trochus (purchased at VT200 per shell) that were transshipped to Samoa to assist the introduction of trochus there under the ACIAR trochus project. In return, the village demanded reseeding of hatchery bred juvenile trochus on their reef by VFD, but this has not happened as promised.

Today however, Mavelao is going through disturbances as a result of an ongoing dispute over the village chiefly title. The village is currently in chaos, with two village chiefs who claim control over two factions of the community. This ongoing dispute, which began sometime in 2004, has translated into total breakdown of the village control systems. Village taboo on trochus fishing is no longer respected. Harvesting has been conducted by members of the factions, both of whom claim rightful ownership of the reef (the team was confronted by a member of one of the factions during this survey). The situation has led to over-exploitation of the trochus resource. Although the taboo system is still in place, less trochus is available on the reef flat than just 4–5 years ago (Sompert Rena pers. com. 2008).

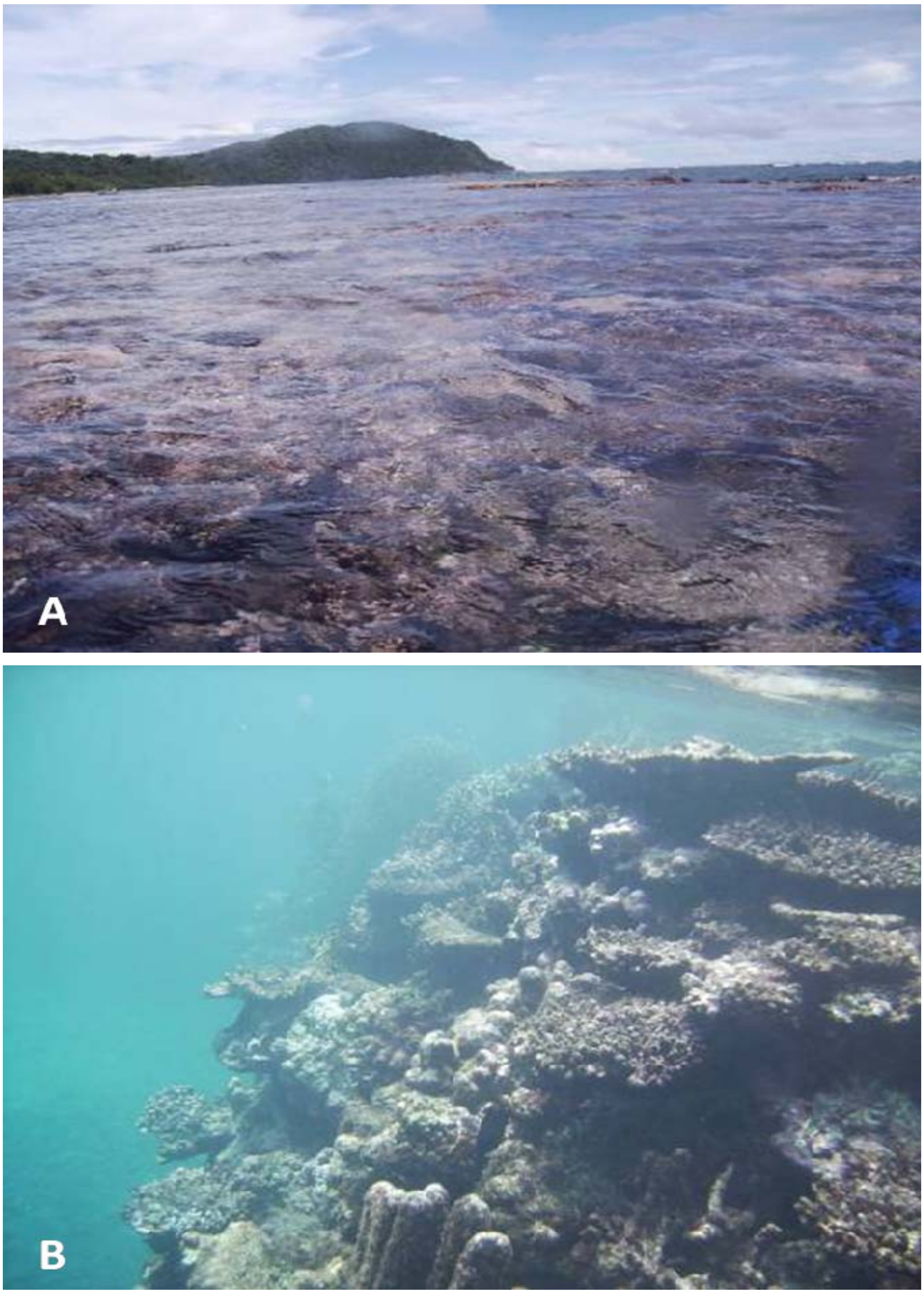

Figure 3: Typical reef systems at Epi Island sites to show trochus habitat—shallow reef platform at low tide (A), abrupt reef edge (B)

4. Survey design and methodologies

The aim of the survey was to examine a large proportion of the reef at the five sites on Epi and collect information to understand distributions, abundances and densities of trochus and sea cucumbers. Invertebrate resource survey protocols used by the coastal component of the PROCFish project (PROCFish/C) were adopted in this survey. Other invertebrate resources, including giant clams, were included as well. The four survey protocols adopted were: timed swim searches along the reef front areas (RFs), mother-of-pearl transects (MOPt), mother-of-pearl searches (MOPs), and shallow-water reef-benthos transects (RBt), but RBt and MOPt were the most important assessment techniques suitable for the reef habitat present on Epi. A more detailed description of these protocols is provided in the following sections (see Figure 4).

4.1 Reef front search (RFs) or timed swim

RFs, which are only conducted if swell conditions permit, are performed snorkelling along the reef front just behind the swells where trochus (*Trochus niloticus*), green snail (*Turbo marmoratus*) and the surf redfish (*A. mauritiana*) generally aggregate (Figure 3). Two observers snorkel side by side, separated by 10 to 15 m. Each observer counts and records the abundance of conspicuous sedentary species observed on the way (focusing on trochus, surf redfish, clams and other gastropods) during five-minute search periods (repeated three times, for a total serving time of 15 minutes). The start and end positions of each RFs station swim are recorded on a global positioning system (GPS). The swim distance can be calculated using MapInfo software, although it varies among stations depending on wind, current and wave conditions. Observation from the surface can also vary with depth and visibility, and this technique is used to give only a general indication of resource status, not to give precise density data.

4.2 Mother of pearl transects (MOPt) and searches (MOPs)

Initially, two divers (using scuba) actively searched for trochus for three 5 minute search periods (Mops) (15 min in total search periods). Distance searched is estimated from marked GPS start and end waypoints. If on these searches more than 3 individual shells is found, the stock was considered dense enough to proceed with the more defined area assessment techniques using transect (MOPt). Otherwise a search period is completed for an MOP search station.

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

4.3 Reef-benthos transects (RBt)

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

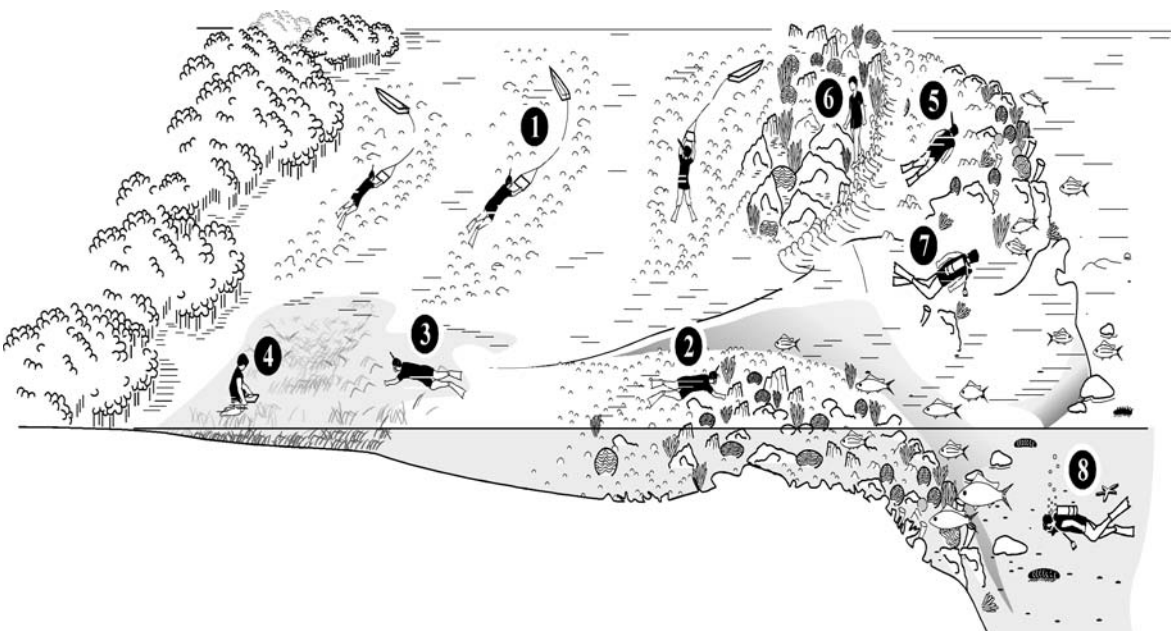

Figure 4: Invertebrate survey profile used by PROCFish/C showing placement of different sampling surveys across different reef zones corresponding to the main reef habitats. Specific trochus surveys are: 2—Reef-benthos transects (RBt); 5—Reef-front searches (RFs); 6—Reef-front search walk (RFSw); and 7—Mother-of-pearl transects (MOPt) and mother-of-pearl searches (MOPs).

Actual position (longitude and latitude) of the sampling stations (one waypoint for an RBt station and two waypoints for an RFs and an MOPt or MOPs station) were logged at 10 m accuracy using a Garmin GPS 72. GPS position data are important in estimating coverage areas for timed search stations using MapInfo and for future monitoring purposes. Records include species counts and sizes; site names; and date and environmental parameters, including descriptors such as relief and complexity, depth and substrate composition. Substrate composition included live and dead coral, rubble, sand and boulders, pavement and consolidated rubble, while substrate cover included fleshy algae, sea grass, crustose coralline algae and encrusting algae. Data were recorded on a standard underwater record sheet.

Figure 5: Jason Raubani, local trainee, measuring trochus on an RBt station on Epi

5. Survey results

5.1 Coverage and species recorded

A fair proportion of the reef areas in the five Epi sites were surveyed. Habitats covered are predominantly the fringing reef flats, the outer reef edges and reef faces, and the reef slopes at a few places, from 0 to 8 m depth. In total, 68 stations of scuba transects (MOPt), RBt, and timed swims (RFs) were completed at the five sites. A summary of the stations completed is shown in Table 2, and a pictorial view of the survey coverage is shown Figure 6. The total surface area covered by this survey was >35,000 m². In total, 40 invertebrate species were recorded on Epi during this survey. The fauna was dominated by small gastropods (21 species), while 9 species of sea cucumber, 2 bivalves, one crustacean, one cephalopod, and 3 species each of starfish and urchins were also found. This low species diversity is testament to the limitations of the island's reef environment. A detailed list of species is presented in Appendix 2.

Table 2: Summary of stations completed at Epi sites

Site	MOPt	MOPs	RBt	RFs	Total
Mapuna Bay	0	2	5	1	8
Burumba	6	0	7	2	15
Mavelao-Valesdir	3	1	5	4	13
Bonkovio-Brisbane	5	0	5	2	12
Lamen Bay	4	2	8	8	22
Total stations	**18**	**5**	**28**	**17**	**68**
With replications	**108**	**30**	**168**	**102**	**408**
Reef area	**8640**	**4500**	**6720**	**15,300**	**35,160**

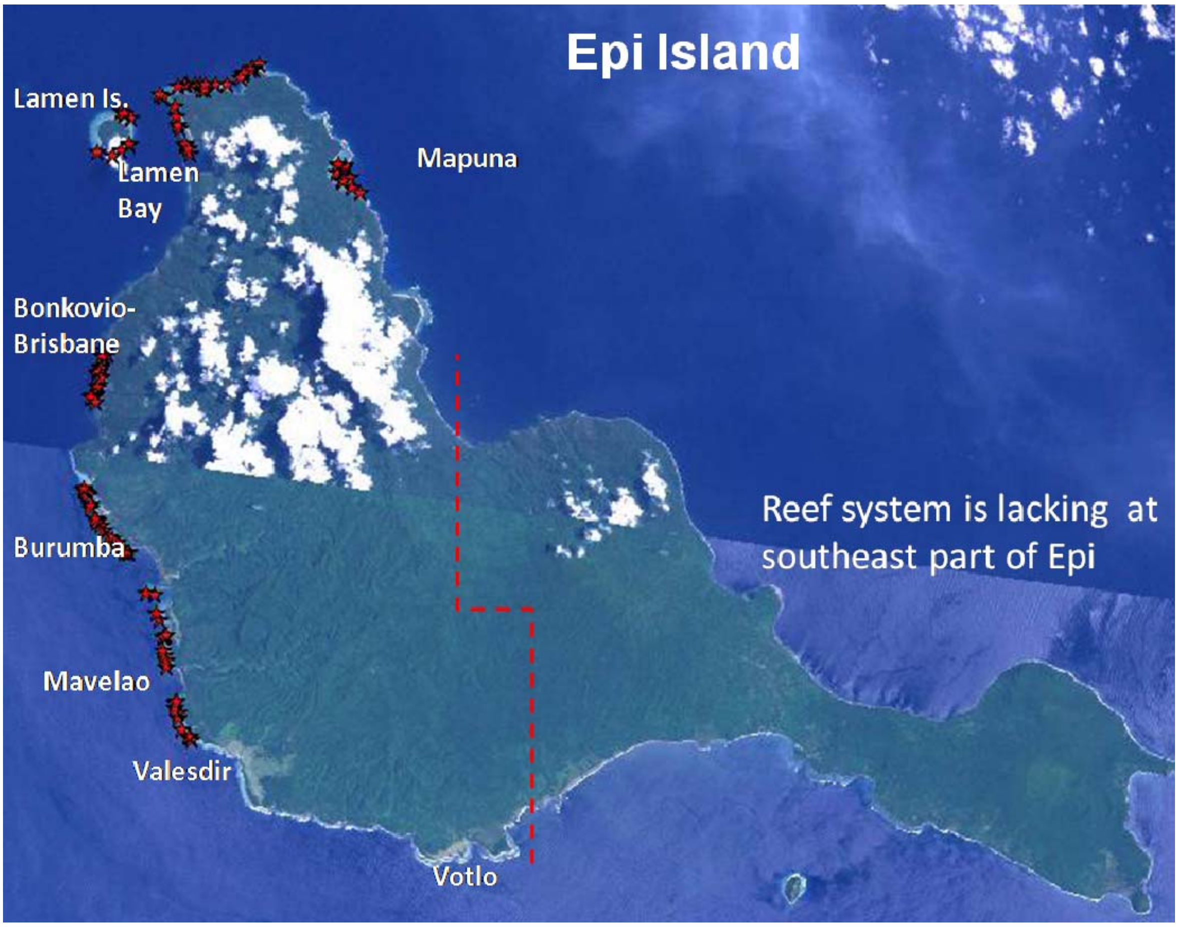

Figure 6: Pictorial view of the survey coverage at the five Epi sites. Red stars are GPS waypoint positions of stations completed at Mapuna Bay, Lamen Bay, Bonkovio-Brisbane, Burumba and Mavelao-Valesdir.

5.2 Trochus presence, density and size distribution

Trochus niloticus was present on the reefs of the five sites assessed on Epi. A total of 802 individuals were recorded during the survey (n = 709 were measured). The majority of the stock was on very shallow reefs (approximately 1.5 m depth) that are easily accessible to fishers walking on foot or using a snorkel. Average station densities of trochus, as recorded through scuba surveys (MOPt and MOPs), ranged from 30 shells per ha at Mapuna Bay to more than 400 shells per ha at Burumba. Average densities for RBt stations on the reef tops and reef platforms ranged from 150 shells per ha at Mavelao to more than 900 shells per ha at Burumba.

On the submerged reef slopes (MOPt and MOPs, 3.0 m average depth), trochus were at greatest density at Burumba, a site on the middle of the west coast. An overall threshold of 500–600 shell per ha for core trochus habitat is suggested as the minimum density that main aggregations should reach before commercial fishing can be considered. Trochus aggregations on reef tops and platforms at this and other sites on Epi were greater than 500 per ha. However, at only a single MOP station within Burumba was the density higher than 500 per ha.

Table 3: Presence and mean density of trochus (individuals per ha, ± standard error [SE]) from different survey types at the five sites on Epi

Station type and site	Density	SE	% of stations with trochus	% of transects or search periods with trochus
MOP Transect				
Lamen Bay	135.4	52.8	4/4 = 100%	11/24 =46%
Mapuna				
Bonkovio-Brisbane	212.5	65.7	5/5 = 100%	21/30 =70%
Burumba	423.6	193.2	6/6 =100%	27/36 =75%
Mavelao Valesdir	125	12	3/3 = 100%	15/18 =83%
MOP Search				
Lamen Bay	18.9	3.8	2/2 = 100%	5/12 =42%
Mapuna	30.3	22.7	2/2 = 100%	5/12 =42%
Bonkovio-Brisbane				
Burumba				
Mavelao Valesdir			1/1 = 100%	3/6 = 50%
Reef Front Search				
Lamen Bay	35.3	12.3	8/8 = 100%	30/48 = 63%
Mapuna	19.6	-	1/1 = 100%	3/6 = 50%
Bonkovio-Brisbane	23.5	0	2/2 = 100%	6/12 = 50%
Burumba	113.7	66.7	2/2 = 100%	11/12 = 92%
Mavelao Valesdir	59.6	20.9 0.8	5/5 = 100%	25/30 = 83%
Reef Benthos Transect				
Lamen Bay	183.9	50.8	8/9 = 89%	24/72 =33%
Mapuna	225	84	5/5 = 100%	14/30 =45%
Bonkovio-Brisbane	833.3	228.6	5/5 = 100%	24/30 = 80%
Burumba	922.6	240.1	7/7 =100%	35/42 =78%
Mavelao Valesdir	150	48.6	4/5 = 80%	13/30 = 43%

Additional data obtained by swimming along the reef front and reef crests (RFs stations) and shallow water reef (RBt stations) are useful for filling out the picture of trochus distribution and status at the five sites surveyed. Despite the fact that the habitat was good, most of the reef crest observations also recorded low densities of trochus (RFs stations), while the reef platforms (RBt stations) held higher density aggregations at times (Figure 7).

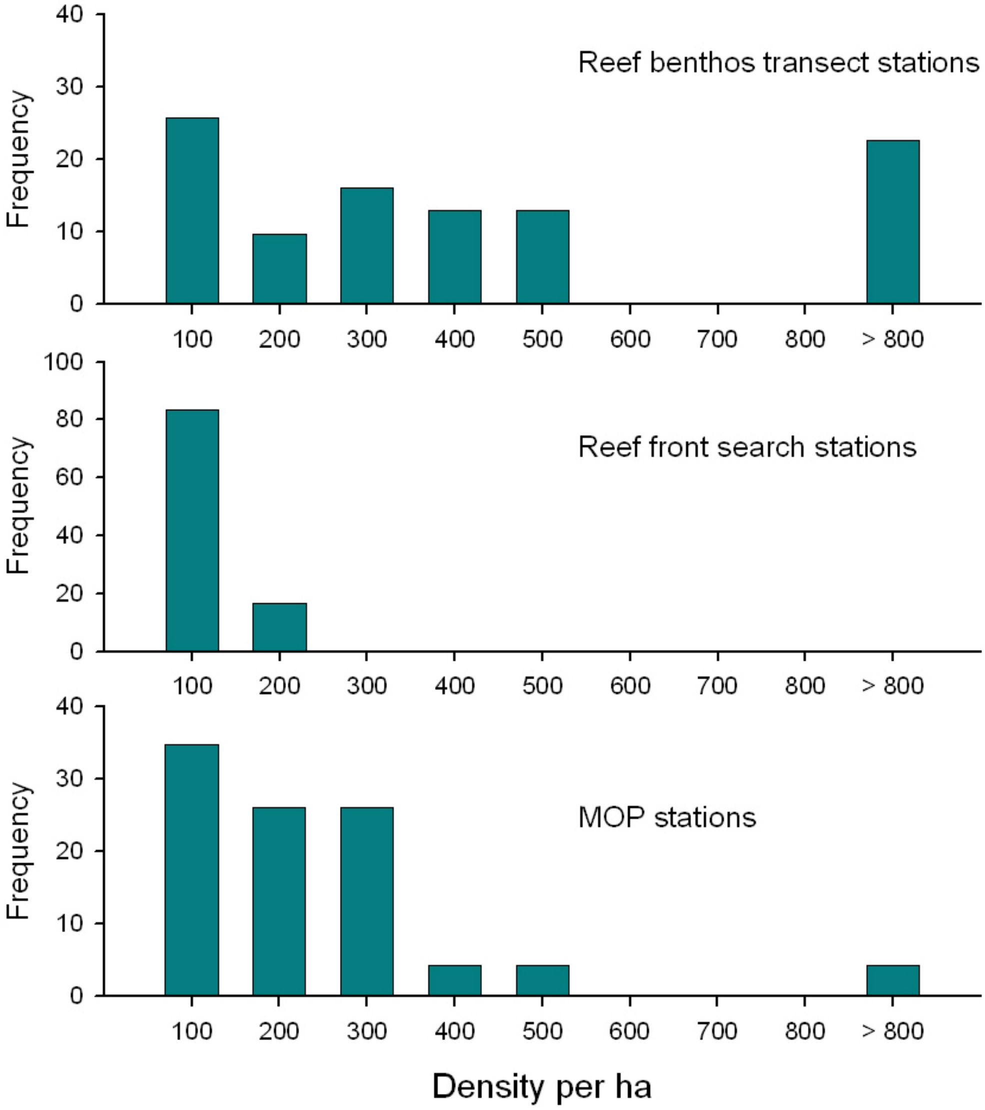

Figure 7: Frequency of densities for three main station types on Epi to show distribution of aggregations of trochus across the reef

Shallow water reef platforms that were partially underwater, or had pools and grooves linking submerged sections for flushing with oceanic water, were some of the most dense areas of trochus (Figure 7—Reef benthos transect stations). In this case, 26% of stations and 36% of transects held trochus at densities of 500 per ha or above. Eighteen percent of transects had densities greater than 1000 per ha, with the highest transect density reaching 3240 per ha, which is 13 trochus in 40 m^2 sampling replicate.

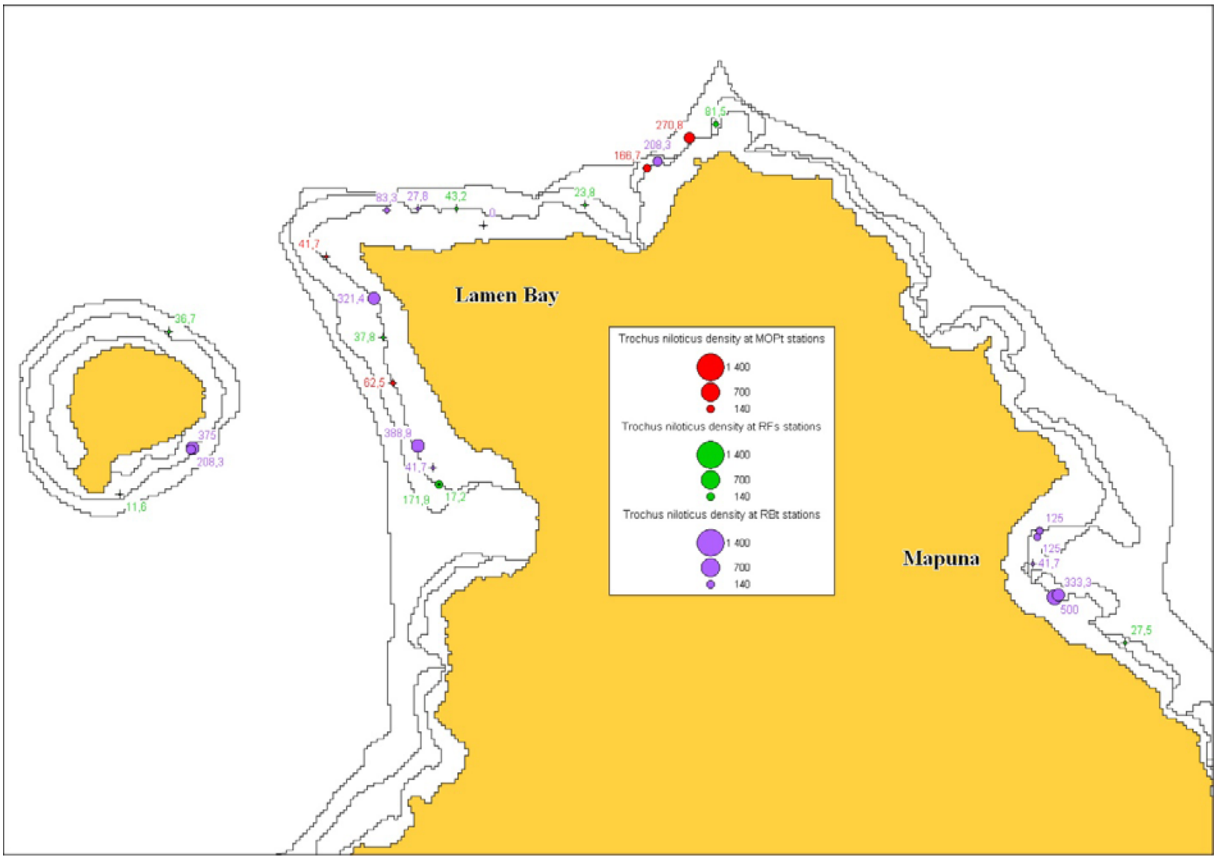

Figure 8: Pictorial view of trochus density at Lamen Bay and Mapuna to show density variations for the three main survey types

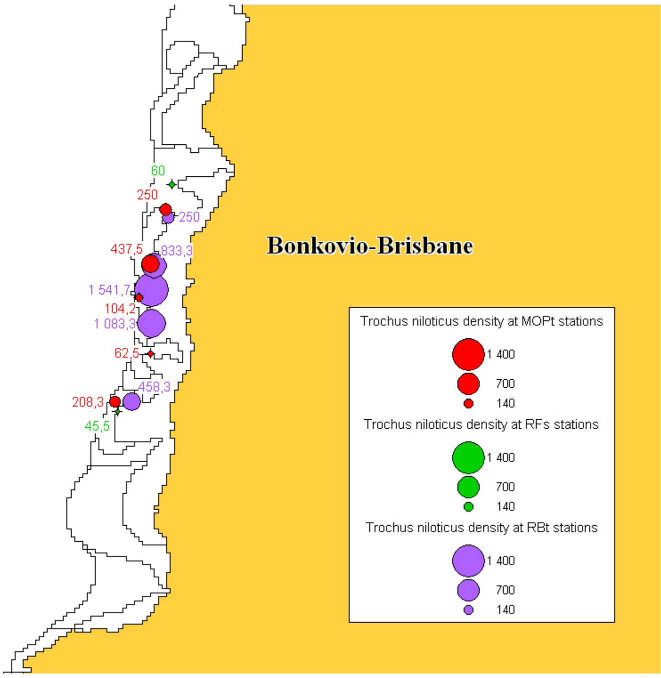

Figure 9: Pictorial view of trochus density at Bonkovio-Brisbane to show density variations for the three main survey types

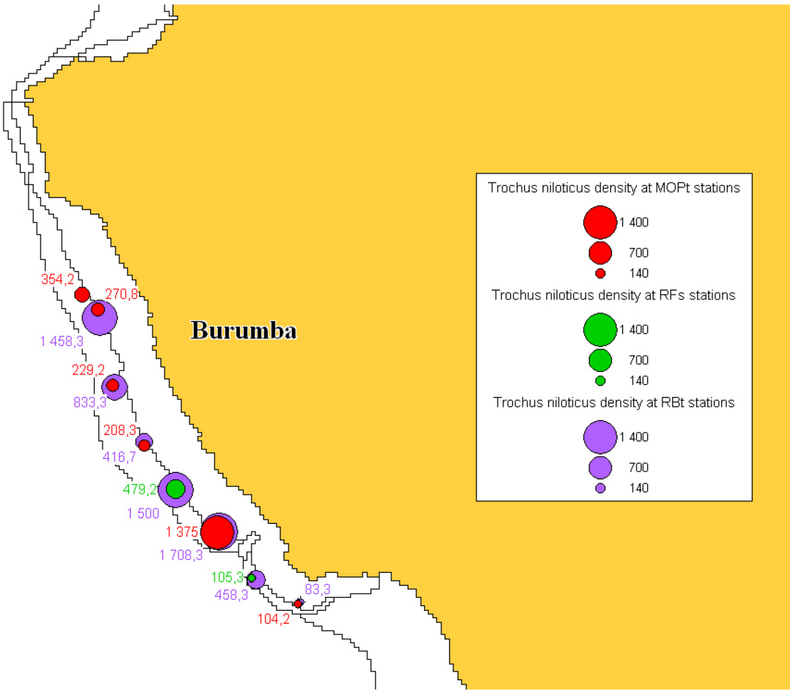

Figure 10: Pictorial view of trochus density at Burumba to show density variations for the three main survey types

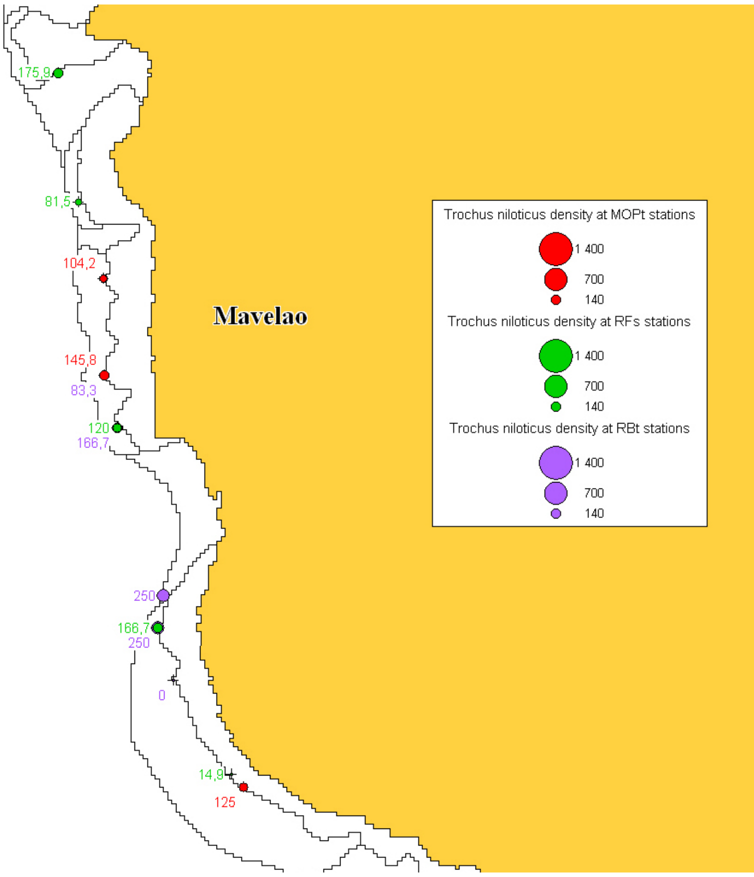

Figure 11: Pictorial view of trochus density at Mavelao-Valesdir to show density variations at different sites for the three main survey types

5.3 Size distribution of trochus across sites

An examination of shell size gives important information on the status of stocks by highlighting new recruitment into the fishery, or the lack of a recruitment signal, which could have implications for the numbers of trochus entering the capture size classes in the next two years. Size distribution analysis can assist to determine fishable stocks in a population. Mean basal diameter for trochus on Epi was 9.3 cm ± 0.1 SE (n = 709, Figure 12), which corresponds to a weight of approximately 250 grams. The trochus population of Epi therefore is dominated by relatively young trochus, which could signal the impact of fishing out the legal size classes.

In Vanuatu, all shells larger than 9 cm could be legally taken before 2005 (right side of dotted line, Figure 12), and they accounted for 77%, 26%, 71%, 68%, and 82% of the shells measured in Mapuna, Bonkovio-Brisbane, Burumba, Lamen Bay and Mavelao-Valesdir, respectively (overall average for Epi was 65%). This indicates that the bulk of the stock is generally within capture size classes. Since 2005, the higher 13 cm limit has also been in place, to protect the largest size classes (this type of minimum and maximum size limit generates what is often called a ‘gauntlet’ fishery. The percentage of stock recorded at this size was 0%, 1%, 6%, 9%, and 15% for Mapuna, Bonkovio-Brisbane, Burumba, Lamen Bay and Mavelao-Valesdir, respectively. If a general capture size class of 8–11 cm is employed, as in other Pacific Island countries and territories, then the data shows that only 29% of trochus fall in this range of fishable stock.

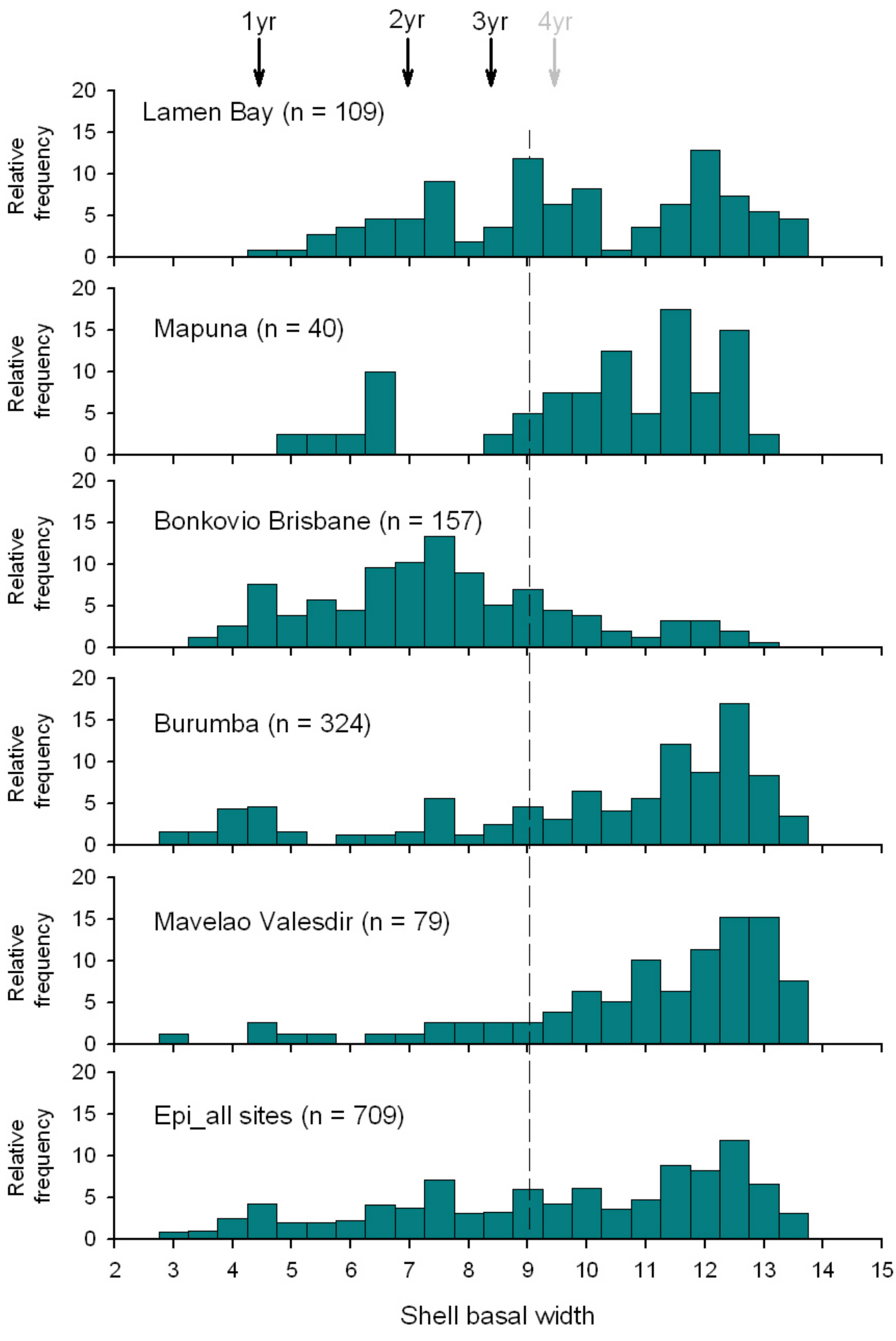

Figure 12: Trochus size distribution graphs for the five Epi sites. Current legal size of 9.0 cm is indicated by vertical line. Arrows on the Lamen Bay graph denote average year class sizes (Asano 1940, in Nash 1993).

At most sites, stocks from the size class measuring more than 11 cm basal width were relatively abundant. This mature proportion of the population is thought to be very important for egg production, as the largest individuals of the population produce a disproportionately large number of eggs, and their eggs are larger and more viable (trochus with shells measuring 13 cm produce three times as many eggs as those measuring 10 cm). Trochus only reach such a mature size class at 6 or more years of age, and therefore any trochus fishery needs to have strict controls in place to ensure there are sufficient females at high enough densities with males (sexes are separate) to have good rates of fertilization and potential good settlement of juveniles.

Interestingly, the site with the greatest number of younger trochus is the same site that had fewer older, larger individuals in the population (Bonkovio-Brisbane). This can be interpreted as a result of recent past fishing targeting larger shells. Also, there is a contrary argument that states that trochus fisheries must be continually fished, not to a point where broodstock densities drop below a critical threshold where fertilization and production is compromised, but to a level that opens up space for new recruits (Asano 1963) in an environment in which space and food may be limited. In some other trochus fisheries, where stock has not been fished for an extended period or there is a maximum basal width for commercial sale, the proportion of shells measuring more than 11 cm makes up 20–50% of the recorded population.

In most cases, recruitment pulses were noted, although young trochus were not always very abundant (young trochus of 4.5 cm are approximately 1 year old and reach first maturity at 7–8 cm when they are approximately 3 years old, see Figure 12). Younger shells are normally only picked up in surveys from the size of about 5.5 cm, when small trochus are emerging from a cryptic style of life, and joining the main stock. Presence of these smaller sized shells at the sites surveyed shows that stock protection will result in increased densities in the short to medium term. Particularly notable recruitment at the northerly sites of Bonkovio-Brisbane, and possibly Mapuna Bay, might mean there were smaller scale spatial differences in success of settlement across Epi after spawning events in late 2006–early 2007.

The suitability of reefs for grazing gastropods can also be highlighted by results collected from other grazing gastropods like the false trochus or green top shell (*Tectus pyramis*). This related, but less valuable species of top shell (algal grazing gastropod with a similar life history to trochus) was not abundant (n = 33 recorded in survey). The mean size (basal width) of *Tectus pyramis* was 6.0 cm ± 0.2 SE.

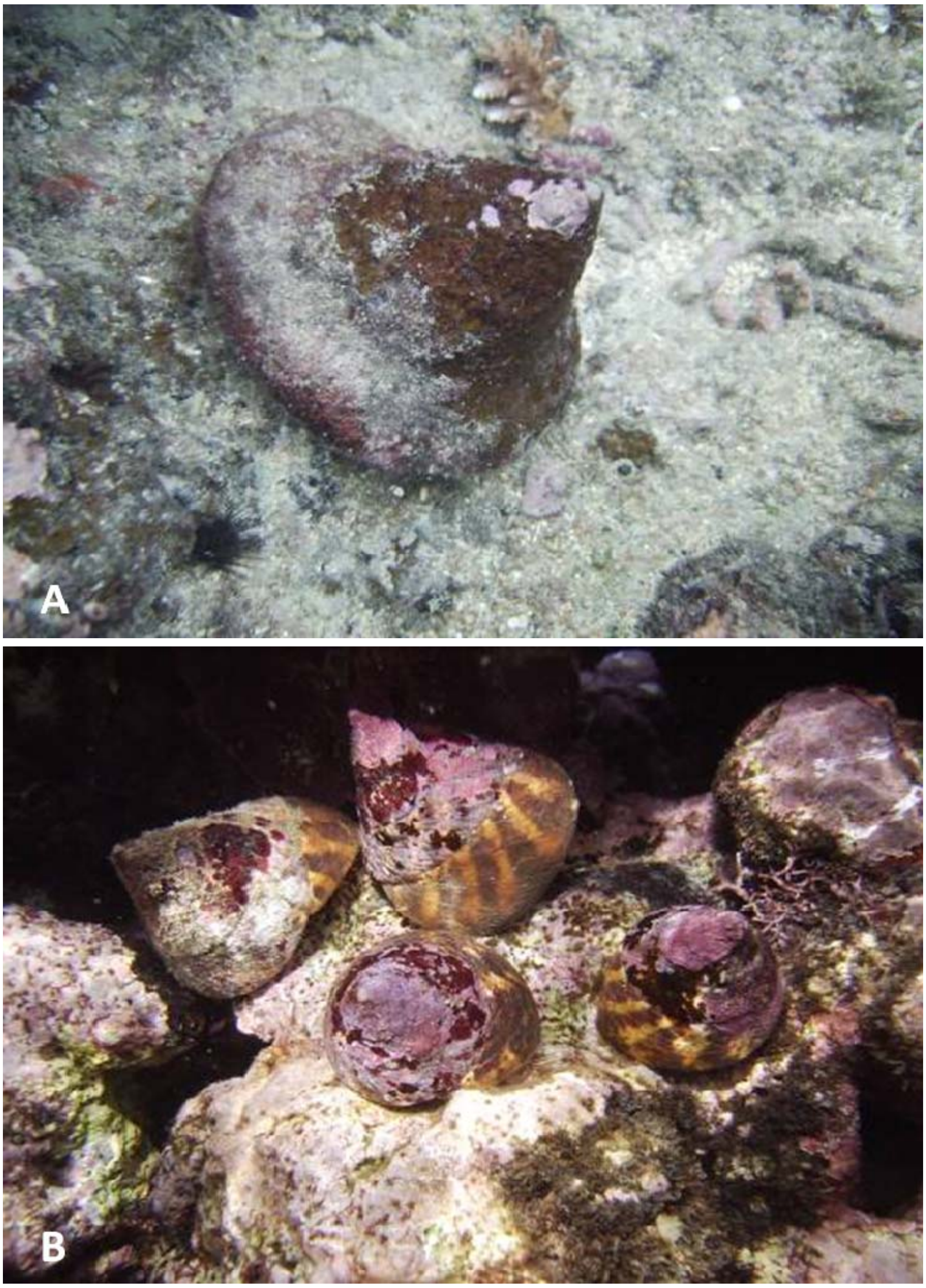

Figure 13: Larger, older shells 11 cm or more (A) dominate population structure at most sites on Epi; and small, young trochus (B) found at all Epi sites indicating active recruitment in the fishery

5.4 Size distribution for trochus across the reef habitat

The distribution of trochus was not even across the reef platforms (RBt stations), crests (RFs stations) and slope habitats (MOP and MOPs stations), with greater aggregations found on reef platforms (Figure 14). Commercial stocks are easily accessible at these shallow water locations, which are susceptible to both fishing and storm events. Trochus sizes are fairly well distributed in the shallow locations, from 3 cm to 13 cm, as compared to crest and slope locations. The reef crest zone of an abrupt reef end at most sites provide limited habitat (trochus do not inhabit the reef face of the crest).

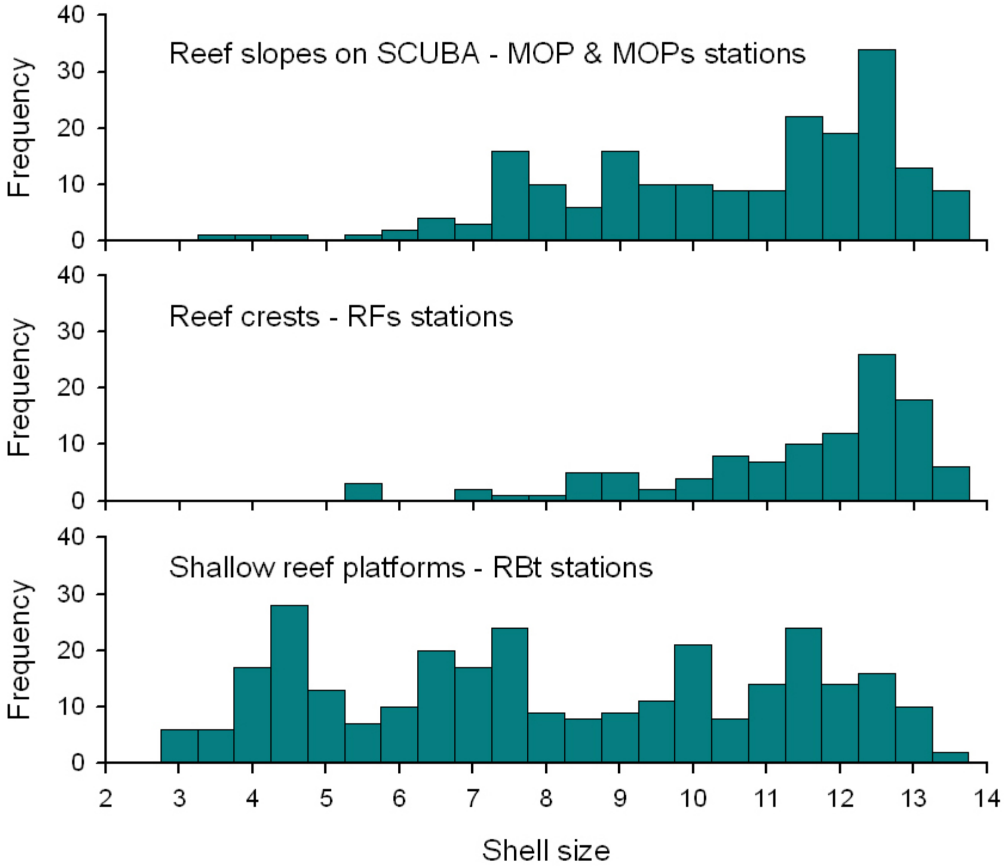

Figure 14: Distribution of trochus size (in cm) across the three habitat types sampled at Epi sites

5.5 Status of trochus fishery on Epi

In FFigure 15, trochus densities for two main MOPt and RBt assessments at the five Epi sites are graphed with all other sites in Vanuatu to provide a comparative status of trochus fisheries. Densities from the MOPt assessments, which were undertaken at 1.5 to 7 meters of water, were well below the sustainable fishable stock level of 500 per ha. Density at Burumba (424 per ha) was better than the other sites for this assessment type but still fell short of this sustainable harvestable level. The amalgamated density for 1.5 to 7 meter depths for the whole island (all Epi), was 251 per ha.

Trochus density from RBt stations conducted in 0 to 1.4 m of water at Burumba and Bonkovio-Brisbane were well beyond the minimum sustainable harvest level (over 800 and over 900 per ha, respectively). On the other hand, the densities at Mapuna Bay, Lamen Bay and Mavelao-Valesdir were well below the minimum sustainable harvest level, at 150, 184 and 225 per ha, respectively. Despite the high densities recorded for Burumba and Bonkovio-Brisbane in this assessment type, the amalgamated density for all of Epi was 448 per ha, again below the benchmark—although close to the minimum sustainable harvest level of 500 per ha. The amalgamated density provides an idea of the status of the trochus fishery on Epi as a whole, which is important when considering management systems on an island by island basis. Although the amalgamated density falls below the minimum sustainable harvest level, strong recruitment at all sites indicated the potential of the resource to recover to this sustainable level.

When compared with other sites surveyed in Vanuatu, overall trochus densities recorded at the five Epi sites for both MOPt and RBt station types were much higher than those recorded at the four PROCFish sites of Paunangisu, Moso, Uri-Uripiv and Maskelynes. In addition, trochus in very shallow waters assessable through RBt assessments are depleted in the four PROCFish sites on Efate and Malekula, while deeper areas (over 2 m) mainly along the outer reef edges accessible only by free diving—especially at Uri-Uripiv and Maskelynes—still maintain some stocks. On the other hand, trochus fisheries at the two Efate sites are not doing well.

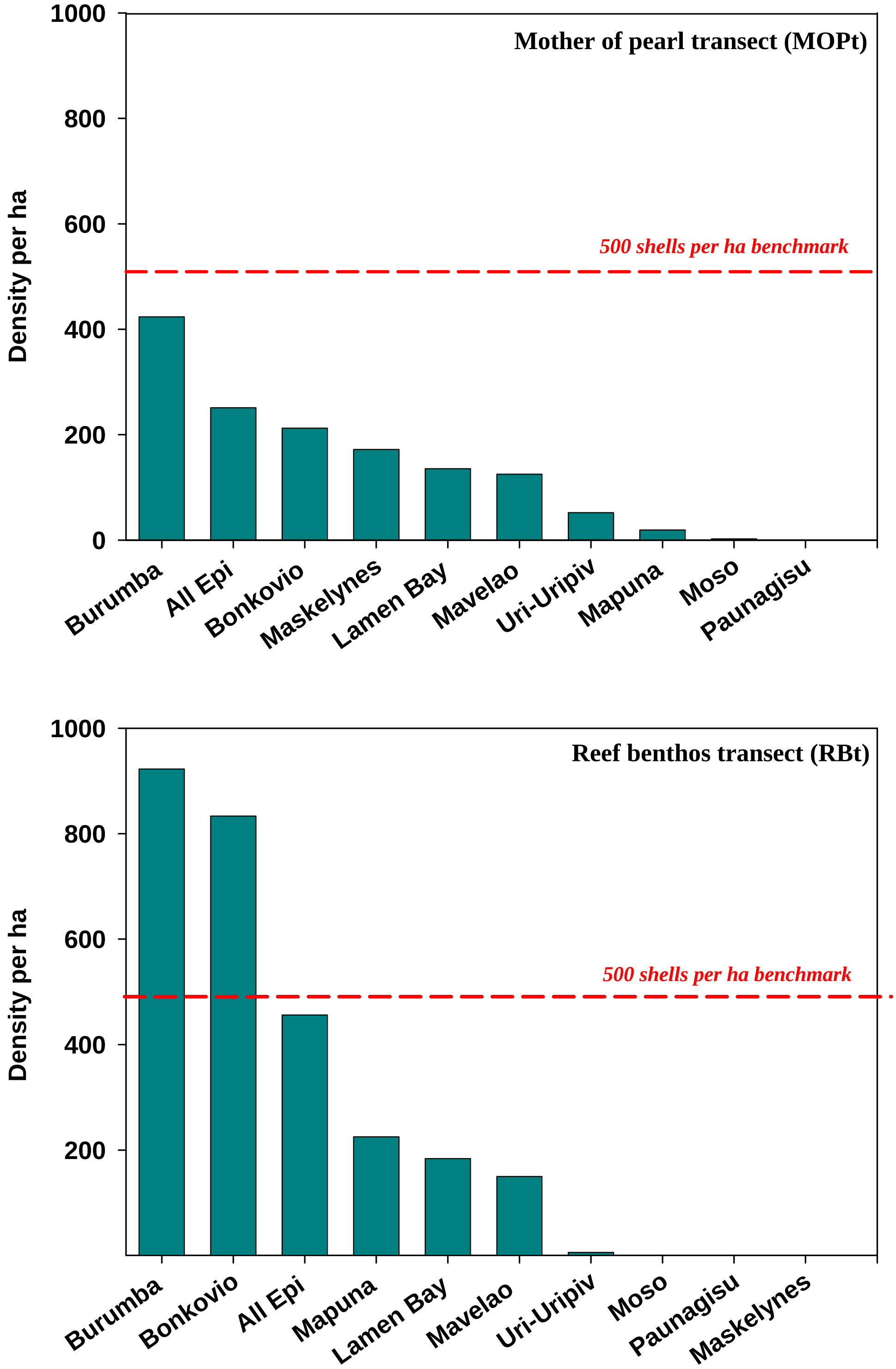

Figure 15: Trochus density comparison for all the sites assessed in Vanuatu by PROCFish in 2003 and this survey to show the status of the fishery at different sites with reference to the sustainable fishable level of 500 shells per ha benchmark (red dotted line) for the two main survey types

5.6 Others resources

5.6.1 Giant clams

Only the elongate giant clam (*Tridacna maxima*) and a specimen of *Tridacna crocea* were recorded in this survey. A total of 90 specimens were recorded at the five sites, dominated by *Tridacna maxima*. Density of *Tridacna maxima* was critically low, ranging from 8 ± 8 SE at Burumba to 47 ± 15 SE at Lamen Bay, as was *Tridacna crocea*, at 2 ± 2 SE per ha at Burumba (Table 4). This relatively low density for *Tridacna maxima* will make resource recovery difficult, as sparse distribution negatively affects spawning success and fertilisation, and therefore the ongoing sustainability of this resource. *Tridacna maxima* is the most common giant clam species present in many areas in the country (Zann and Ayling 1990). Other giant clam species present in Vanuatu, such as *Tridacna squamosa* and *H. hippopus*, were absent on Epi as a result of limited suitable habitat.

Table 4: Density of giant clams at Epi sites

Site	Species	Density	SE	% of stations with giant clam
Bonkovio-Brisbane	*Tridacna maxima*	13	6	4/10=40%
Burumba	*Tridacna crocea*	2	2	1/13=8%
Burumba	*Tridacna maxima*	34	17	6/13=42%
Lamen Bay	*Tridacna maxima*	47	15	8/13=62%
Mapuna Bay	*Tridacna maxima*	8	8	1/5=20%
Mavelao-Valesdir	*Tridacna maxima*	26	16	3/8=38%

5.6.2 Sea cucumbers

The fringing platform reef of Epi provides suitable habitat for a limited number of commercial sea cucumber species. Only nine of the 18 sea cucumber species present in Vanuatu were recorded in this survey. The most important species are *S. chloronotus*, *A. mauritiana*, *B. argus*, *H. atra* and *H. whitemaei* (Table 5). The reef habitat system at Lamen Bay is relatively well developed, supporting all nine species recorded, as opposed to other sites, which possess limited habitat for sea cucumbers.

Table 5: Total sea cucumber counts at the five sites on Epi

Species	Mavelao-Valesdir	Lamen Bay	Mapuna Bay	Burumba	Bonkovio-Brisbane	Total
Actinopyga lecanora		3				3
Actinopyga miliaris		4				4
Holothuria atra		19		6	4	29
Holothuria whitemaei		20	6		3	29
Thelenota ananas		2				2
Actinopyga mauritiana	18	9	10	33	21	91
Bohadschia argus	4	24	2	1	11	42
Bohadschia graeffei	1	3				4
Stichopus chloronotus	3	194		4	90	291

The medium-value surf redfish, *A. mauritiana* (Figure 16A), which typically shares the same habitat as *Trochus niloticus*, was moderately well distributed in the five sites, being present at between 3% and 30% of RBt stations and between 40% and 50% of MOPt stations. However, its densities for RBt assessments vary, ranging from 8 ± 5 SE per ha at Lamen Bay to 113 ± 50 SE per ha (Table 6) at Burumba. Of the four PROCFish sites in Vanuatu, only Uri-Uripiv had density for surf redfish at 30 per ha, the rest had relatively low densities. In areas where fishing impact is low, density of surf redfish can be high. For instance, this species is recorded at densities above 400–500 specimens per ha in some other locations in the Pacific assessed by PROCFish.

The medium-value greenfish, *S. chloronotus* (Figure 16C) was the most important species in Epi. Density recorded by shallow water RBt stations was above 1000 per ha at Lamen Bay and Bonkovio-Brisbane, which tend to have suitable habitat for greenfish, whereas densities at other sites were relatively low. Densities for greenfish at other sites in Vanuatu were much lower than at these two sites; the highest recorded by PROCFish was at Uri-Uripiv (110 per ha) (Friedman et al. 2006). The highly valued black teatfish (*H. whitemaei*) (Figure 16B) was present in moderate numbers at RBt and MOPt stations at Lamen Bay, Bonkovio-Brisbane and Mapuna Bay: 18 ± 10 SE and 25 ± 17 SE per ha, respectively. Densities recorded at other sites in Vanuatu by PROCFish were similarly low, indicating typically low abundance of this species. The fourth important species is the tiger or leopardfish, *B. argus* (Figure 16D), also present in moderate density at Lamen Bay and Bonkovio-Brisbane. Other species are present in densities lower than these four species, as shown in Table 6.

Table 6: Density of sea cucumbers at shallow RBt and deeper MOPt stations at Epi sites

Station type and site	*Species*	*Density*	*SE*	*% of stations with sea cucumbers*
RBt				
Bonkovio-Brisbane	*Actinopyga mauritiana*	75	31	7/30 = 23%
Bonkovio-Brisbane	*Bohadschia argus*	67	49	5/30 = 17%
Bonkovio-Brisbane	*Holothuria atra*	17	10	2/30 = 7%
Bonkovio-Brisbane	*Holothuria whitemaei*	25	17	3/30 = 10%
Bonkovio-Brisbane	*Stichopus chloronotus*	1042	499	21/30 = 70%
Burumba	*Actinopyga mauritiana*	113	50	12/42 = 29%
Burumba	*Holothuria atra*	42	24	5/42 = 12%
Burumba	*Stichopus chloronotus*	24	15	3/42 = 7%
Lamen Bay	*Actinopyga mauritiana*	8	5	2/61 = 3%
Lamen Bay	*Bohadschia argus*	114	83	11/61 = 18%
Lamen Bay	*Bohadschia graeffei*	9	9	2/61 = 3%
Lamen Bay	*Holothuria atra*	71	24	12/61 = 20%
Lamen Bay	*Holothuria whitemaei*	18	10	4/61 = 7%
Lamen Bay	*Stichopus chloronotus*	1277	653	42/61 = 69%
Mapuna	*Actinopyga mauritiana*	108	47	9/30 = 30%
Mapuna	*Holothuria whitemaei*	25	17	2/30 = 7%
Mavelao-Valesdir	*Actinopyga mauritiana*	33	24	4/30 = 13%
MOPt				
Bonkovio-Brisbane	*Actinopyga mauritiana*	33	28	2/5 = 40%
Bonkovio-Brisbane	*Bohadschia argus*	4	4	1/5 = 20%
Bonkovio-Brisbane	*Holothuria atra*	8	8	1/5 = 20%
Bonkovio-Brisbane	*Stichopus chloronotus*	29	8	4/5 = 80%

Burumba	*Actinopyga mauritiana*	24	11	3/6 = 50%
Lamen Bay	*Actinopyga lecanora*	5	5	1/4 = 25%
Lamen Bay	*Bohadschia argus*	16	5	3/4 = 75%
Lamen Bay	*Holothuria whitemaei*	16	5	3/4 = 75%
Lamen Bay	*Stichopus chloronotus*	120	75	2/4 = 50%
Lamen Bay	*Thelenota ananas*	5	5	1/4 = 25%
Mavelao-Valesdir	*Bohadschia argus*	28	18	2/3 = 67%
Mavelao-Valesdir	*Bohadschia graeffei*	7	7	1/3 = 33%

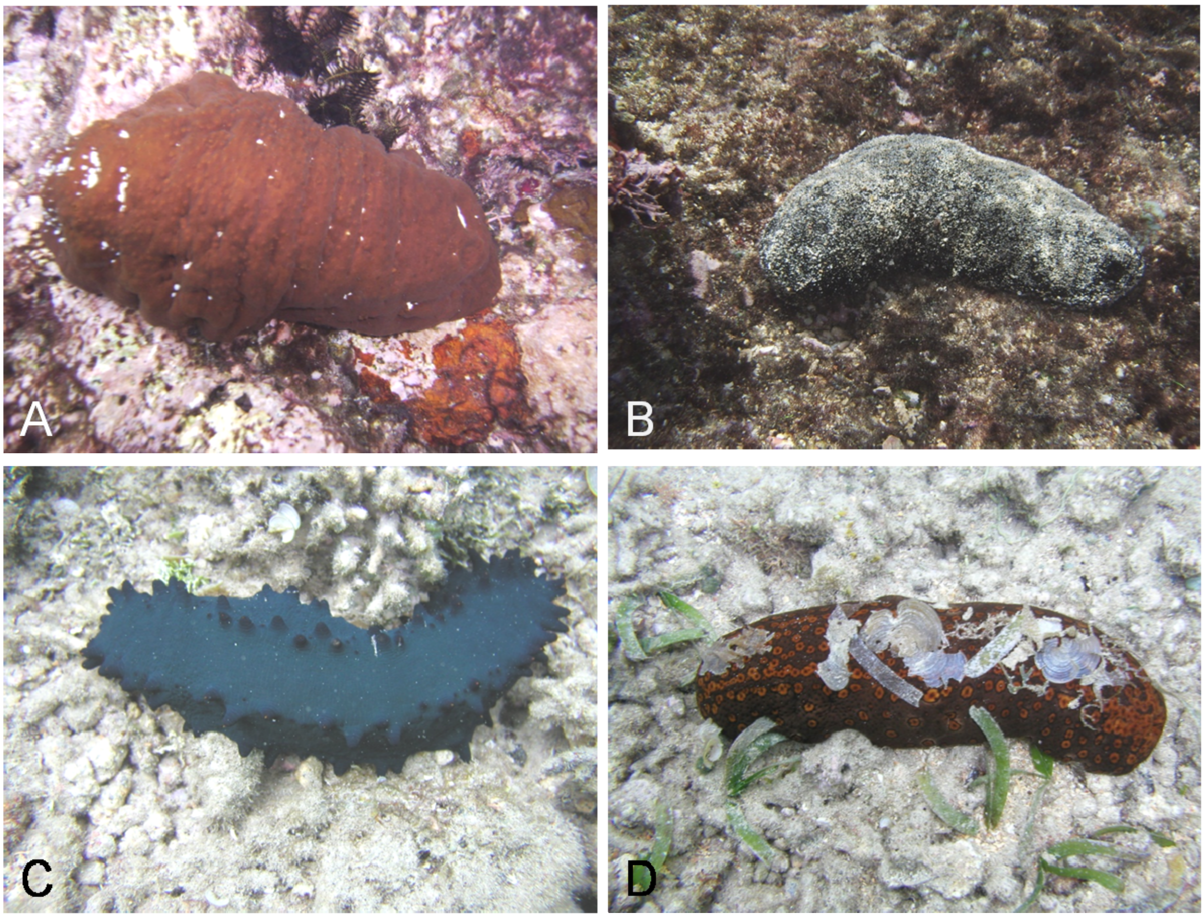

Figure 16: Common commercial sea cucumbers present at Epi sites—*Actinopyga mauritiana* (A), *Holothuria whitemaei* (B), *Stichopus chloronotus* (C) and *Bohadschia argus* (D)

5.7 Environmental parameters

5.7.1 Coral cover

Coral growth on Epi is very impacted globally, with dead coral substratum forming a large proportion of bottom composition in all the sites assessed. Live-coral cover was relatively low (less than 20%) at the western sites of Mavelao-Valesdir, Burumba, Bonkovio-Brisbane and Lamen Bay (Figure 17). Live coral at Mapuna Bay was healthier, with 33% coverage and a relatively larger number of finfish (Figure 18D). Dead coral, which is comprised of present and past dead corals, dominates the bottom cover, making up 40% to 70% of the substrate composition at all the sites (Figure 17, Figure 18A). Presence of dead but intact coral heads and recently killed ones could be directly linked to the existing crown-of-thorns starfish (*Acanthaster planci*) outbreak on the western reefs of Epi.

Pavement was also a significant substratum type (Figure 17, Figure 18B) associated with the fringing platform reef of Epi. Pavement, together with dead coral substratum, provides grazing space for trochus and other gastropods. Although crown-of-thorns starfish predation is a tragedy for the reef, this event seems to be beneficial for trochus and other grazing gastropods. Corals, like other invertebrates, compete for space and, in some cases, can totally dominate the biome.

With the death of the corals, space is freed for other invertebrates to colonise the bottom. When that happens, trochus find a lot more niches and a lot more epiphytes growing on the dead corals to graze upon.

5.7.2 Crown-of-thorns starfish

The coral-eating crown-of-thorns starfish (*Acanthaster planci*) is a serious problem at the western reefs of Epi (Figure 18C). Crown-of-thorns starfish was the invertebrate species recorded second most often (213 specimens) on Epi, after *Trochus niloticus*. Between 40 and 60 specimens per site were recorded at Mavelao-Valesdir, Burumba, Bonkovio-Brisbane and Lamen Bay, while none was recorded at Mapuna. The eastern side of the island is currently not affected by this outbreak. This may have been prevented by westward currents over the northern tip of the island generated by southeast winds. Larvae originating from the northern tip of the island at Lamen Bay are prevented from entering the east side of the island. However, the coral predators could slowly move eastward from aggregations at the northern tip, and this could mean disaster for corals on the east coast.

Crown-of-thorns starfish can become very destructive to live coral cover if densities become higher than natural, as one starfish can devour as much as 2–6 m^2/year of coral. These starfish begin to eat coral at about six months of age (1 cm), and grow over two years to about 25 cm in diameter. During a severe outbreak, there can be several crown-of-thorns starfish per m^2, and they can kill most of the living coral in an area of reef, reducing coral cover from the usual 25%–40% of the reef surface to less than 1%. The reef can take up to a decade to recover.

Table 7: Total *Acanthaster planci* density per site on Epi

Site	*Density*	*SE*	*% of stations with crown-of-thorns starfish*
Bonkovio-Brisbane	356	147	10/10=100%
Burumba	264	47	10/13=100%
Lamen Bay	45	16	8/13=62%
Mapuna Bay	0	0	0/5=0%
Mavelao-Valesdir	292	99	6/8=74%

Crown-of-thorns starfish was recorded at 100% of stations at Bonkovio-Brisbane and Burumba, at 74% of stations at Mavelao-Valesdir, and at 62% of stations at Lamen Bay, while, notably, none was recorded at Mapuna. These high densities are indicative of a general active outbreak. On the Great Barrier Reef of Australia, the following system is used for defining outbreaks of crown-of-thorns starfish:

Incipient outbreak: the density at which coral damage is likely. Occurs when there are 0.22 adults recorded per two-minute manta tow; or more than 30 adults and sub-adults per ha using scuba diving counts. (Starfish may be mature at two years or at a size of 20 cm diameter, but for the definition of an outbreak, a size of greater than 26 cm is used.)**.** ***Active outbreak***: crown-of-thorns densities are greater than 1.0 adults per two-minute manta tow or, if scuba diving, greater than 30 adult starfish per ha.

The outbreak in Epi may have been recent, but has devastated live coral growth in the area. Crown-of-thorns starfish are still present in dead coral areas in high densities, suggesting that they may change their diet to algae or micro-organisms other than coral polyps when live corals become limited (young Acanthaster planci feed on algae until about six months of age (Niles, 2003).

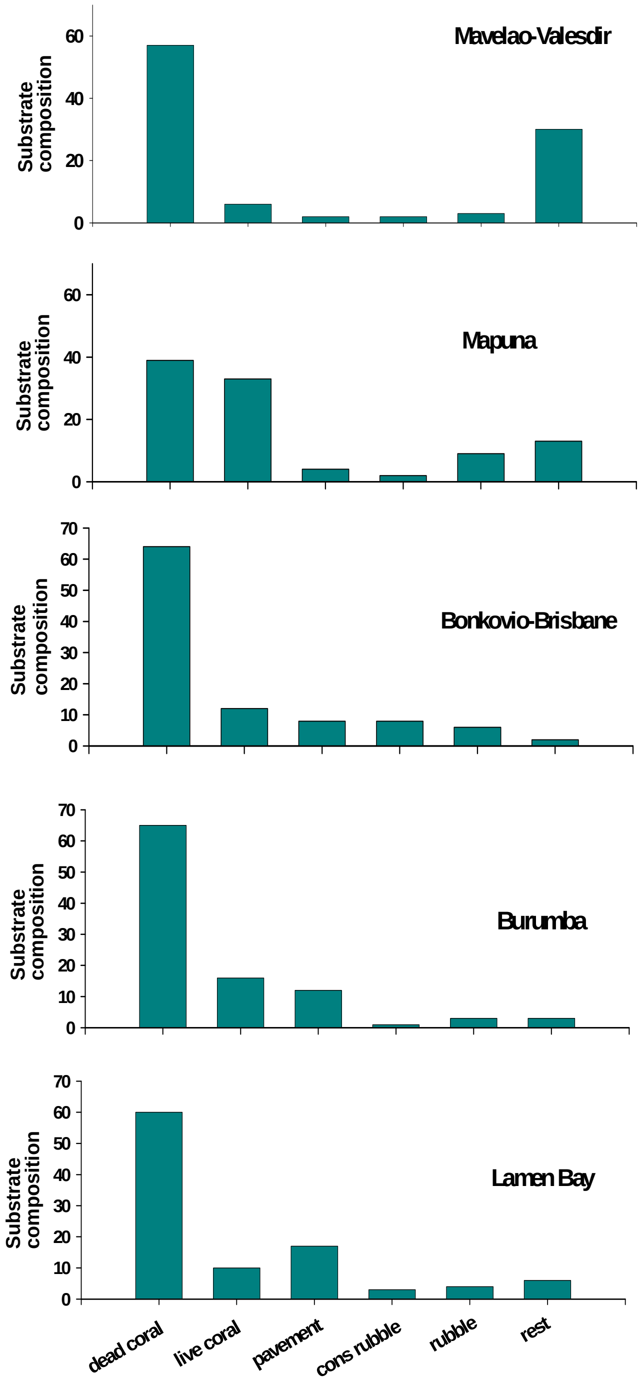

Figure 17: Average substrate composition at Epi sites to show status of habitat condition supporting trochus and the general health of live coral

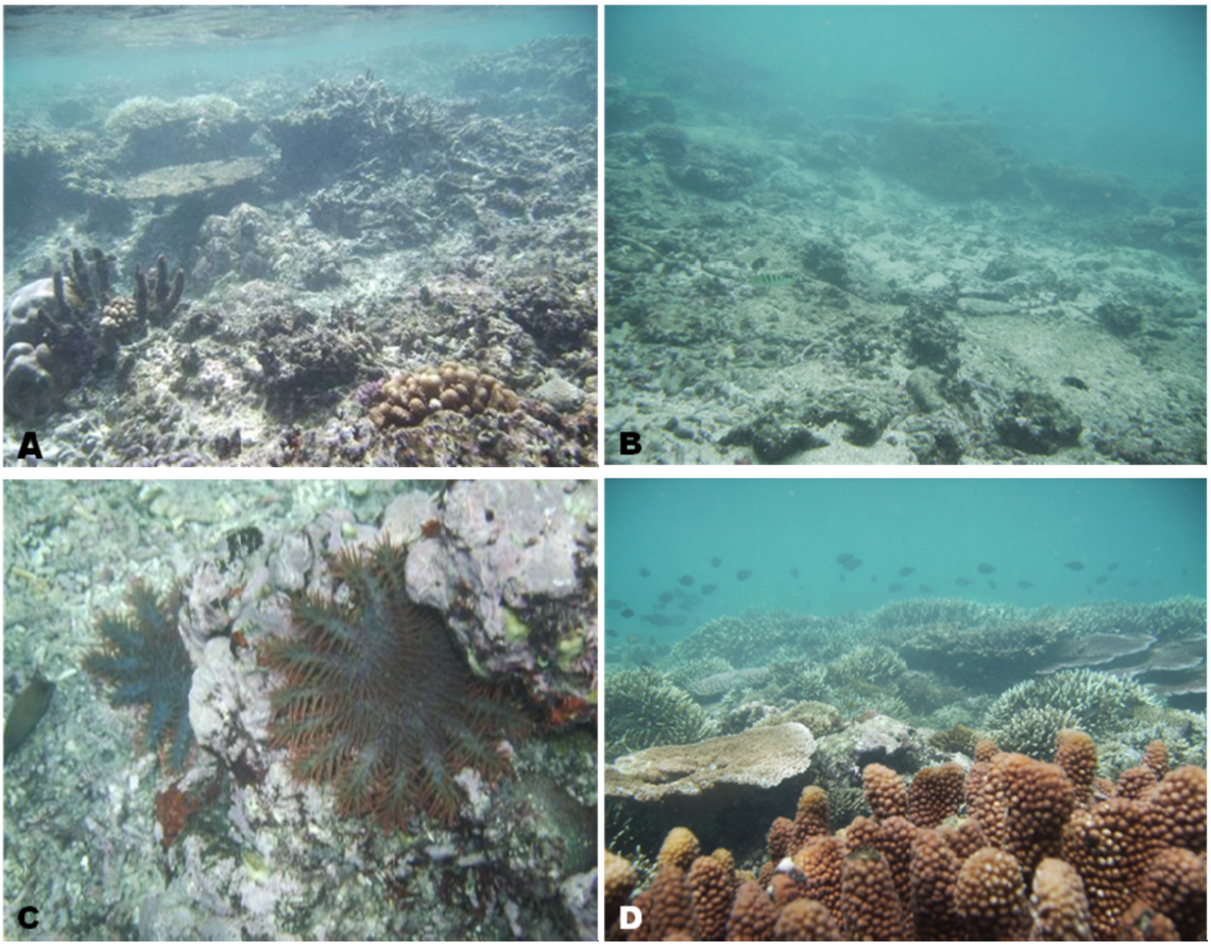

Figure 18: Habitat characteristics at Epi sites—dead coral substratum dominant at most Epi sites (A), pavement substratum also common (B), crown-of-thorns starfish common on all western reefs of Epi (C), healthier live coral cover with good fish numbers at Mapuna on the east coast (D)

6. Summary of results and recommendations

6.1 Summary of Trochus niloticus *results*

- *Trochus niloticus* are endemic to Vanuatu, but the lack of extensive rubble backreef in more protected locations on Epi and the level of exposure of fringing reef, with limited areas of shallow shoaling reefslope, somewhat restrict the potential for both juvenile settlement and adult growers of this commercial species.

- *Trochus niloticus* were commonly recorded across available reef at all the sites sampled. The distribution of trochus was not even across the reef platforms, crests and slope habitats, with larger aggregations on the reef platforms. Commercial stocks are easily accessible at these shallow water locations, and susceptible to both fishing and storm events.

- The density of trochus noted in the survey suggests that stocks are relatively healthy, but 'core' aggregations (where trochus are typically in greatest abundance) have significant potential for further growth to increase the overall abundance and the size of the individual shells.

- Size class information reveals that past harvests have not comprehensively fished out all the large size classes of the stock, which is important for sustainability, as the largest individuals of the population produce a disproportionately large number of eggs, and their eggs are larger and more viable (13 cm trochus produce three times as many eggs as 10 cm trochus). Trochus only reach the larger mature size classes at 6 or more years of age, and therefore any trochus fishery needs to have strict controls in place to ensure there are sufficient females (at high enough densities with males), to ensure good rates of egg fertilization, and the potential for good settlement of juveniles.

- Size class information also reveals that juvenile trochus, although cryptic, are well represented at most sites across Epi. Young trochus were detected in all site surveys (32% of shells measured less than 8 cm), and this provides a positive signal for upcoming recruitment into the fishery. The number recorded, although lower than the actual figure present, due to the cryptic nature of the smaller size classes, is sufficient to indicate whether a strong class of juveniles is entering the fishery (first maturity of trochus is at 7–8 cm, which corresponds to approximately 3 years of age). In this case, both Bonkovio-Brisbane and Burumba both had especially good settlement and survival of juveniles from the spawning period in late 2006 to early 2007.

- Trochus population in Epi is dominated by relatively young trochus shells, with mean basal diameter at 9.3 cm ± 0.1 SE (just above the legal harvestable size of 9.0 cm). This is indicative of the impact of continued fishing of trochus larger than 9 cm. However, larger sizes still dominate overall size composition at each site apart from Bonkovio-Brisbane, which is the only site with a lower density of larger animals.

- A relatively low percentage of stock recorded (less than 16%) are within the newly legislated upper legal size limit (13 cm or larger), indicating that the new upper size limit is too high and does not protect a sufficient larger breeding population. In addition, larger trochus (over 11 cm) are highly susceptible to shell infection and the thick shell wall of larger animals is known to reduce the quality of blank button cuts. Reducing this upper size limit by one or two centimetres (to 12 or 11 cm) could be more effective. For example, if a capture size class of 8–11 cm is employed (as in other Pacific Island regulations), then only 29% of the stock falls in the fishable range, while the rest of the stock is protected.

- Trochus shells recorded on Epi in this survey show normal growth. Stocks are healthy and the stunted stocks recorded at Bonkovio-Brisbane (Vanuatu Fisheries Department 1996) have disappeared. Heavy fishing of the stock has thinned down the population, allowing more grazing space for the new population to grow normally.

- Looking at the status of the fishery across the sites, trochus at Burumba and Bonkovio-Brisbane recorded densities above 500 per ha, which qualifies these sites to be within sustainable harvest levels. However, despite high density at Bonkovio-Brisbane, less than 30% of the stock are within the legal size class (larger than 9 cm), while over 70% are under that size, meaning that fishing of this stock would not be in the best interest of resource sustainability if stocks are to be protected to support further replenishment of the fishery.

- Amalgamating trochus density for all sites resulted in densities just below the minimum sustainable harvest level. Amalgamated data is useful when assessing the resource level for Epi as a whole, which is relevant for management. However, strong recruitment at all the sites indicates potential for strong recoveries with stricter management.

6.2 Summary for sea cucumber results

- Four sea cucumber species are important on Epi: the high-value black teatfish (*H. whitemaei*); the medium-value surf redfish (*Actinopyga mauritiana*), greenfish (*S. chloronotus*) and leopardfish (*B. argus*); urf redfish and leopard fish were well distributed in the five sites, while greenfish was more important in the west coast reefs where water conditions are normally calm. The only place where all nine sea cucumber species were recorded was in Lamen Bay. Greenfish is present in the highest density, at over 1000 per ha, while the other species were present at relatively low density. Sea cucumber densities on Epi are not as high as those in other Pacific Island sites.

6.3 Summary for giant clam results

- Only two species of giant clams (*Tridacna maxima* and *Tridacna crocea*) were record on Epi, dominated by *Tridacna maxima*. *Tridacna maxima* densities recorded during this survey were lower than the ones recorded at Uri-Uripiv and Maskelynes by PROCFish, but in a similar range (20–40 per ha) as at Paunagisu and Moso. Giant clam habitat on Epi is too restricted to support a large diversity of giant clams.

6.4 Summary of reef habitat condition

- Reefs along the west coast of Epi are less attractive, with relatively poor coral cover, and are influenced by siltation from rivers and stream runoff. Coral cover at Mavelao, Burumba, Bonkovio-Brisbane and Lamen Bay was less than 20%, while corals at Mapuna were more healthy, with 33% live coral cover, and supported a moderate finfish population. The coral-eating crown-of-thorns starfish is a pest of live coral on west coast reefs contributing to the high loss of live corals, but it is absent at Mapuna on the east coast.

6.5 Recommendations for management

6.5.1 *Trochus niloticus*

- The natural reef habitat conditions found on Epi were suitable for trochus, but not extensive, and lack the full range of conditions that are needed to support a large stable trochus fishery. The lack of scale or deficiencies in the range of cryptic habitats could mean that settlements may be more irregular or susceptible to storm events than would be the case in larger, more complex reef systems. Resource custodians and fisheries managers will have to apply extra management protocols to ensure they protect the spawning mass of the available stocks.

- Trochus density on Epi island is below the minimum sustainable fishable threshold of 500 per ha. Any fishing at this stage will only further reduce the existing population to levels where strong recovery becomes difficult due to a reduced population of spawners. Fisheries managers and resource custodians might consider attempting to get most of the 'core' fishery areas up to or above a threshold density of at least 500–600 per ha before any commercial fishing can be considered.

- Trochus fisheries at the five Epi sites are receiving active recruitment, and therefore once threshold levels (500–600 per ha) are reached, and this situation still prevails (20% or more of shells measuring over 8.0 cm), then harvests can be considered.

- For each of the sites to successfully get its fishery up to the minimum sustainable harvest threshold of 500 per ha or above, fisheries managers and resource custodians may have to look at whole island based fishery management as opposed to the current system of individual village and clan based management. This would be the best solution to assist uniform recoveries at all the sites.

- The reefs of Burumba and Bonkovio-Brisbane have the potential to support higher densities of trochus than they currently do, and resting fishing would be an investment to help increase production to near former levels.

- A rule of thumb harvest policy of 150 shells per core fishery hectare per year (or roughly 120 shells per football field sized reef area) might be appropriate for managing trochus fisheries. Due to the narrowness of the area and small scale of the supporting system, a more conservative approach might be taken on Epi.

- The newly introduced upper size limit of 13 cm is too high and does not protect a sufficiently large breeding population. Fisheries managers might consider reducing this upper limit to 11 cm to protect larger spawners (11 cm and up), which can have poor shells for blank cutting (due to boring sponge) but good spawning capacity. Consideration should also be given to reducing the current 9 cm lower size limit to 8 cm to give a 3 cm window (8–11 cm) harvest range to establish a 'gauntlet' fishery for maximum protection of both juveniles and of the larger breeding stocks.

- Harvest monitoring by fishery managers is an essential part of a fishing activity but to date has not been carried out. Harvest monitoring is highly recommended for Epi to ensure fishers are taking only harvestable sizes and are returning illegal sized shells while they are alive and healthy back to sea at original locations. Good monitoring facilitates good data collection and reporting and sound decision making.

- The existing ban on the export of raw shell, which restricts the buying of shells only to local processing factories, is proving to be disadvantageous to resource owners on Epi. The policy prevents competition in pricing, preventing resource owners from getting the best price for their shells. Fisheries managers should consider reviewing the policy banning raw shell exports to open up the market to promote better prices. Opening the market might give the resource owners of Epi the opportunity to sell their trochus shells at a better price .

- The traditional method for extracting the meat is to boil the trochus, which affects the shell nacre and thus reduces the quality of the shell. Raw meat extraction methods used in other Pacific Island trochus fisheries should be promoted in Vanuatu. The sale of trochus meat would be another added value.

- Local processing of the shell into button blanks is a wasteful practice and thus is NOT the most efficient economic policy. The factory must cut 10 mt of raw shell to produce only 1 mt of button blanks, of different grades; Vanuatu is therefore receiving a lower total economic return than it could expect from the export of raw shells. In other words, processing reduces 9 mt of valuable shell to second and third grade products and unutilized waste products such as powder and unused pieces. Exporting the whole shell reduces waste, encourages efficient utilization of the raw material and creates better income flow to resource owners.

- The local shell price of VT200–370 (US $1.74–3.22) a kilo has been stagnant for the last 20 years or so. In the Pacific Islands, local trochus shell prices have ranged from US $3.00 to $6.00 per kg. In some countries and territories, such as Palau and Yap State in the Federated States of Micronesia, trochus have been sold to traders alive (with meat), raising the value of the shell in terms of the overall shell weight. Resource owners in Epi have been prevented from receiving internationally competitive prices for their trochus shell. This puts extra pressure on the resource as fishers harvest more to satisfy their needs. Fisheries managers should consider opening the market to better offers (regionally and internationally) to attract better product valuation and prices so that resource owners get maximum value from their resource.

- The continued existence of the local market is undermining both community and national government management efforts in Epi. For instance, trochus transplanted to Mapuna Bay in 2003 (with the help of significant government funding) were harvested and sold to the factory agent in 2007, reducing the spawning stocks to pre-introduction levels. Enforcement of taboos has weakened in all communities, because trochus could be fished and sold almost daily in the last few years. Fisheries managers should consider closing down the fishery in the whole country, as has been done for the sea cucumber fishery, to cut off market forces and realistically rest the fishery. A moratorium assures total compliance, creating a healthy environment for the resource to rebuild itself to a sustainable level at relatively little cost to both the government and resource custodians.

- Removal of trochus broodstock from Lamen Bay (400 shells) for transplantation to Mapuna Bay and from Mavelao-Valesdir (1000 shells) for translocation to Samoa in 2003 might have been unsustainable. The introduced trochus at Mapuna Bay were harvested in 2007, defeating the whole purpose of the activity and resulting in failures for both communities (loss of trochus for both areas). A sustainable translocation should not destabilize the donating fishery and maximum protection must be provided at the receiving end. Removal of trochus from Epi should be discouraged at all costs because it is not a sustainable practice.

- The resulting low density of trochus at Mapuna Bay failed to indicate any obvious long term improvements in the status of trochus resources as a result of the ACIAR/VFD trochus transplantation and recruitment study (Jimmy and Amos 2004). Fisheries managers must establish maximum protection measures to allow research studies to deliver best results that can be used for management decisions and to justify the high costs of running research and development activities.

- Some communities on Epi have requested reseeding with hatchery bred juvenile trochus for restocking purposes. Restocking with hatchery bred trochus is an unproven method of replenishing a natural trochus population; therefore the technique should not be used or promoted as a source of restocking the wild fishery until it has been proven to work.

- Development of a national trochus fishery management plan and monitoring programme is urgently needed to guide sustainable management and utilisation of the fishery.

- The participation of local trainees Jason Raubani and Sompert Gereva was effective. Both staff have acquired skills needed to conduct similar surveys in other areas in the country and should be consulted for advice when planning similar surveys. It would be also helpful that SPC Reef Fisheries Observatory team (invertebrate assessment team) is notified of future survey plans in Vanuatu so that other advices can be provided if necessary.

6.5.2 Sea cucumber

- The decision to place a moratorium on sea cucumber fishing is a good one. Closing the fishery allows for total compliance, ensuring recovery of the fishery and community stability with regard to sea cucumber management. Awareness and education regarding the moratorium need to be disseminated widely through the communities.

- A national sea cucumber fishery management plan and monitoring programme should be developed to guide use of the fishery by the communities, control exports, and provide much needed information to fisheries managers.

6.5.3 Crown-of-thorn starfish

- The coral-eating crown-of-thorns starfish outbreak is a real problem on West Epi reefs. Current density is above natural density, and the limited live corals in these areas have been almost wiped out by crown-of-thorns predation. The presence of this high crown-of-thorns aggregation can directly affect settlement and development of new coral colonies. Responsible government agencies and non-governmental organisations, in collaboration with Epi communities, should take the necessary steps to remove crown-of-thorns starfish from the reefs as a matter of urgency.

6.5.4 Community consultation and concerns

- The chiefs and village elders from the five villages (Figure 19) were concerned about the declining state of their trochus fishery and possible future loss of one of their main sources of income. The weakening of community taboos that had been assisted by continuous buying of shells, declining respect for the traditional system and demand for income were the main causes of the reduction of trochus in the five villages.

- The chiefs and villages elders of Epi wanted to see the national government, through the VFD, take global action to control the trochus fishery, as they themselves do not have any power to stop buyers from buying shells or their people from selling trochus. They said the best option for them would be for the government to close the fishery for the whole country for some years so that the people of Epi would have no other means of selling their trochus. This, they believe, would allow the resource to rebuild without any disturbance. Closing the fishery could be helpful for them in strengthening their local management system in terms of cutting out trochus shell market influence, which has been seen as a source of disregard and disunity regarding the central village taboos and a source of overall weakening of the system.

- The five villages have other important sources of income, such as kava, copra, peanuts, root crops, and domesticated animals and fish, which are exported to Port Vila markets. These alternative activities are more important nowadays than trochus in supporting the villagers. Therefore, closing the trochus fishery in Epi for the purpose of management would not affect their current income activities and thus would not be a concern for them.

Figure 19: Village chiefs and elders from Moriu, Lamen Bay and Lamen Island, Bonkovio, Burumba, and Mavelao who were present at the consultation meeting at Lamen Bay representing 70% of trochus fishing communities on Epi

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Appendices:

Appendix 1: Trochus export production from Vanuatu 1969–2006

Year	mt	Year	mt
1969	2.0	1988	86.0
1970	7.0	1989	100.0
1971	31.0	1990	170.0
1972	71.0	1991	130.0
1973	56.0	1992	150.0
1974	88.0	1993	160.0
1975	170.0	1994	107.0
1976	213.0	1995	56.0
1977	102.0	1996	84.0
1978	271.0	1997	78.0
1979	37.0	1998	104.5
1980	54.0	1999	496.8
1981	49.0	2000	0.0
1982	50.0	2001	73.0
1983	0.0	2002	67.0
1984	0.0	2003	53.0
1985	75.0	2004	35.6
1986	75.0	2005	36.0
1987	67.0	2006	36.0

Appendix 2: Invertebrate species present on Epi

Species group	Species	Species group	Species
Bêche-de-mer	*Stichopus chloronotus*	Gastropod	*Turbo argyrostomus*
Bêche-de-mer	*Thelenota ananas*	Gastropod	*Turbo crassus*
Bêche-de-mer	*Actinopyga mauritiana*	Gastropod	*Vasum ceramicum*
Bêche-de-mer	*Actinopyga lecanora*	Octopus	*Octopus cyanea*
Bêche-de-mer	*Actinopyga miliaris*	Star	*Acanthaster planci*
Bêche-de-mer	*Bohadschia argus*	Star	*Culcita novaeguineae*
Bêche-de-mer	*Bohadschia graeffei*	Star	*Linckia laevigata*
Bêche-de-mer	*Holothuria atra*	Urchin	*Echinometra mathaei*
Bêche-de-mer	*Holothuria whitemaei*	Urchin	*Echinothrix diadema*
Bivalve	*Tridacna maxima*	Urchin	*Heterocentrotus mammillatus*
Bivalve	*Tridacna crocea*		
Cnidarians	*Stichodactyla sp.*		
Crustacean	*Panulirus versicolor*		
Gastropod	*Cerithium nodulosum*		
Gastropod	*Conus emaciatus*		
Gastropod	*Conus lividus*		
Gastropod	*Conus sp.*		
Gastropod	*Cypraea caputserpensis*		
Gastropod	*Cypraea annulus*		
Gastropod	*Cypraea moneta*		
Gastropod	*Cypraea mauritiana*		
Gastropod	*Dendropoma sp.*		
Gastropod	*Drupa morum*		
Gastropod	*Lambis truncata*		
Gastropod	*Latirolagena smaragdula*		
Gastropod	*Tectus pyramis*		
Gastropod	*Thais aculeata*		
Gastropod	*Trochus niloticus*		
Gastropod	*Trochus sp.*		
Gastropod	*Trochus maculata*		
Gastropod	*Turbo chrysostomus*		

Appendix 3: Reef-benthos transect (RBt) assessment data review (Lamen Bay)

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	41.0	16.7	61	357.1	74.3	7	42.5	14.0	9	63.8	14.1	6
Actinopyga mauritiana	8.2	5.7	61	250.0	0.0	2	7.7	5.2	9	34.7	6.9	2
Bohadschia argus	102.5	34.3	61	568.2	112.3	11	114.2	82.6	9	256.9	169.4	4
Bohadschia graeffei	8.2	5.7	61	250.0	0.0	2	9.3	9.3	9	83.3		1
Conus lividus	4.1	4.1	61	250.0		1	3.1	3.1	9	27.8		1
Conus sp.	4.1	4.1	61	250.0		1	4.0	4.0	9	35.7		1
Culcita novaeguineae	4.1	4.1	61	250.0		1	4.6	4.6	9	41.7		1
Cypraea annulus	4.1	4.1	61	250.0		1	4.6	4.6	9	41.7		1
Cypraea caputserpensis	4.1	4.1	61	250.0		1	3.1	3.1	9	27.8		1
Cypraea moneta	4.1	4.1	61	250.0		1	3.1	3.1	9	27.8		1
Dendropoma sp.	45.1	22.3	61	550.0	145.8	5	38.6	19.3	9	115.7	4.6	3
Echinometra mathaei	536.9	147.4	61	1,637.5	338.1	20	543.2	266.5	9	814.8	355.3	6
Echinothrix diadema	16.4	9.9	61	333.3	83.3	3	17.2	9.1	9	51.6	9.9	3
Holothuria atra	65.6	19.3	61	333.3	47.0	12	71.0	23.9	9	106.5	24.8	6
Holothuria nobilis	16.4	8.0	61	250.0	0.0	4	17.9	9.9	9	53.6	15.0	3
Lambis truncata	12.3	7.0	61	250.0	0.0	3	13.9	9.8	9	62.5	20.8	2
Latirolagena smaragdula	53.3	24.2	61	650.0	100.0	5	49.4	33.0	9	222.2	27.8	2
Linckia laevigata	303.3	91.5	61	660.7	178.3	28	332.0	192.4	9	332.0	192.4	9
Panulirus versicolor	16.4	8.0	61	250.0	0.0	4	13.9	7.3	9	41.7	8.0	3
Stichodactyla sp.	12.3	9.1	61	375.0	125.0	2	12.6	8.7	9	56.5	14.9	2
Stichopus chloronotus	1217.2	287.0	61	1,767.9	389.1	42	1,277.3	653.1	9	1,437.0	718.0	8
Tectus pyramis	36.9	25.4	61	562.5	312.5	4	41.7	26.9	9	93.8	52.1	4
Tridacna maxima	41.0	11.9	61	250.0	0.0	10	42.8	15.2	9	64.2	16.7	6
Trochus niloticus	188.5	38.2	61	460.0	60.7	25	183.9	51.0	9	206.8	51.6	8
Trochus sp.	28.7	10.3	61	250.0	0.0	7	27.8	10.1	9	50.0	9.4	5
Turbo argyrostomus	20.5	12.1	61	416.7	83.3	3	20.1	10.6	9	60.2	12.2	3
Turbo crassus	4.1	4.1	61	250.0		1	3.1	3.1	9	27.8		1
Vasum ceramicum	20.5	8.9	61	250.0	0.0	5	18.7	9.7	9	56.2	8.6	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

Appendix 4: Reef-benthos transect (RBt) assessment data review (Mapuna)

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	108.3	35.3	30	361.1	60.5	9	108.3	46.8	5	180.6	27.8	3
Holothuria nobilis	25.0	18.4	30	375.0	125.0	2	25.0	16.7	5	62.5	20.8	2
Latirolagena smaragdula	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Panulirus versicolor	16.7	11.6	30	250.0	0.0	2	16.7	16.7	5	83.3		1
Stichodactyla sp.	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Tridacna maxima	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Trochus maculata	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Trochus niloticus	225.0	63.8	30	482.1	99.7	14	225.0	84.0	5	225.0	84.0	5
Turbo argyrostomus	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Vasum ceramicum	16.7	16.7	30	500.0		1	16.7	16.7	5	83.3		1
Actinopyga mauritiana	108.3	35.3	30	361.1	60.5	9	108.3	46.8	5	180.6	27.8	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

Appendix 5: Reef-benthos transect (RBt) assessment data review (Bonkovio-Brisbane)
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	516.7	126.8	30	815.8	165.4	19	516.7	288.6	5	516.7	288.6	5
Actinopyga mauritiana	75.0	27.2	30	321.4	46.1	7	75.0	30.6	5	93.8	31.3	4
Bohadschia argus	66.7	31.6	30	400.0	100.0	5	66.7	48.6	5	166.7	83.3	2
Cerithium nodulosum	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Conus sp.	16.7	11.6	30	250.0	0.0	2	16.7	10.2	5	41.7	0.0	2
Cypraea caputserpensis	16.7	16.7	30	500.0		1	16.7	16.7	5	83.3		1
Echinometra mathaei	1450.0	388.3	30	2,558.8	552.2	17	1,450.0	650.5	5	1,450.0	650.5	5
Echinothrix diadema	75.0	66.9	30	1,125.0	875.0	2	75.0	75.0	5	375.0		1
Heterocentrotus mammillatus	216.7	76.5	30	812.5	147.5	8	216.7	158.9	5	361.1	241.0	3
Holothuria atra	16.7	11.6	30	250.0	0.0	2	16.7	10.2	5	41.7	0.0	2
Holothuria nobilis	25.0	13.9	30	250.0	0.0	3	25.0	16.7	5	62.5	20.8	2
Linckia laevigata	75.0	24.4	30	281.3	31.3	8	75.0	27.6	5	93.8	26.2	4
Stichodactyla sp.	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Stichopus chloronotus	1041.7	253.7	30	1,488.1	316.5	21	1,041.7	499.5	5	1,302.1	550.2	4
Tectus pyramis	108.3	35.3	30	361.1	60.5	9	108.3	50.3	5	135.4	54.8	4
Trochus niloticus	833.3	140.0	30	1,041.7	146.4	24	833.3	228.6	5	833.3	228.6	5
Trochus sp.	16.7	11.6	30	250.0	0.0	2	16.7	10.2	5	41.7	0.0	2
Turbo argyrostomus	41.7	17.3	30	250.0	0.0	5	41.7	22.8	5	69.4	27.8	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

Appendix 6: Reef-benthos transect (RBt) assessment data review (Burumba)
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	291.7	58.4	42	532.6	75.9	23	291.7	84.8	7	291.7	84.8	7
Actinopyga mauritiana	113.1	33.2	42	395.8	65.0	12	113.1	49.6	7	197.9	54.8	4
Conus emaciatus	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
Conus lividus	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
Conus sp.	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
Cypraea annulus	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
Cypraea moneta	11.9	11.9	42	500.0		1	11.9	11.9	7	83.3		1
Echinometra mathaei	59.5	28.0	42	416.7	123.6	6	59.5	32.6	7	83.3	41.7	5
Heterocentrotus mammillatus	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
Holothuria atra	41.7	18.9	42	350.0	61.2	5	41.7	24.1	7	97.2	36.7	3
Latirolagena smaragdula	339.3	71.7	42	712.5	96.4	20	339.3	114.1	7	475.0	105.9	5
Linckia laevigata	17.9	10.1	42	250.0	0.0	3	17.9	8.4	7	41.7	0.0	3
Panulirus versicolor	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
Stichopus chloronotus	23.8	14.3	42	333.3	83.3	3	23.8	15.4	7	83.3	0.0	2
Tectus pyramis	53.6	18.1	42	281.3	31.3	8	53.6	17.5	7	75.0	15.6	5
Thais aculeata	29.8	15.2	42	312.5	62.5	4	29.8	15.0	7	69.4	13.9	3
Tridacna maxima	11.9	8.3	42	250.0	0.0	2	11.9	7.7	7	41.7	0.0	2
Trochus niloticus	922.6	135.4	42	1,107.1	143.2	35	922.6	240.1	7	922.6	240.1	7
Trochus sp.	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
Turbo argyrostomus	29.8	15.2	42	312.5	62.5	4	29.8	17.5	7	69.4	27.8	3
Vasum ceramicum	11.9	8.3	42	250.0	0.0	2	11.9	7.7	7	41.7	0.0	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

Appendix 7: Reef-benthos transect (RBt) assessment data review (Mavelao-Valesdir)
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	433.3	78.5	30	565.2	85.0	23	433.3	118.3	5	541.7	61.3	4
Actinopyga mauritiana	33.3	15.8	30	250.0	0.0	4	33.3	24.3	5	83.3	41.7	2
Conus sp.	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Cypraea annulus	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Cypraea mauritiana	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Echinometra mathaei	191.7	81.0	30	718.8	218.8	8	191.7	97.4	5	239.6	109.4	4
Echinothrix diadema	200.0	78.1	30	750.0	189.0	8	200.0	71.4	5	250.0	65.9	4
Heterocentrotus mammillatus	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Latirolagena smaragdula	666.7	116.4	30	1,000.0	116.1	20	666.7	238.3	5	666.7	238.3	5
Linckia laevigata	25.0	18.4	30	375.0	125.0	2	25.0	25.0	5	125.0		1
Panulirus versicolor	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Tectus pyramis	16.7	11.6	30	250.0	0.0	2	16.7	10.2	5	41.7	0.0	2
Thais aculeata	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Tridacna maxima	41.7	21.0	30	312.5	62.5	4	41.7	22.8	5	69.4	27.8	3
Trochus maculata	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Trochus niloticus	150.0	35.2	30	346.2	35.1	13	150.0	48.6	5	187.5	39.9	4
Turbo argyrostomus	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Turbo chrysostomus	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Vasum ceramicum	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

Appendix 8: Mother-of-pearl transect (MOPt) assessment data review (Bonkovio-Brisbane)
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	195.8	32.7	30	293.8	30.5	20	195.8	41.5	5	195.8	41.5	5
Actinopyga mauritiana	33.3	13.3	30	166.7	26.4	6	33.3	28.4	5	83.3	62.5	2
Bohadschia argus	4.2	4.2	30	125.0		1	4.2	4.2	5	20.8		1
Echinometra mathaei	145.8	46.8	30	397.7	85.6	11	145.8	31.6	5	145.8	31.6	5
Heterocentrotus mammillatus	166.7	47.7	30	384.6	75.5	13	166.7	74.2	5	277.8	54.2	3
Holothuria atra	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Linckia laevigata	50.0	15.4	30	166.7	20.8	9	50.0	21.4	5	62.5	22.5	4
Panulirus versicolor	8.3	5.8	30	125.0	0.0	2	8.3	5.1	5	20.8	0.0	2
Stichodactyla sp.	8.3	5.8	30	125.0	0.0	2	8.3	5.1	5	20.8	0.0	2
Stichopus chloronotus	29.2	9.8	30	125.0	0.0	7	29.2	8.3	5	36.5	5.2	4
Tectus pyramis	4.2	4.2	30	125.0		1	4.2	4.2	5	20.8		1
Tridacna maxima	25.0	9.3	30	125.0	0.0	6	25.0	7.8	5	31.3	6.0	4
Trochus niloticus	212.5	47.6	30	303.6	57.6	21	212.5	65.7	5	212.5	65.7	5
Turbo argyrostomus	4.2	4.2	30	125.0		1	4.2	4.2	5	20.8		1
Acanthaster planci	195.8	32.7	30	293.8	30.5	20	195.8	41.5	5	195.8	41.5	5
Actinopyga mauritiana	33.3	13.3	30	166.7	26.4	6	33.3	28.4	5	83.3	62.5	2
Bohadschia argus	4.2	4.2	30	125.0		1	4.2	4.2	5	20.8		1
Echinometra mathaei	145.8	46.8	30	397.7	85.6	11	145.8	31.6	5	145.8	31.6	5
Heterocentrotus mammillatus	166.7	47.7	30	384.6	75.5	13	166.7	74.2	5	277.8	54.2	3
Holothuria atra	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Linckia laevigata	50.0	15.4	30	166.7	20.8	9	50.0	21.4	5	62.5	22.5	4
Panulirus versicolor	8.3	5.8	30	125.0	0.0	2	8.3	5.1	5	20.8	0.0	2
Stichodactyla sp.	8.3	5.8	30	125.0	0.0	2	8.3	5.1	5	20.8	0.0	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

Appendix 9: Site mother-of-pearl transect (MOPt) assessment data review (Burumba)
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	232.6	27.8	36	279.2	25.9	30	232.6	28.7	6	232.6	28.7	6
Actinopyga mauritiana	24.3	8.4	36	125.0	0.0	7	24.3	11.3	6	48.6	6.9	3
Conus sp.	10.4	7.7	36	187.5	62.5	2	10.4	7.1	6	31.3	10.4	2
Culcita novaeguineae	3.5	3.5	36	125.0		1	3.5	3.5	6	20.8		1
Echinometra mathaei	17.4	14.2	36	312.5	187.5	2	17.4	13.6	6	52.1	31.3	2
Stichodactyla sp.	6.9	6.9	36	250.0		1	6.9	6.9	6	41.7		1
Thais aculeata	3.5	3.5	36	125.0		1	3.5	3.5	6	20.8		1
Tridacna crocea	3.5	3.5	36	125.0		1	3.5	3.5	6	20.8		1
Tridacna maxima	59.0	29.7	36	265.6	109.4	8	59.0	33.8	6	88.5	44.5	4
Trochus maculata	3.5	3.5	36	125.0		1	3.5	3.5	6	20.8		1
Trochus niloticus	423.6	88.4	36	564.8	104.7	27	423.6	193.2	6	423.6	193.2	6
Trochus sp.	3.5	3.5	36	125.0		1	3.5	3.5	6	20.8		1
Turbo argyrostomus	17.4	8.8	36	156.3	31.3	4	17.4	6.4	6	26.0	5.2	4
Turbo chrysostomus	6.9	6.9	36	250.0		1	6.9	6.9	6	41.7		1
Vasum ceramicum	6.9	4.8	36	125.0	0.0	2	6.9	4.4	6	20.8	0.0	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.