The status of green snail (*Turbo marmoratus*) resource in Vanuatu and recommendations for its management

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by

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Participants and community members involved in green snail resource surveys at Aneityum Island.

Executive summary

Green snail is an important resource in Vanuatu, both as a food item and a commodity. It has, however, been fished to near extinction. The moratorium on commercial harvests and shell exports in 2005 has begun to bear fruit. The results of resource assessment surveys at western Efate reefs and Aneityum Island in September and October 2013 reveal that the species has reappeared on reefs at Takara, Moso, Mangaliliu, Hat Island and Tukutuku Bay. While the southern coast of Efate has yet to be assessed, harvesting activities in these areas are an indication of the recovery of stocks. Wild stock translocations and hatchery-reared juveniles were used in recovery efforts on Efate, and to date, there are signs of replenishment from adult translocations, while reseeding with hatchery-reared juveniles has yet to produce positive results. Poor habitat conditions and or poaching may have caused the loss of adult green snail released at Moso Island. Future translocation or reseeding activities for green snail or trochus should avoid this area of Sunae reef on Moso Island and including the reef of Siviri and Undine Bay.

At Aneityum Island, green snail stock is present on most reef areas around the island. Despite having relatively high number of green snail, there are signs of impacted population of younger shells less than 170 mm shell height which could be the result of continued collection for subsistence which is affecting recruitment rates in shallow water areas. Obviously the green snail population in Aneityum is skewed towards older shells (greater than 170 mm shell height). Larger shells (i.e. those greater than 170 mm shell height) are typically overgrown with calcareous algae and attaching limpets on the exterior of the shell. The interior of older green snail shell is infected by shell boring worms which damaged the quality of the shell. These older shells are stronger breeders and need to be protected by setting a maximum harvest size limit, should the fishery be reopened. The new minimum and maximum harvest size limit proposed here is from 150 mm to 180 mm shell height. Suitable green snail reefs at Mystery Island are restricted to the western section of the reef, and although the area has been protected for over a decade, green snail abundance was lower than at Anelgouhat and Anejo, indicating the importance of reef habitat, which should be considered when planning marine protected areas.

In other areas in the country, green snail has been observed on various areas on Malekula at the Maskelyne Islands, Wiawi Conservation Area, Uripiv Island and Rano Island. Continued assessment surveys are recommended in these areas and including the reefs of Emae, Erromango, Santo and the Banks Islands to identify stocks in those areas. Illegal harvesting of green snail has increased on Efate, Aneityum and in Malekula, which is a concern. Young green snail shells have been harvested for meat and for shell souvenir which are sold at handicraft stalls. Sale of shells at the Port Vila markets increased in 2012 but have ceased. While the enforcement of the ban has been effective in Port Vila, it does not stop subsistence harvesting activities. Awareness and education outreach about the existing total ban on green snail and the need for communities to act to protect green snail and discourage any collecting activities to give existing stocks a chance to fully recover.

Green snail shell and operculum makes a good shell product for the local shell souvenir market. With the growing number of tourism arrivals in Vanuatu, will create increase demand for handicraft products. If commercial fishing for green snail is permitted in the future, it would be in the best interest of local Ni-Vanuatu handicraft sellers that the green snail shell market is protected for domestic markets only. In support of this a total ban on commercial exports of green snail shell products is proposed when the existing ban is reopened.

Vanuatu have supplied live adult green snail to other Pacific Island countries for introduction purposes. However, the need for local adult green snail transplantation has become more important to help with the recovery of depleted stocks. Therefore current effort should focus on rebuilding local green snail populations through transplantation activities using locally available stocks as a matter of priority. Future donation of live stock to other countries should be allowed when the resource has fully recovered and that extraction of stocks should be based stock assessment surveys.

1. Introduction

Green snail (*Turbo marmoratus*) and trochus (*Tectus niloticus*) are the principal gastropod shell resources in Vanuatu. For generations, the meat has been a source of protein while the shell has been used in traditional handicrafts. The sale of green snail shells is an important source of income for coastal communities in areas where the resources are present. Commercial fishing for green snail and trochus started in the late 1800s to early 1900s but was not reported. Shell products from the Pacific Islands were transshipped through Australia where they were stockpiled for export to Asian markets. Production records in Vanuatu became available after World War II, and by the 1970s, the mother-of-pearl (i.e. trochus, pearl oyster and green snail) industry reached peak production when resources were exploited throughout the Australasia and Pacific Islands regions.

In 1967, the government of Vanuatu (formerly the Condominium of the New Hebrides) assisted the government of French Polynesia with the introduction of adult green snails sourced from Efate Island. In 1994, stocks of adult green snail were collected from Aneityum Island and introduced to Tonga for the development of the resource there. However, the lack of effective management of the fishery in Vanuatu led to the collapse of the green snail fishery in 1994. It was not until 10 years later that it became apparent the fishery was no longer productive and needed to be closed. A 15-year moratorium went into effect in 2005 followed by the regulation in 2009. As part of the resource recovery plan, adult green snails were translocated to the main island of Efate from Aneityum Island, which had reasonably healthy stocks to assist with revitalising the resource elsewhere. Hatchery production and re-seeding trials were conducted through the support of the Japan International Cooperation Assistance to assess opportunities to re-develop the resource in depleted areas in the country.

The present assessment, which was conducted mid-way into the moratorium period, was necessary in order to: determine the state of green snail stock recovery on Efate; assess the condition of the stock on Aneityum Island; determine the impact of adult translocations and juvenile reseeding activities; and propose measures needed to assist in the full recovery of the resource. Consultations and underwater surveys were conducted on the islands of Efate and Aneityum in September and October 2013 by a team from the Vanuatu Fisheries Department and respective community members from the two areas, and led by the Secretariat of the Pacific Community (SPC) Coastal Fisheries Science and Management Section's Fisheries Scientist in charge of invertebrate assessments. This report presents the results of these surveys and proposes measures to improve the effective control of the resource so that stocks can recover to healthy levels.

1.1 Green snail biology and distribution

Green snail (*Turbo marmoratus*), or great green turban snail, is the largest species of the gastropod family Turbinidae, and one of the largest herbivorous marine gastropods, growing to 230 mm in shell width and weighing up to 3 kg in live weight (Yamaguchi and Kikutani 1989). Green snails inhabit the forereef zone, which consists of caves and overhangs, and which is impacted by wave action. Juveniles up to 80 mm shell width are found in the subtidal zone within the first five meters of slope, while larger adults over 100 mm are found in deeper water down to 15 m (Kikutani et al. 2002). Cryptic juveniles can be difficult to find but larger adults become too large to hide and can be visible from the surface. Coralline algae and blue-green algae are the main food for green snail although they also feed on other algae such as the red algae.

Green snail has separate sexes and breeding is by external fertilisation of gametes released from male and female green snails. The fertilised eggs develop into larval stages that drift in the sea and then settle onto the sea floor as juveniles within three to five days (Fig. 1). Fertilisation rates are improved when adult male and female snails are clustered together, which reduces the swimming distance for gametes, thereby increasing the chances for fertilisation. In Vanuatu, green snail first reach maturity at 150 mm in shell height (Devambez 1959, 1961) while in the Ryukus Islands in Japan, mature eggs were observed to reach 130 mm shell height (Yamaguchi and Kikutani 1989). It takes up to three to four years for settled juvenile green snails to reach sexually mature sizes

of 130 mm (shell height). Larger shells are more fecund, and a 2-kg female green snail can spawn up to 7 million eggs (Yamaguchi and Kikutani 1989). Green snails prefer surf zones and reef slopes with crevices, ledges and caves. Juvenile green snails hide in crevices and holes within the reef. Adults are less able to hide due to their larger size and move around at night to feed on plants (red and green algae). The natural distribution of the green snail ranges from the western Indian Ocean (Kenya and the Seychelles) to Southeast Asia (Indonesia, Malaysia and the Philippines) and up to the Ryukyu Islands of Southern Japan, and to the western Pacific Islands (Papua New Guinea, Solomon Islands and Vanuatu). Introductions (Fig. 2) have extended the distribution range of green snail as far east as French Polynesia and Tonga (Yamaguchi and Kikutani 1989)[1].

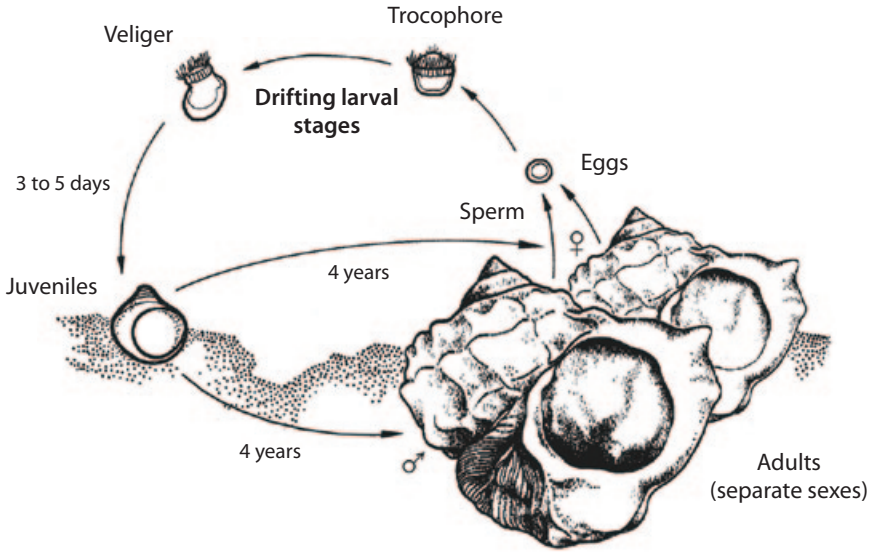

Figure 1. Life cycle of the green snail (Illustration: Mike King).

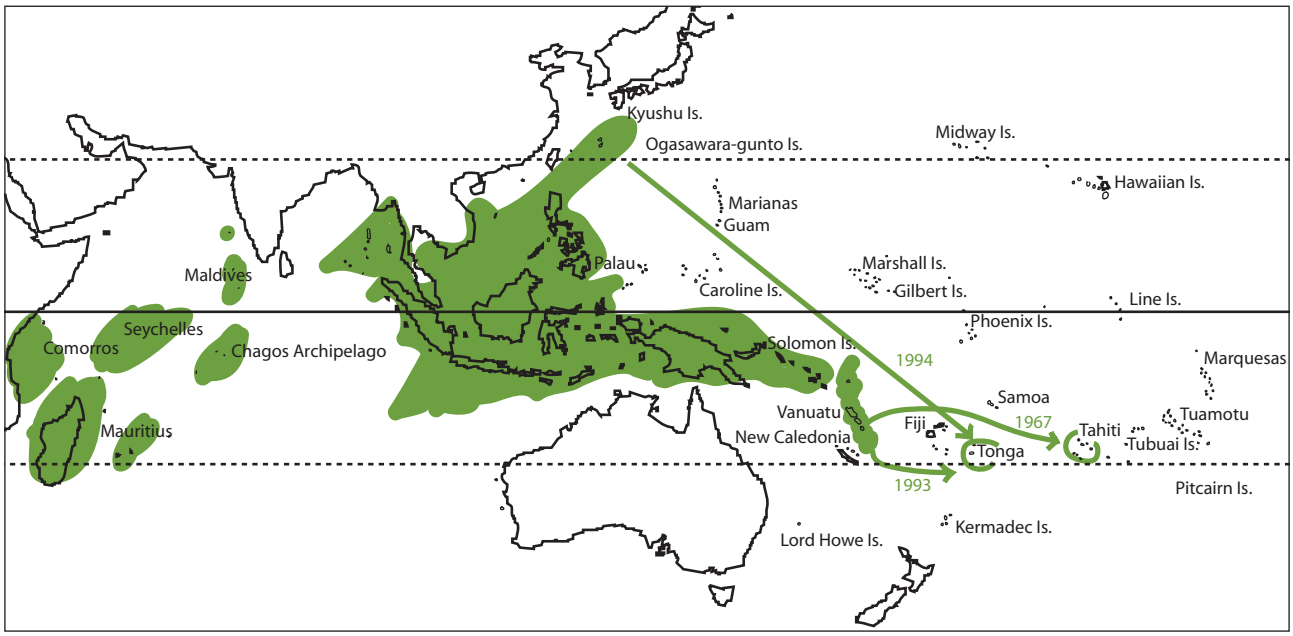

Figure 2. Distribution range of green snail (*Turbo marmoratus*) and introductions in the Pacific Islands region (green arrows) (map from Kikutani et al. 1995).

[1] Different surveys measured the size of green snail in different ways; shell height, widest shell diameter and the widest diameter of the shell operculum.

1.2 Fishing, exports and shell use

Green snail is collected by hand by wading at low tide on the reef crest, and by snorkeling or free diving in outer reef areas. Diving with an underwater breathing apparatus (UBA) is prohibited by the 1989 Vanuatu fishery regulation. UBA may have been used in the past but was not reported. Shells are brought ashore alive in canoes or boat. The main means of extracting the meat is by boiling the shell and removing the meat, which is consumed; although if a large number of green snails are collected, the shells may be buried in sand for some weeks to allow the meat to deteriorate. Shells are then cleaned and left for a few days to dry before they are packed ready for sale. The meat is normally eaten as a source of protein within coastal villages or bartered with inland people or with other islanders. In the past, merchant ships came and purchased the processed shells. The shell (without the operculum) is sold to buyers in bags, which can be kept for some time, to be picked up by the next inter-island ship.

The main green snail production areas in Vanuatu are Aneityum, Erromango, Malekula and Gaua and Vanua Lava (David 1985; Cillaurren et al. 2001). Other areas where green snails have been fished are the Torres Islands, Santo, Malo, Ambae and Maewo, Pentecost, Ambrym, Pamma, Epi, Emae and Efate (Bell and Amos 1994). The earliest recorded exports were in 1938 just before World War II followed by records for 1950 to 1958 (Van Pel 1956) followed by an absence of information from 1957 to 1968 followed by lack of information for nine years in the 1960s (Fig. 3). Export information became available from 1969 to 1982 (Grandperrin and Brouard 1983), from 1983 to 1991 (McElroy 1992) and from 1992 up to 2004 (Vanuatu Fisheries Department Annual reports) (Fig. 3, Appendix 1). The last major exports were in 1993; before then, exports collapsed in 1995. It became apparent in year 2000, that the fishery had collapse and could no longer support export production which led to decision to close the fishery in 2005. Export figures for 1981 to 1991 were based on the upper figures reported by McElroy (1992), Vanuatu Fisheries Division reports and the Vanuatu Bureau of Statistics that was aggregated and provided by Dr Tim Adams (Former Director of Fisheries and Aquaculture Division of SPC).

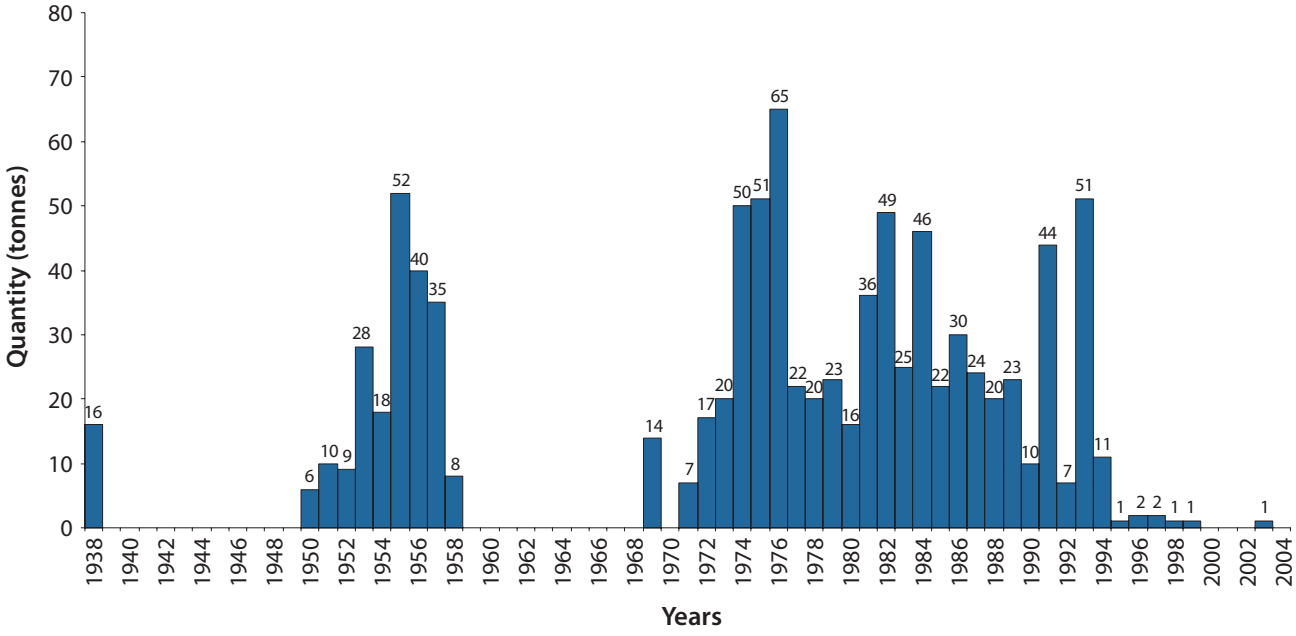

Figure 3. Historical green snail shell exports from Vanuatu (whole and processed shell products).
Note: 15 years export ban enforced from 2005 to 2020.

Several shell processing factories were established in Port Vila and Santo in the late 1980s (Dalzell 1990). By 1990, six factories were processing green snail and trochus shells for export but by the middle of the 1990s, many of the processors closed down due to a shortage of shells. Today, only one shell processing factory (Hong Shell Company Ltd) remains active (in Port Vila) but no longer processes green snail and has been facing a shortage of trochus shells. The export value for high grade green snail cuts (strips) ranged from USD 16,000–20,000 per tonne in the 1990s. Local purchase prices in Vanuatu were around VAT 1,700–2,000 per kilogram of raw unprocessed shell (Bell and Amos 1994) while polished shells were sold at VAT 4,000–5,000 per piece in the 1980s. Current export market prices are unknown although likely to be higher.

Green snail shell is exported either whole or processed into cuts or strips, and the main market is South Korea. The shell is used in the making of highly prized furniture inlay work, buttons, jewelry and souvenir products. Products made from green snail are rare and mostly unknown by people in Vanuatu. People who own the resource or those managing the green snail fishery have little idea of what the shells are used for or their economic value. Figure 4 shows some of the typical inlay work on wooden furniture, lamps, jewelry and letter boxes used mostly by Asians, especially in Korea, Japan and China. The photographs were provided by Mr Kenichi Kikutani, who has done much work on green snail in Japan, and in the Pacific Islands, including Tonga and Vanuatu. Local development of skills in shell crafting is an important capacity building needs in Vanuatu if the green snail fishery is to be protected for local marketing purposes in future.

Figure 4. Green snail shell lamp stand (top left and top right), inlay work (bottom left and right pictures) (Photos: Mr Kenichi Kikutani).

1.3 Past resource assessments

Green snail assessment surveys (by timed snorkel) were conducted in 1959 and 1961, covering the areas of Anelgouhat and Port Patrick on Aneityum, Port Narvin on Erromango, Cook's Reef on Emae, and Tutuba Island in Santo (Devambez 1961). Two surveyors in the second assessment in 1961 counted 13 green snails in 10 minutes of snorkeling, whereas in 1959 it took 45 minutes for 6 divers to collect 11 green snails at Anelgouhat in Aneityum. Similar assessments repeated at Port Patrick, Aneityum, Port Narvin, Erromango, Cooks Reef on Emae, and Tutuba Island concluded that the green snail stock was abundant at Aneityum and other islands for commercial fishing. Assessment surveys conducted by SPC in 2003 at the Maskelyne Islands, Uripiv, Moso and Paunangisu recorded two living specimens in a community protected area at Uripiv Island on Malekula (Friedman et al. 2008). In 2008, a study on green snail gut content was undertaken at Aneityum Island by the Japan International Cooperation Agency (JICA) to assess potential feed for hatchery-produced green snail; no report of this work is available, however. Prior surveys conducted in some of the important green snail fishing grounds (Pakoa et al. 2008; Gibbs et al. 1998; Lamont et al. 1999; Saunders et al. 2000; Hill 2004; Done and Navin 1990) did not record green snail, which highlights their scarcity and the importance of conducting specific green snail habitat surveys.

1.4 Management measures and regulations

Green snail harvesting and export is currently banned under a 15-year moratorium that went into effect in 2005 and became a regulation in 2009. The new Fisheries Regulation Order 28 of 2009 repealed the former regulations, which enforced a minimum harvest size limit of 150 mm widest shell diameter and required a license for exporting. The new Regulation 53 of Republic of Vanuatu Fisheries Act [Cap 315] states:

1. A person must not take, harm, have in his or her possession, sell or purchase any green snail during the period starting on 1 October 2005 and ending on 1 October 2020.
2. The Director of Fisheries may authorize a person to take or have in his or her possession a green snail for the purpose of carrying out scientific research.

The new regulation makes it illegal for anyone including resource owners to collect or keep any green snail shell (parts or products) for the purpose of consumption, processing or selling. The only exception provided in the regulation is for the use of green snail for research purposes, which can be permitted by the Director of Fisheries.

The 1983 government policy restricting exports of whole shell and encouraging local processing has worked against green snail stock management. The increased number of processing factories in the 1980s and 1990s in Port Vila and Luganville contributed to escalating fishing pressure, and eventually led to the collapse of the green snail fishery in 1994. Limited management control and competition for a limited supply of green snail shell have increased fishing pressure on the resource. The collapse of the fishery led to the decision to close the commercial green snail fishery in 2005.

1.4.1 Adult translocation and reseeding

Translocation of adult shells to replenish depleted stocks and to develop the resource in new locations, and reseeding of hatchery-produced juveniles are management options for green snail fishery. The first successful introduction of adult green snail was from Vanuatu to French Polynesia in 1967 (Yen 1991). Of the 300 shells shipped, 42 survived the 12-day voyage from Port Vila to Papeete. The shells, which were released at the southeastern part of Tahiti Island (at Tautira), successfully recruited along the east, and to the north and south of the island, and with further introductions made to 56 other reefs, resulted in the establishment of a green snail resource in French Polynesia (Yen 1991). Green snail fishing in French Polynesia is managed under an indefinite ban, with a fishing season allowed for the whole country when there is a sufficient harvestable stock based on resource assessments (Yen 1991). Another introduction, from Vanuatu to Tonga, was made in 1993 with adult green snails sourced from the Anelgouhat area on Aneityum. Of the 320 shells introduced, 251 survived the journey and were released at Euaiki Island and at Vaini Reef on Tongatapu. An assessment

11 months after release found 23% of the released stock (Kikutani et al. 1995) and an assessment by SPC (Pakoa et al. 2008) recorded a specimen at Euaiki Island on Tongatapu. Dedicated assessments at released sites at Ha'apaii and Euaiki are needed to ascertain whether a population has become established in Tonga.

Translocation of green snail stock within Vanuatu has been a recent activity. With the assistance of the Japanese government through the JICA "Grace of the Sea" project, 1,200 adult green snails were transferred to Efate between 2007 and 2008 (Jimmy et al. 2008). Of the total shipment from the Anawonjei area on Aneityum, 812 survived and were released on the reefs of Mangaliliu, Lelepa and Moso islands on western Efate (Table 1 and Fig. 5). The transferred stock comprised primarily large adult shells (mean size of 180 mm shell height). Green snail had been overfished on Efate although some specimens were observed at Pango Reef prior to the translocation (Tony Taleo, Vanuatu Fisheries Officer, pers. comm.), suggesting the presence of some local stocks of green snail on Efate.

Table 1. Released tagged green snail recoveries, including juveniles at Lelema and Moso (Japan International Cooperation Agency Grace of the Sea project).

Release sites	Tagged release 2007	Tagged recovered 2012	Untagged recovered 2012
Moso (Sunae)	150	0	0
Lelepa (Lakantamas)	195	13	12
Mangaliliu	463	Present — not counted	Present — not counted
Hat Island	No release		6 juveniles

Note: tagged release shells and shells marked with numbered tags or penciled marks on the shell operculum for identification purposes.

Figure 5. Green snail stock received by Chief Kalkot Mormor of Mangaliliu (left) and adults being tagged ready to be released (right) (Photos: Sompert Gereva).

Hatchery-reared green snails were first received by Vanuatu from Tonga sometime in early 2000s and were sent to Aneityum for reseeding although they all died. Hatchery breeding is currently being undertaken under the JICA "Grace of the Sea" project. From the many juveniles produced and reseeded at Mangaliliu and Uripiv Island on Malekula, high mortality and a loss of juveniles remain the main challenges. While trials are still being conducted, reseeding of hatchery-reared green snails has yet to be proven as an effective management tool for rebuilding depleted green snail stocks. At this stage, the high cost of conducting hatchery breeding, grow-out and reseeding trials is not cost effective and this option needs to be considered if such trials are to continue in the future.

1.4.2 Traditional management

While the traditional management system of *tabu* is still widely practiced in Vanuatu, it was unable to restrain the pressure from commercial fishing of green snail in the past (Johannes and Hickey 2004). Community-based management is relatively effective in controlling resources for subsistence use, but is less effective in controlling commercial fishing activities. This is because exporters and buyers are licensed by the national government, and the community often is unable to control green snail harvesting by its members who want to harvest and sell for an income. Aneityum Island is an exception, however. Its remoteness from the marketing center of Port Vila, and the regular income-earning opportunities from ecotourism through cruise ship visits to Mystery Island have helped ease fishing pressure on green snail. Reseeding juvenile green snails and translocating adult shells on Efate were conducted jointly with the communities of Lelepa, Mangaliliu and Moso who allowed their reefs to be used in this study.

2. Aim and objectives of this study

This study assesses the status of green snail resource recovery in Vanuatu and proposes measures needed to protect existing stocks while they recover. Efate Island was targeted for this study as one of the affected areas and recipient of translocated stocks. Aneityum has been supplying green snail stocks for introduction purposes although existing stocks have not been adequately studied. An assessment of the stock on Aneityum is important for management purposes and for making sound decisions on future introduction needs. Aneityum Island and Efate (Undine Bay area) are the study sites for a community climate change adaptation project implemented by the Vanuatu Fisheries Department and funded by the Secretariat of the Pacific Regional Environment Programme. Information on invertebrate resources and coral reef condition gathered from these assessments will be used as a baseline for future assessments on reef conditions for climate change monitoring purposes. Specifically, the objectives of the study are to:

- assess the condition of green snail resources at Aneityum Island and advise on measures that the community and the Vanuatu Fisheries Department can take to protect the stock;
- assess the recovery of green snail stocks on Efate and provide advice on management measures to ensure stock recovery;
- assess the condition of stocks translocated to Efate and advise on effective translocation sites and measures to protect translocated shells;
- assess the situation of green snail fishing activities on Efate and suggest ways to stop current harvesting activities so as to allow the speedy recovery of stocks;
- collect information on green snail sightings from other areas in the country for future resource assessments; and
- collect invertebrate baseline information for climate change baseline monitoring purposes for Undine Bay and Mystery Island pilot climate change sites.

3. Methodology

3.1 Collection of catch and local marketing of shells and exports

The Vanuatu Fisheries Department has received several reports of harvesting and sales of green snail around Efate. Monitoring handicraft markets in Port Vila by fisheries enforcement officers has resulted in confiscations of green snail shells, which are held at the Fisheries Department. These confiscated shells have been measured and counted. Observation visits were made to handicraft markets in Port Vila to check if green snail shells and operculum are being sold. A few sellers at the market were asked some general questions about where the shells were collected, who collected them and from where, and if they knew about the current prohibition on commercial harvesting and sale. Further information on fishing activities was shared by fisheries officers who had learned of fishing activities from the communities on Efate and Malekula. At Aneityum, information on fishing activities was gathered by talking to fishers and from consultation meetings held at Anelgouhat 2013 and from local elders and fishers who were met during resources field surveys. Members of the Aneityum Council of Chiefs, heads of families, teachers from Anelgouhat Primary School, Aneityum Tourism Committee, fishers, and village members who were present at the meeting shared their views.

3.2 Resource survey design for Efate

Assessment surveys on Efate were based on several considerations.

1. The original green snail release sites should be targeted to check on the introduced stock and if recruitment has occurred.
2. Other surveys conducted by the Vanuatu Fisheries Department have covered some reefs within the site of interest.
3. The habitat of interest for this assessment is the reef crest and slope.
4. The need to conduct a baseline assessment of Undine Bay for the climate change pilot study.
5. The survey team will have to travel to Aneityum and sufficient time must be allocated for this assessment.

Reef conditions and the distribution of invertebrates from Undine Bay to Siviri and to the northern coast of Moso Island were assessed using manta tow and transect surveys. Transect surveys were conducted on suitable reef habitats of trochus and green snail along the northern coast of Moso Island (Sunae and Tassiriki areas). Other surveyors scanned the reef area in search of trochus and green snails in order to gain a rough understanding of the area and whether the species were present. At the green snail release site at Lelepa Islands, the reef platform where green snails were located was shallow and suitable for transect assessment. At the release site at Lelepa, the reef platform where green snails were released is shallow and surrounded by deep areas thereby limiting the movement of shells. Assessments of the release sites at Mangaliliu and potential recruitment areas of Trimas and Tukutuk Bay and Takara were assessed in 2012 by the Vanuatu Fisheries Department.

3.3 Resource survey design for Aneityum

Aneityum was considered to be the primary survey site because of the large area available to be surveyed and that this would be the first major baseline survey of invertebrate resources of the island. In the planning phase, several considerations were made:

1. Aneityum is a relatively large island that presents logistical challenges when getting around the island.
2. The island is divided into five customary regions — Anelgouhat, Umej, Anewonjei, Anejo and Anawonsei

— where each region has its own paramount chief. Therefore, it was thought necessary to divide the assessments by these regions in order to make information available to respective community members.

3. The Mystery Island marine protected area and the Port Patrick Marine Reserve has not been assessed, thus there is a need for baseline information from these areas.
4. The reef areas of these regions are not the same and, therefore, sampling effort should, at the least, be based on the size of reef present.
5. Green snails are found on reef crests and reef slopes that are exposed to wave action, and assessments should focus on these habitats.
6. Local residents have excellent knowledge about their resources and fishing grounds, and their advice regarding main aggregation areas must be sought prior to conducting surveys at each site.
7. Community leaders and fishers need to be informed of the results of the survey work and should share their management concepts; meetings, therefore, should be organised at the end of the surveys.

3.4 Resource survey methodology

Two resources survey protocols were used: the shallow water scuba search (SWSs) also referred to as mother-of-pearl searches (MOPs), and reef benthos transect surveys (RBt). SWSs surveys were conducted in 3–12 m while RBt were conducted in 0–3 m (Fig. 6 left) (Friedman et al. 2008; Pakoa et al. 2008). In SWSs, two divers swam along reef contours at five-minute timed intervals and recorded all macro invertebrates within a 3-m swathe in depths not greater than 12 m (Fig. 6 right). Green snail, trochus, giant clam, and other invertebrates encountered within the 3-m swath were measured and the data recorded on waterproof data sheets. Each five-minute timed search covered a distance of roughly 88 m, based on the mean length of five-minute timed scuba searches across the Pacific. Estimated total area coverage per station of SWSs was 1,584 m^2. Each RBt station was 40 m long by 1 m wide with 6 parallel transects, for a total area of 240 m^2.

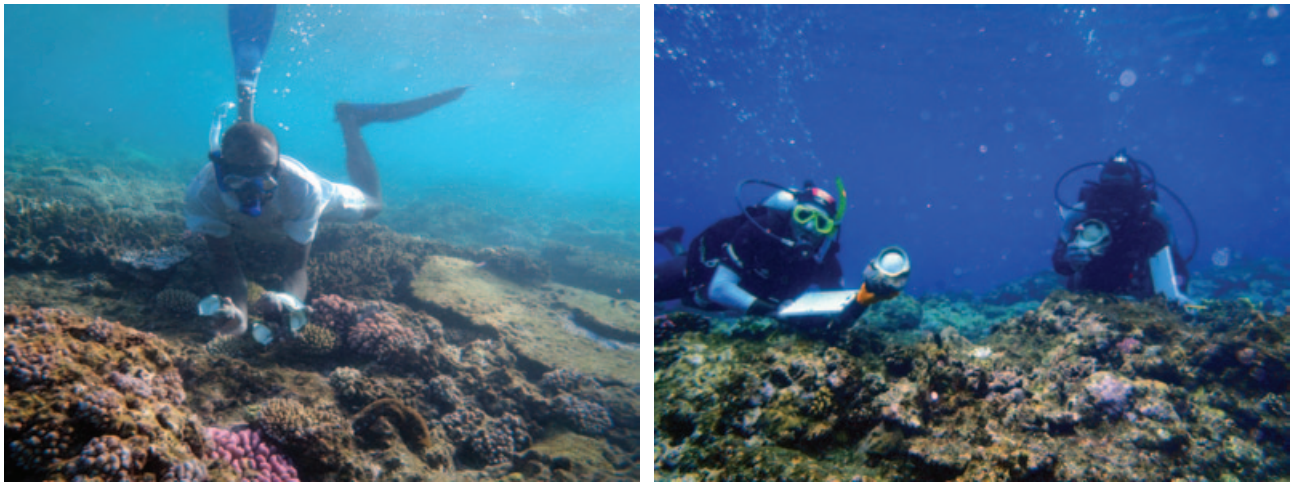

Figure 6. Green snail resource assessments by reef benthos transect (left) and shallow water scuba search (right) (Photos: Kalo Pakoa).

3.5 Data recording, analysis and reporting

Green snail size was recorded by measuring shell height, measured from the apex to the bottom of the notch as indicated by (a), widest diameter of the shell (b) in Figure 7. Both measurements have been used in other assessments on Efate, which has resulted in sizes of more than 240 mm, such as in the assessment by Dumas et al. (2012). A third measure, the diameter of the operculum, (c) (Fig. 7 left), was not taken during this assessment, but has been used in other assessments to understand green snail size structure. Shell height measure (a) is a more reliable and recommended measurement method to use (Kikutani et al. 2002). In this assessment, general observations were made of shells underwater, in homes, and on the beach for algal growth and shell quality. Further observation and photographs were taken of an old green snail sample killed for its meat and to observe the damage on the inner part of the shell. Global positioning system (GPS) positions of sampling stations were recorded, a single position for each RBt station, and start and end positions for the shallow water scuba search stations, using GARMIN etrex GPS (GARMIN Corporation 2010). The GPS information is useful for geographic information system (GIS) work on sampling distribution and the distribution of species density across survey sites.

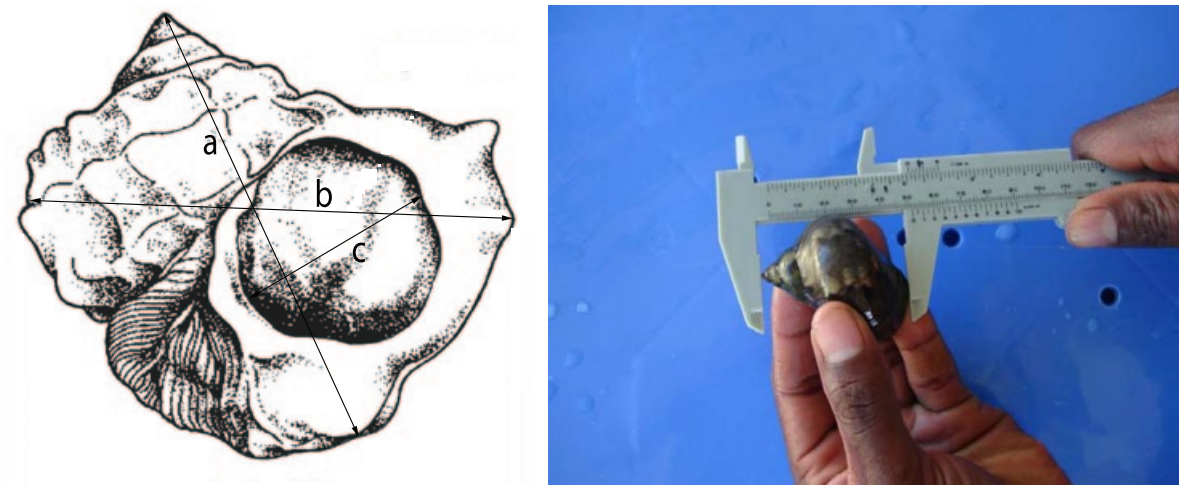

Figure 7. Size measurement in green snail shell height (a), widest shell width (b) and operculum diameter (c) (left; Anon. 2005). Shell height measurement of juvenile green snail (right; Photo: Robert Jimmy).

Waterproof data sheets were rinsed in fresh water, dried, checked on a daily basis and filed. A preliminary result for Aneityum data was used to brief the community about the state of their green snail resource. Data were entered in the Reef Fisheries Integrated Database at SPC in Noumea as part of the data processing training attended by two of Vanuatu's trained fisheries officers. The abundance of green snail (individuals per hectare) was assessed by sites in the two islands whereas the population structure was assessed separately for Efate and for Aneityum.

Estimates of green snail stocks were not performed because the national ban is still in effect and, therefore, all fishing activities are illegal. At the consultation meeting in Aneityum, the community was strongly opposed to the release of resource information that might be used to fuel renewed commercial fishing activities. Information on stock estimates could be used by fishers or buyers to persuade the lifting of the ban to allow commercial fishing or be used to fuel illegal harvesting activities. For this reason the release of information on the standing stock and harvestable stocks of green snail in Aneityum and Efate at the present time and by this study is not recommended. Stock estimate analysis can be performed in future using comparative data to assess population changes. In these surveys the total reef habitat areas for Aneityum have been extracted from GIS and presented in this report as reference for refinement in future stock assessment needs.

4. Results

4.1 Green snail fishing, sales and observations

The harvesting of green snail for its meat and shell (which is sold as souvenirs at handicraft markets in Port Vila) has increased on Efate in the last five years. Forty-five green snail shells confiscated by Fisheries Enforcement officers in 2012 and 2013 were dominated by young shells under the minimum legal harvest size of 150 mm (i.e. 60% of the maximum allowable size) (Fig. 8). Shells less than 100 mm were not captured in the seized products but small-sized shell operculum were sold at the market in 2012 (Fig. 9 top right) indicating that juveniles were being harvested on Efate (70% of the operculum on sale are from juvenile green snail). Green snail shells were no longer offered for sale at the handicraft markets in 2013, although operculum are still being sold (Fig. 9 top right). The harvesting of green snail for its meat has increased on Efate and has been occurring on Aneityum (Fig. 9 bottom left) despite the community ban on such activities. At Rano Island on Malekula, juvenile green snail shell was found on the beach near a fire place. Some of the green snail harvesting activities that were reported to the Fisheries Department and observed in the field are summarised in Table 2. Harvesting activities for food is difficult to monitor and control, public education on the importance of protecting the resource while it recovers is the best approach.

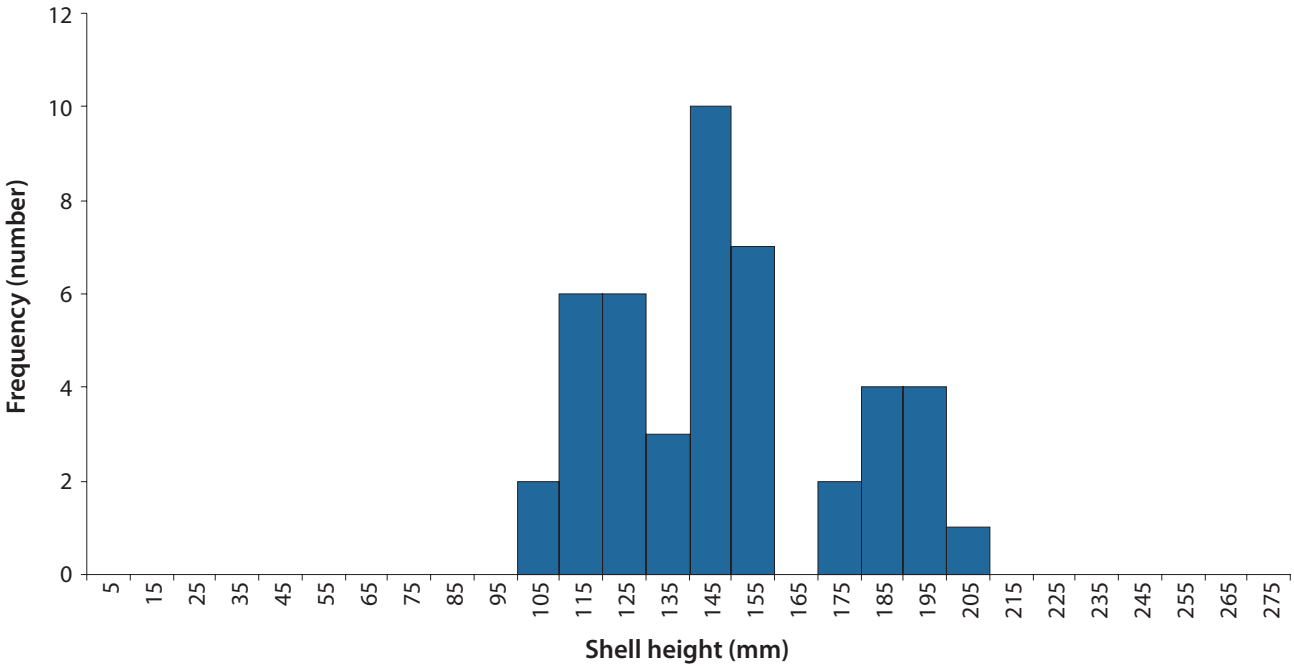

Figure 8. Size structure (shell height) of green snail products confiscated from Port Vila markets by Fisheries Enforcement officers.

Figure 9. Polished green snail shell and operculum at the market in Port Vila (top; Photos: Ian Bertram). Green snail meat ready for cooking on Aneityum (bottom left; Photo: Kalo Pakoa), and the burnt shell of a juvenile green snail at Rano Island, Malekula (bottom right; Photo: Andrew William).

Table 2. Green snail harvesting information from Vanuatu Fisheries Department officers.

Date	Place	Report
2011	Erueti	Market vendor selling green snail shells said she collected the shells from the Erueti area.
2012	Pango, Erakor	Fishers from Pango Village have reported seeing green snail outside the reef during spear fishing dives (Tony Taleo, Vanuatu Fisheries Officer, pers. comm.)
2013	Mangaliliu	Mangaliliu villagers reported dead green snail shells on the beach near a fire in the Trimas area.
2013	Mangaliliu, Trimas, Tukutuku	Bag of shells confiscated from a village tour operator north of the Bauerfield airport, shells were collected from the Trimas area.
2013	Bukura, Devils Point	Market vendor selling green snail operculum at the market in Port Vila sources the items from family members who collect the shells from the area.
2013	Teouma, Whitesand, Eratap	Market vendor selling operculum reported to have recovered the items left on the beach by fishers.
2013	Uripiv Island, Malekula	Many small-sized operculum of green snail were observed on the beach at Uripiv Island.
2013	Rano Island, Malekula	Burned shells of juvenile green snail were observed on the beach, indicating the shells were cooked on the fire.
2013	Aneityum	Dead shells were observed on the beach and in the water at Port Patrick and Anelgouhat; chiefs and fishers confirm fishing for meat is a continuous activity despite the ban on harvest the shells for food, which is enforced by the Council of Chiefs of the Island.

4.2 Resource status on Efate

New green snail specimens were recovered from reefs at Takara, Moso, Lelepa, Mangaliu, Trimas and Tuktuku on Efate. In addition, tagged green snails were recovered at adult translocation sites at Mangaliliu and Lelepa, while none of the tagged green snails were recovered at Moso. Newly recovered and newly recruited green snails and the tagged green snail at Lelepa are shown in Figure 10. From assessments by Vanuatu Fisheries Department staff and from this assessment, green snail (live or dead) were absent from the reefs of Undine Bay, Siviri and Sunae, possibly because the reefs in these areas were predominantly in poor condition and water clarity was poor and silt cover on many sections of the reef rendering the habitats highly unsuitable for green snail and trochus, which require clear water and healthy reef habitats.

The less-than-adequate reef system extends to Sunae Reef at the northern tip of Moso Island where adult green snails were released in 2008. Reefs in this area are highly unsuitable habitats, which may explain the lack of recovery of the introduced shells. This raises the question as to why this area was selected as a site for green snail transplant. Reefs farther west of Sunae to the Tassiriki side of Moso Island are highly suitable reef systems for green snail which are serviced by oceanic flow, complex reef topography rich in coralline algae and live coral cover in some areas. It was on one of these reefs where a green snail specimen measured 151 mm was recorded (Fig. 10 bottom left photo). Assessment of the same reef area in 2003 by SPC (Friedman et al. 2008) did not record green snail in the area. A summary of sites where green snail were recovered on Efate by this and other surveys conducted by the Vanuatu Fisheries Department is provided in Table 3.

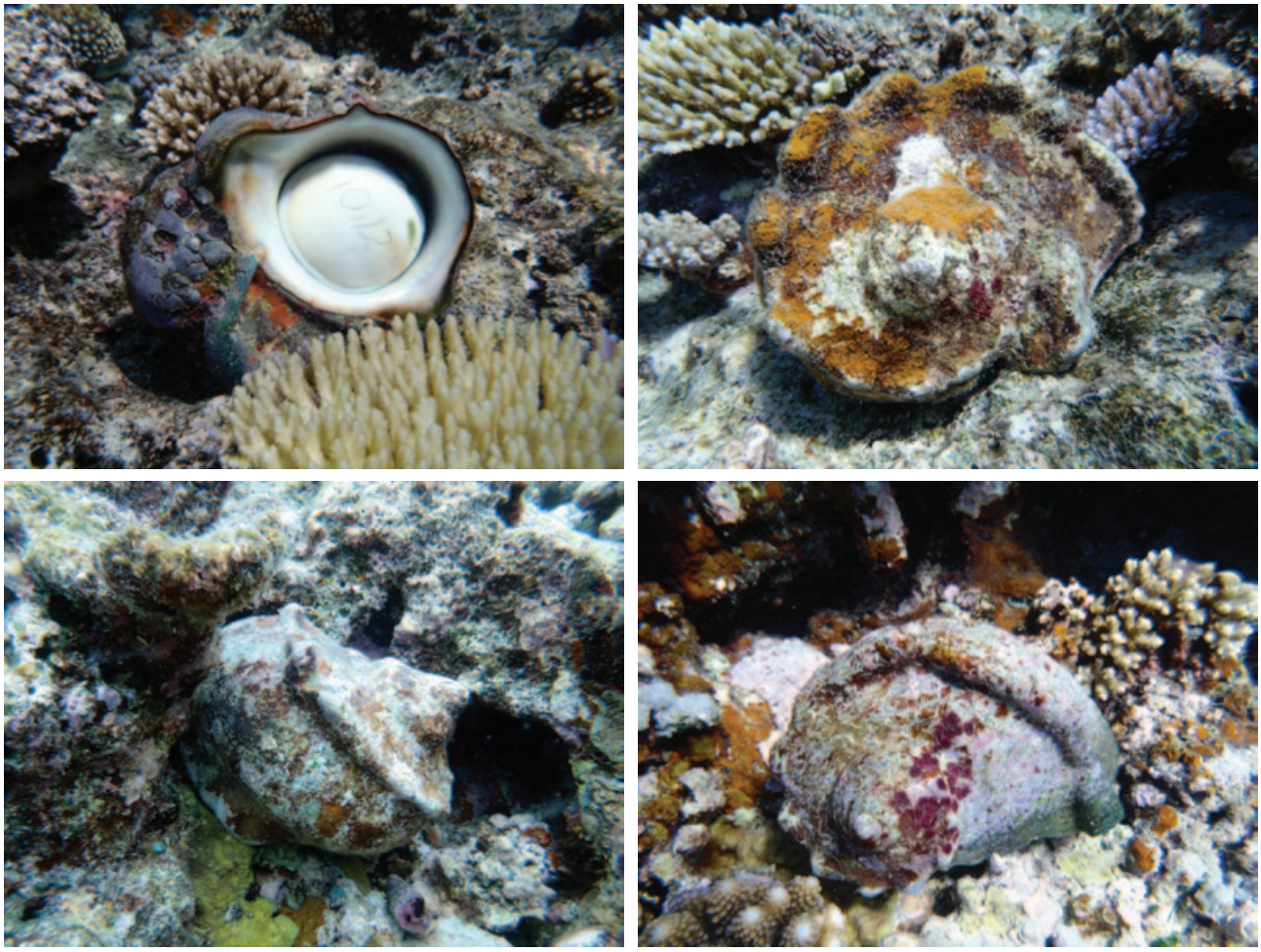

Figure 10. Adult green snails introduced from Aneityum (top photos) and new recruited shells at Moso and Lelepa (bottom photos) (Photos: Kalo Pakoa).

Table 3. Observed green snails from Efate, Moso, Lelepa and Hat Island sites.

Island	Sites	Records	Assessment	Comments
Efate	Undine Bay	0	This survey	Unsuitable reef habitat
Efate	Siviri	0	This survey	Unsuitable reef habitat
Moso	Sunae	0	This survey	Unsuitable reef habitat
Moso	Tasiriki (north reef)	1	This survey	Suitable habitat
Lelepa	Lakantamas (Lelepa)	37	This survey	Suitable habitat but limited
Hat Island	Hat Island	6	JICA surveys	Suitable habitat
Efate	Takara (Efate)	4	*Tabu* area surveys	Suitable habitat (Dumas et al. 2012)
Efate	Mangaliliu — Tuktuk	26	*Tabu* area surveys	Suitable habitat (Dumas et al. 2012)

4.2.1 Size distribution of green snail on Efate

Of the 195 green snails released at Lelepa Island, 135 (69%) were recovered in 2007 and measured; sizes ranged from 140–230 mm in shell height and a mean size of 186 mm (Fig. 11) (Jimmy et al. 2008). Size data from assessment surveys at Takara and Mangaliliu (Dumas et al. 2012) used the widest width measurement (Fig. 7, measurement method (b)), which is larger than the shell height and, therefore, cannot be aggregated with existing data. Both sizes are useful but the consistency of using an agreed on way of measuring size for this species should be maintained. In the current size composition, 91% of the shells recorded were over 150 mm and only one shell was measured at 250 mm shell height.

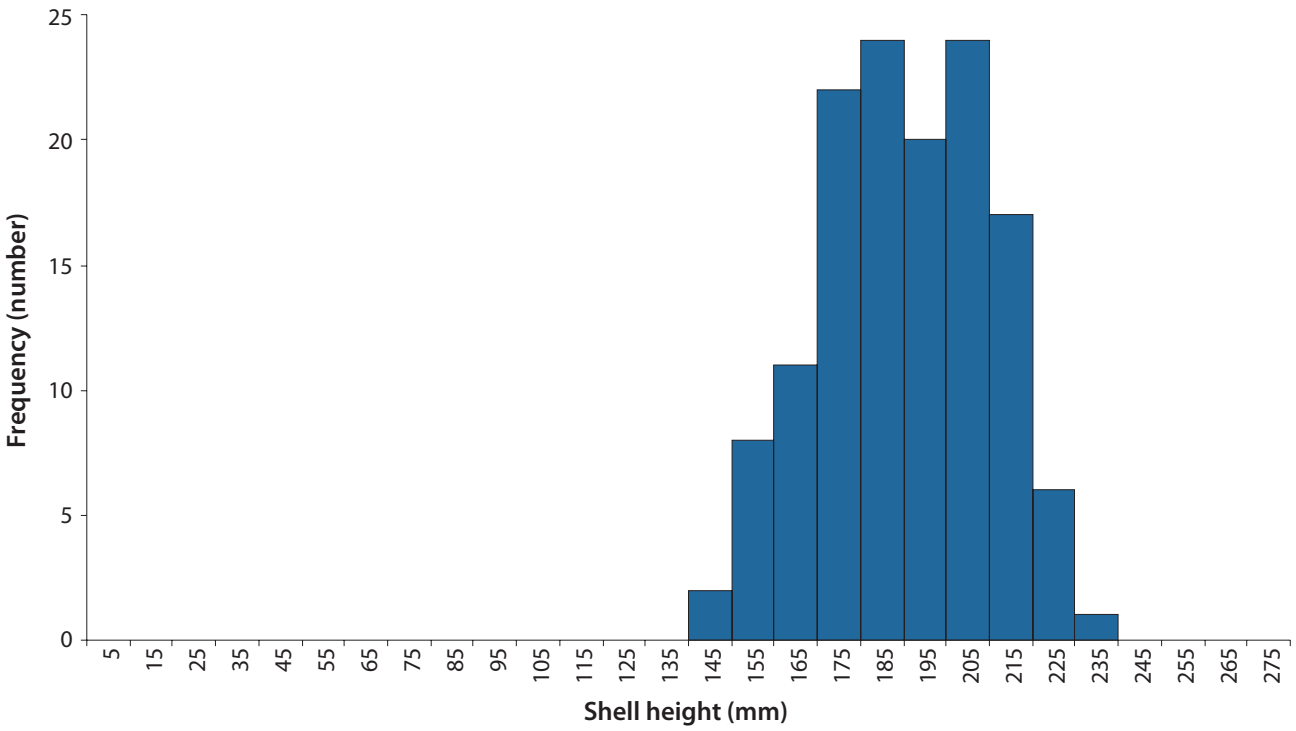

Figure 11. Size structure (shell height) for the introduced green shells at north Efate.

The existing stock of green snail on Efate comprised both young and older shells ranging from 135–255 mm in shell height with a mean size of 193 mm (n = 34) (Fig. 12). Some of the tagged shells have lost the pencil marks written on the outer surface of the operculum, making it impossible to separate tagged and untagged shells. However, most of the specimens recorded were older shells which indicated a dominance of the stock re-introduced from Aneityum (Fig. 11).

Shell size measurements need to be standardised to "shell height" for consistency. Juvenile green snail specimens recovered at Hat Island by fisheries officers a few months prior to the current survey were not measured. Shell size structure from this assessment (Fig. 12) correspond with the size structure of shells confiscated from the market in Port Vila (Fig. 8), indicating that green snail stocks from Efate are young. The newly recruited green snail should be entering their reproductive size range from130–150 mm or three to four years of age (Yamaguchi and Kikutani 1989). These beautiful coloured, less defected young shells are being targeted by handicraft sellers on Efate. The present study, however, was not designed to recapture released green snails that were previously released on Efate.

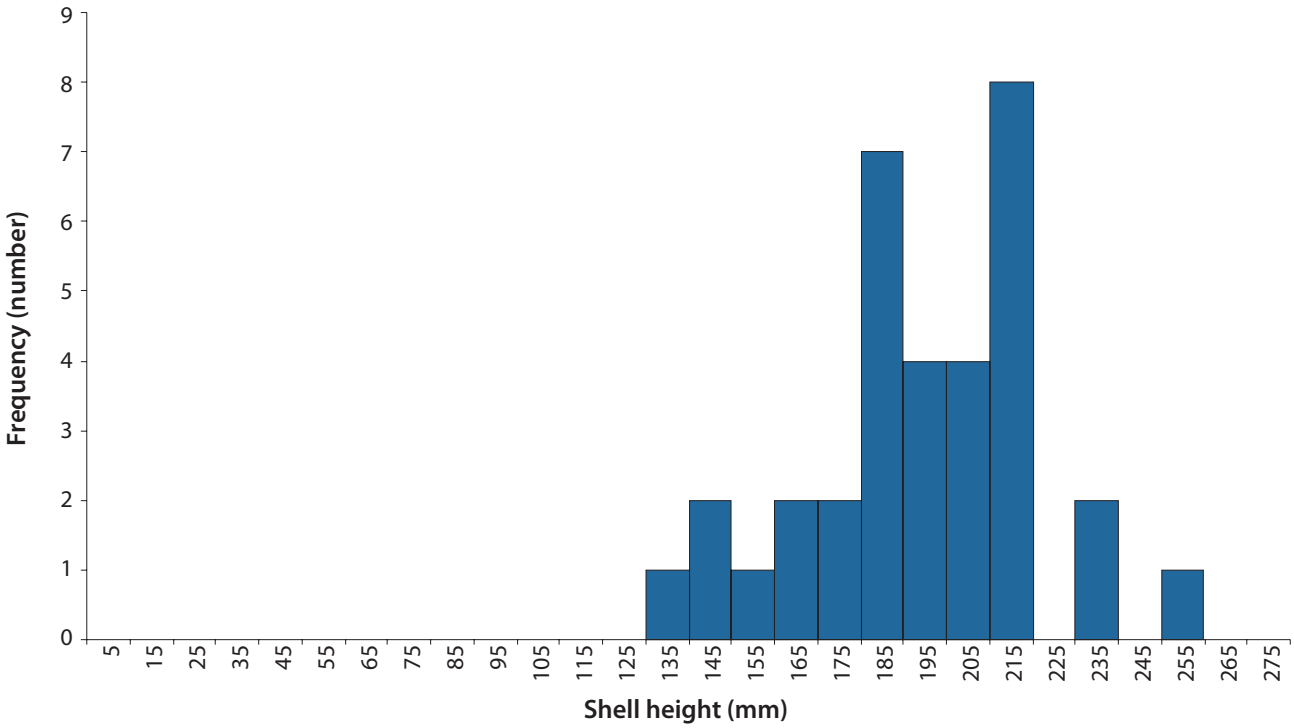

Figure 12. Size structure (shell height) for green snail recorded at Efate by this survey.

4.2.2 Green snail recruitment pattern on Efate

Recent green snail harvesting has been reported at Devils Point, Bukura, Pango, Erakor, Eratap, Teouma, Whitesands and Erueti (Fig. 13). These areas are of interest for future assessments. The recruitment pattern of invertebrates follow the source and the sink of the recruited larvae and juveniles with the effect of current flow through the influence of wind speed, tidal changes and the coastal reef formation (Black et al. 1995). In French Polynesia, introduced green snails were released on reefs at the southern tip of Tahiti Island (Tautira). The prevailing southeasterly wind-generated currents have helped the flow of juvenile recruitment along the east coast of the island resulting in successful establishment of green snail after 13 years (Yen 1991). In Tongatapu lagoon in Tonga, trochus (*Tectus niloticus*) was found to follow similar recruitment pattern from the introduced stock east of the lagoon to the western reefs following the east to west current flow pattern in the lagoon (Pakoa et al. 2010). Subject to suitable habitats, these experiences point to south-easterly locations of islands such as Efate in this case as appropriate island location for the translocation of adult green snail.

Figure 13. Green snail location sites on Efate (red circles); white circles are the recovery sites, and black circles are reported fishing sites. The current study covered Undine Bay, Sunae, Tassiriki, Lakantamas and Hat Island; Vanuatu Fisheries Department assessments took place at Takara, Mangaliliu, Katoa, Trimas and Tukutuku (Dumas et al. 2012). Adult green snail transplant sites are Katoa, Mangaliliu, Lakantamas and Sunae.

In the case of Efate Island, adult green snails were translocated to Mangaliliu, Lelepa and Moso are on the western side of the island. While information on current flow around Efate is not available, the western side of Efate is sheltered from the prevailing south easterly wind and current flow. Larval dispersal to the south, southeast, eastern and the northern reefs of Efate would go against dominant current flow experience based on general knowledge. However, proper hydrographical assessment of current flow patterns affecting Efate is important for a good understanding of dominate current flows that may assist in more effective site selection for green snail and trochus translocation. Thus the translocated green snail adults on West Efate could not have been the only source of recruitment of green snail revealed in the south and north of Efate Island. Additional recruitment from wild green snail stock of Efate is a possibility.

4.3 Resource status at Aneityum Island

4.3.1 Reef habitat areas

Of the nine geomorphological classifications of Aneityum is based on the reef habitat classification by Andrefouet et al. (2005). The estimated shallow reef habitat area available to support marine invertebrates at Aneityum which comprise the nine habitat types total 8,161 ha (Fig. 14, Appendix 2). Of this the potential habitat of green snail is restricted to the forereef and the subtidal reef flat areas, which makes up 1,338 ha in total reef area. Green snail would inhabit a proportion of the available suitable reef habitat area. For the purpose of stock estimates, the total reef habitat area where green snails are located from this assessment provide useful basis for determining the best reef habitat (ground truth) for population estimation purposes for each region.

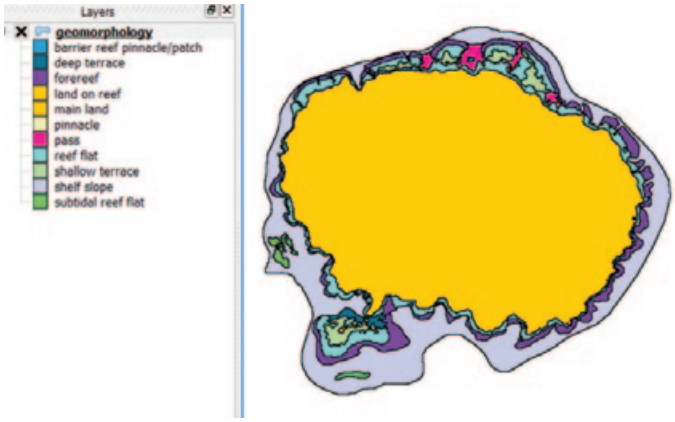

Figure 14. Reef habitat classification for Aneityum Island (Source: Andréfouët et al. 2005).

4.3.2 Survey coverage and green snail presence

In total, 75 stations of SWSs and RBt were completed in nine days. More sampling stations were completed at sites with relatively larger reef areas such as at Anejo, Anelgouhat and Mystery Island. At Anawonjei, the fringing reef area is limited to the northern portion of the coastline and is lacking from the rest of the east coast to Umej. Although some sporadic reef patches in the area could be important habitats for green snail, persistent rough seas limited assessment efforts. Anawonjei Reef is important for green snail, and the stock of 1,200 adult green snails translocated to Efate in 2007 originated from this area. The reef at Anawonsei is highly suitable for green snail but is limited in area, and therefore the survey coverage was sufficient to provide stock status information. Umej on the southern coast of the island comprises a narrow fringing reef and drop off with a general lack of suitable habitat for green snail. A map illustrating sampling stations is provided in Figure 15 with detailed sample area coverage provided in Appendix 3.

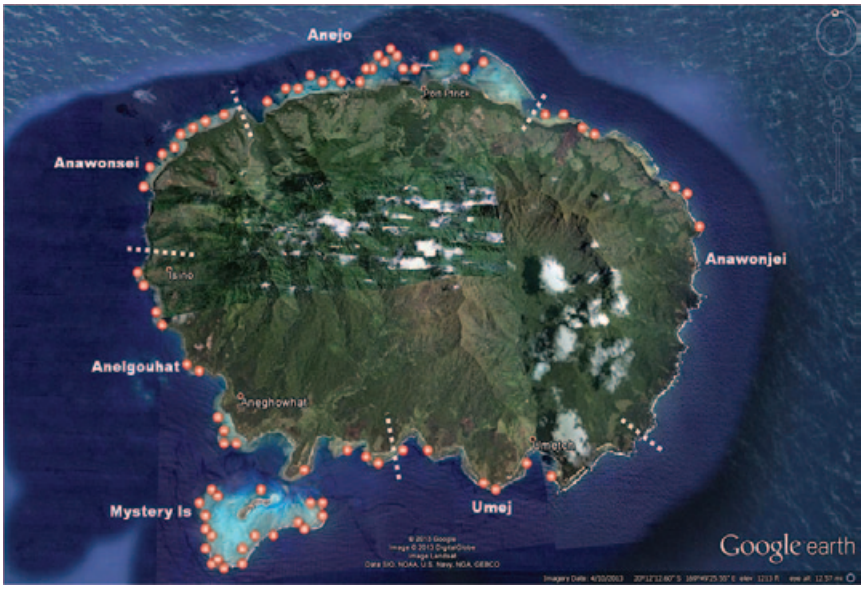

Figure 15. Survey sites at the five locations (tribal areas) on Aneityum Island.

Green snail was present at all sites surveyed at Aneityum with a total of 667 individuals recorded. The number of green snails observed per site corresponds more to the suitability of habitat present rather than sampling effort (Table 4). For instance, fewer green snails (76 individuals) were observed at the Mystery Island marine protected area than at Anejo (205 observed), although both sites had the same number of

stations sampled. In contrast, a greater number of green snail was observed at Anelgouhat even though there were fewer sample stations (14 stations) than at Anejo and Mystery Island; thus, the habitat suitability at the reef slope is important. Generally, there were more green snails recorded in deeper reef slope assessments (shallow water scuba assessments) at Anelgouhat (174 individuals) as compared to other sites. The reefs of south west to south Aneityum (from Anelgouhat to Umej) are narrow reef formations whose reef platform is exposed at low tide. The reef slope habitat is highly complex comprising overhangs and caves which provide suitable habitat for green snail (Fig. 16). The marked difference in green snail observations at Anelgouhat could be related to the fringing reef's formation, a shallow fringing reef platform that is often exposed at low tide and with few habitats for green snail. Sixty-six percent of observations were made by SWSs assessment.

Table 4. Survey coverage and number of green snails observed at Aneityum.

Sites	SWSs (3–12 m)		Reef transect (0–3 m)		Total area (ha)	Total green snail observed
	No. of stations	Green snails observed	No. of stations	Green snails observed		
Anelgouhat	6	174	8	41	1.1	215
Anejo	8	93	12	112	1.6	205
Anawonsei	3	59	5	29	0.6	88
Mystery Island	7	52	13	24	1.4	76
Anawonjei	3	50	4	15	0.6	65
Umej	2	12	4	6	0.4	18
Total	**29**	**440**	**46**	**227**	**5.7**	**667**

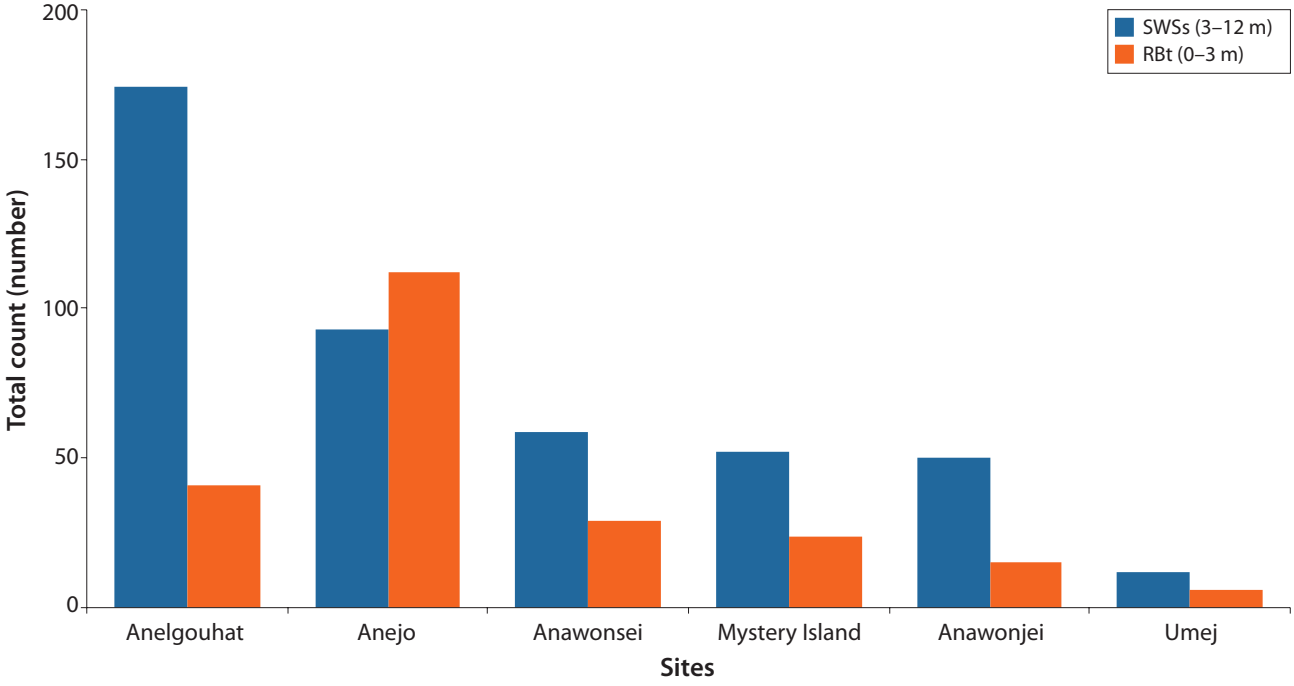

Figure 16. Green snails observed by depths and sites at Aneityum.
Shallow water scuba search (SWSs), blue bar; reef benthos transect (RBt), orange bar.

4.3.3 *Green snail abundance (density)*

Green snail counts were converted to densities or the number of individuals per hectare for the two assessment types (Table 5). Green snail was present at 100% of SWSs survey stations at all sites except for Mystery Island where green snail was present at 86% of SWSs stations. Larger coverage area employed by scuba search surveys (1,584 m^2 per station) enabled higher probability of encountering green snails on the reef, which was intended for this baseline survey. In contrast, green snail was recorded in 31–75% of RBt stations and these are stations on reef crests and the breaker zone, which are often difficult to access.

SWSs enable a more consistent coverage of suitable green snail habitat on the reef slope and over a larger reef area per station, which is useful for this baseline assessment. Areas of juvenile settlement in intertidal zones of the reef crest are important for green snail juveniles and should not be overlooked in assessments. Merging densities from the two assessments provides a useful average that can be used for stock extrapolation purposes. Having three types of densities allows flexibility but also a more accurate density analysis for the intertidal zone (0–3 m), the subtidal zone (3–12 m) of the whole habitat based on the assessment types used (Fig. 17). The low standard error of the mean densities for the SWSs surveys (Fig. 17) is indicative of the representativeness of the sampling coverage.

Table 5. Density summary by assessment types (depths) for green snail at Aneityum.

Sites	Surveys	Mean	SE	n	Mean_P	SE	n	%_P
Anelgouhat	SWSs	155.2	41.3	7	155.2	41.3	7	100
Anejo	SWSs	72.6	20.9	8	72.6	20.9	8	100
Anawonsei	SWSs	122.8	15	3	122.8	15	3	100
Mystery Island	SWSs	46.4	12.4	7	54.1	11.5	6	86
Anawonjei	SWSs	104	26.1	3	104	26.1	3	100
Umej	SWSs	37.5	25	2	37.5	25	2	100
Anelgouhat	RBt	213.5	97.2	8	284.7	116.6	6	75
Anejo	RBt	388.9	168.5	12	777.8	253.8	6	50
Anawonsei	RBt	241.7	211	5	402.8	340.5	3	60
Mystery Island	RBt	76.9	38.9	13	250	72.2	4	31
Anawonjei	RBt	156.3	104	4	208.3	127.3	3	75
Umej	RBt	62.5	39.9	4	125	41.7	2	50
Anelgouhat	SWSs-RBt	186.3	54.1	15	215.0	58.5	13	87
Anejo	SWSs-RBt	262.4	105.8	20	374.8	141.9	14	70
Anawonsei	SWSs-RBt	197.1	128.0	8	262.8	164.8	6	75
Mystery Island	SWSs-RBt	66.2	25.5	20	132.5	42.0	10	50
Anawonjei	SWSs-RBt	133.9	57.4	7	156.2	62.6	6	86
Umej	SWSs-RBt	54.2	26.6	6	81.2	32.1	4	67

SWSs = shallow water scuba search; RBt = reef benthos transects; SWSs-RBt = statistics for both methods combined; Mean = overall mean density; Mean_P = mean present density for stations where the green snail is present; SE = standard error; n = number of stations; %_P = percentage of stations when a record (green snail) is present.

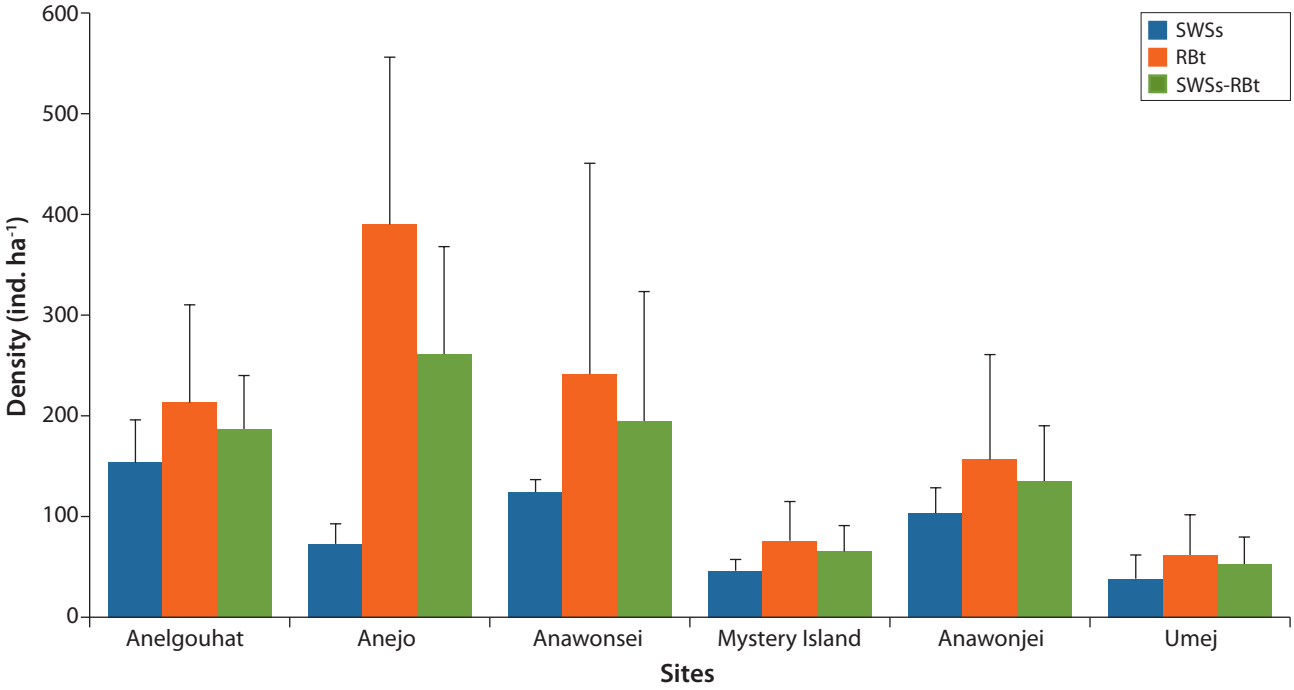

Figure 17. Mean density of green snail by sites assessed in Aneityum and assessment type with standard error.

4.3.4 Population size structure

Almost all of the green snails observed (98%) were measured for population structure assessment (433 specimens from SWSs assessments and 227 from RBt surveys). A larger sample size provides a reliable estimate of mean sizes (measured by shell height) by sites assessed and by depth. There was no marked difference between the sizes of green snail present in the intertidal zones or reef crest zones (0–3 m) and those present in the subtidal reef zone (3–12 m) at Aneityum (Fig. 18). Umej is an exception; there, green snails present in shallow water were relatively smaller (mean shell height 144 ± 7 mm) than in deeper water habitats (mean shell height 192 ± 4 mm). The reef formation at Umej possesses green snail habitat (overhangs and caves) in parts of the reef drop-offs and only certain areas along the edges of the drop-offs are inhabited by juvenile green snails. According to locals, mass mortality of juvenile fish and shellfish, including trochus and green snail, has been seen at Umej Reef annually during spring tides. They believe the fringing reef of Umej is higher and becomes exposed at spring tides. Heating of the tidal pools during the day caused unusually high mortality of marine species that are collected for food. This could explain the lack of adult shells in shallow reefs although this event needs to be properly assessed.

The frequency of shell height reveals a skewed population towards older shells (66% of the sample). A shell height of 180 mm is proposed by this study as the maximum green snail harvest size limit when the fishery reopens. Green snail sizes recorded in all habitats ranged from 35 mm to 240 mm shell height. Compared with the maximum shell size found at Tokunoshima Island, Japan (215 mm shell height; Kikutani et al. 2002), the green snail of Aneityum reach a larger size with maximum size of up to 240 mm shell height. In total, 32 (5%) shells were found to be less that 110 mm and 78 shells (12% of total) were found to be less than the 150 mm minimum harvestable size in Vanuatu. In Vanuatu, green snail reaches sexual maturity at 110 mm shell height, thus the presence of juvenile shells (Figs. 19 and 20) show active recruitment of the present stock.

On the whole, however, the size frequency reveals a disturbed stock structure of less than 180 mm, which is typical of overexploitation through fishing (Fig. 19). Fishing of green snail meat is a common practice on Aneityum and the meat of small to medium size shells, which are found on shallower reef slopes, are targeted for its softer meat compared with larger adults whose meat is slightly tougher. Fishing of green snail meat is discouraged by the Council of Chiefs of the island, although people do not respect this.

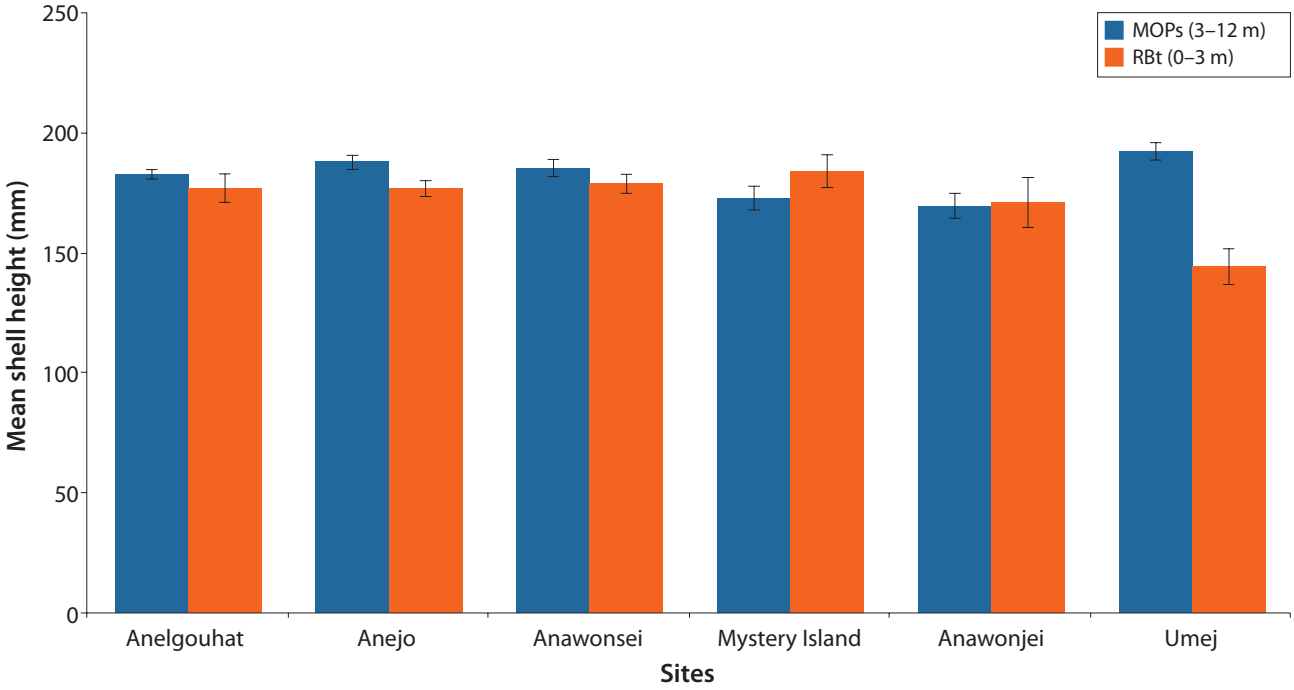

Figure 18. Mean sizes (shell height) of green snail by sites and habitat type.

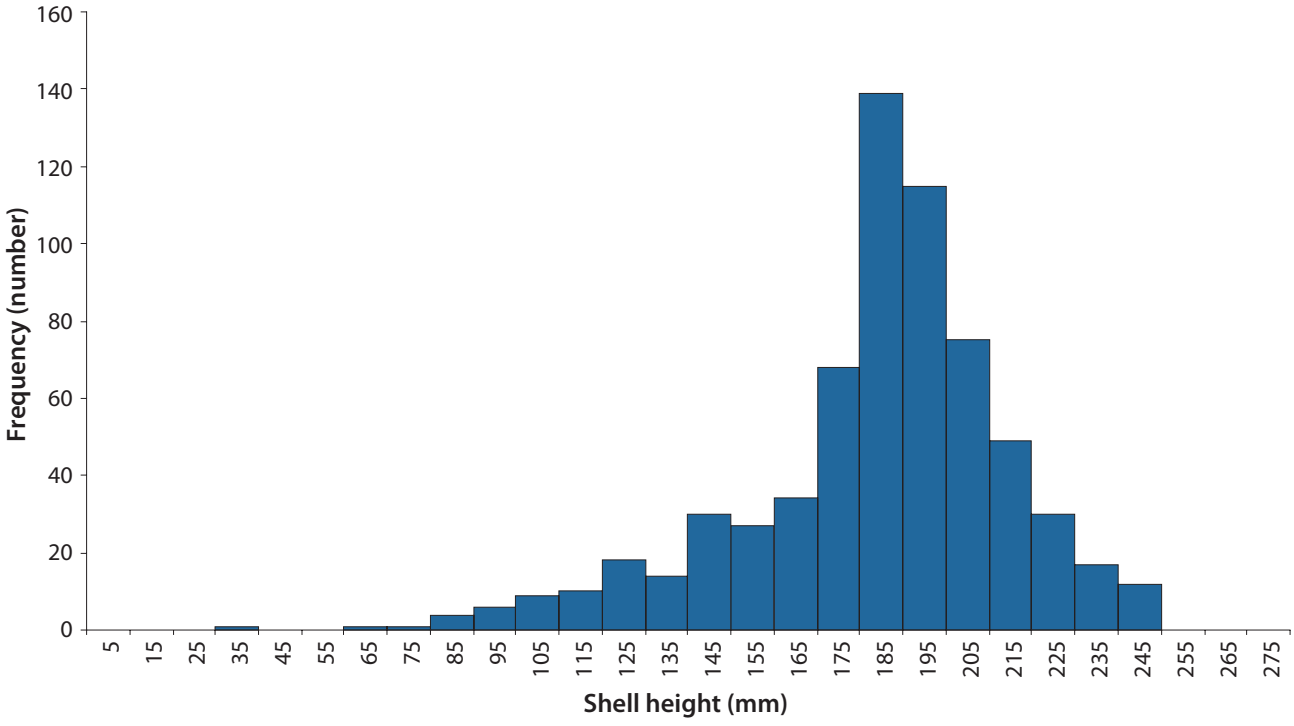

Figure 19. Green snail size structure for all sites assessed at Aneityum.

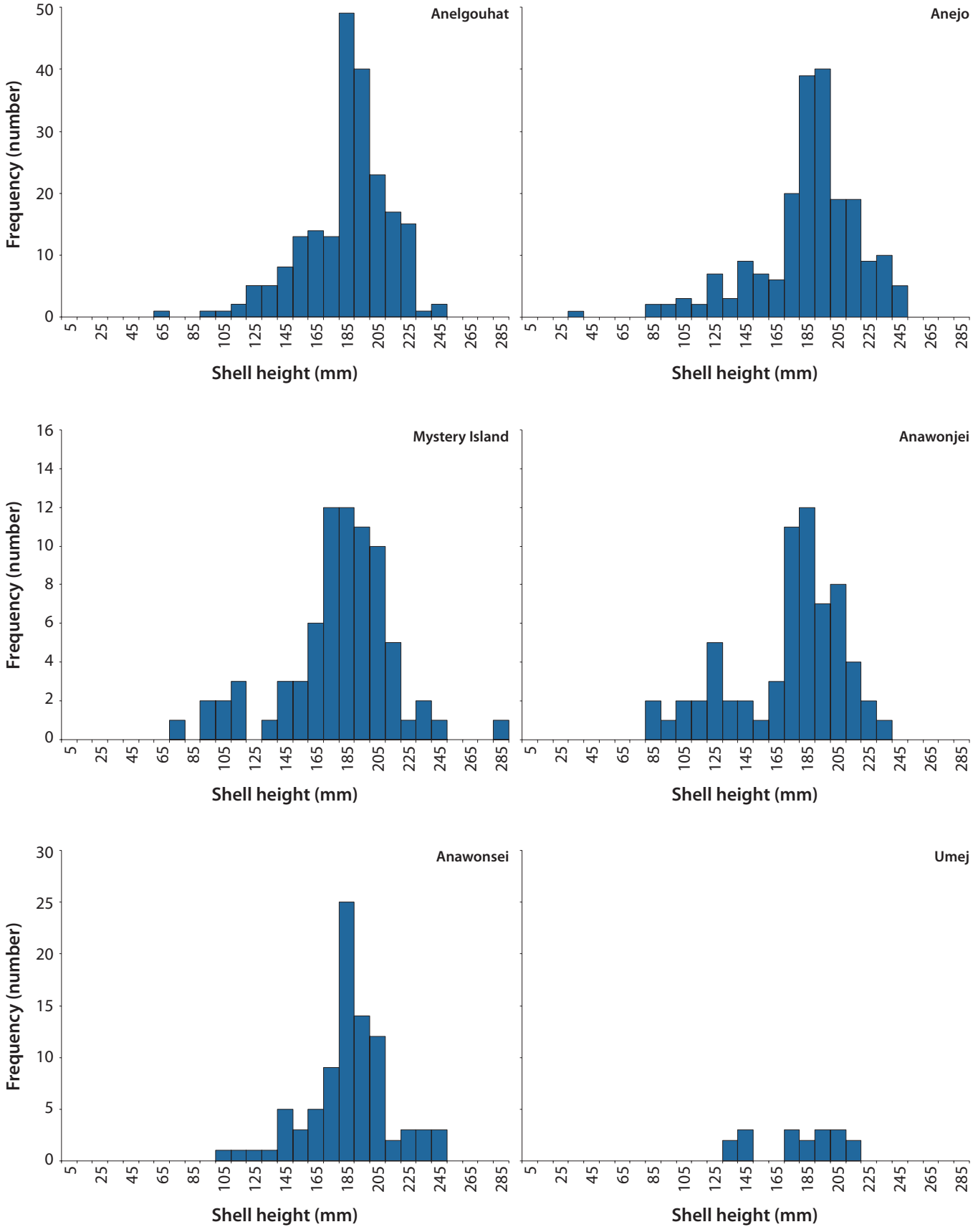

Figure 20. Green snail size structure by sites, Aneityum.

4.3.5 *Shell quality and breeding capacity*

Shells found in the villages, and encountered at sea and on the beaches, as well as a few samples taken, were assessed for inner and outer shell quality. Generally, larger older shells (greater than 180 mm) have very poor shell quality in both the exterior and interior layer. The interior layer tends to be infected by parasitic boring worms (seen as black marks on the interior layer) (Fig. 21, right) whereas the outer layer is often overgrown by calcareous algae and limperts (Fig. 21, left), which results in the damage and loss of the green outer layer, and lower shell quality. It is important to protect these old shells as breeding stock because they are more fecund (over 7 million eggs per shell) than smaller adult green snails. Shell quality assessments should also be undertaken as part of resource assessment surveys to enable an estimate of the stock of high quality shell for fishing purposes.

Figure 21. Damaged shells of larger green snail: coralline algae overgrowth and limpet attack on the outer layer (left) and boring worm attach on the inner shell (right), brown marks are worm marks (Photos: Kalo Pakoa).

4.4 Sighting and reports of green snail in other areas

Since the collapse of the fishery, green snail have become rare throughout the islands. Surveys conducted by SPC in 2003 recorded two adult specimens at Uripiv Island, Malekula (Friedman et al. 2008). The sale of green snail shells began to appear at handicraft stalls in Port Vila, and by 2012 more handicraft market vendors were selling polished green snail shells and operculum. Another SPC-led invertebrate surveys in 2011 revealed two juvenile green snails (130 and 150 mm) on the subtidal reef slope of Vulai Island, Maskelyne (Fig. 22), and this was followed by three other specimens recorded south of Uliveo Island by a team from the Vanuatu Fisheries Department (Jayven Ham, Vanuatu Fisheries Officer, pers. comm. 2012).

The Wiawi Conservation area (northwest Malekula) is of much interest. Since its establishment in 1995, the marine resources in this area have not been surveyed. A snorkel count survey conducted by members of the community in November 2013 following advice by one of the participants of the present training recorded 115 green snail specimens in one morning or an estimated 13 green snails observed per person per snorkel hour. Although preliminary, the results provide useful information on the existing green snail stock. According to Devambez (1961) this is indicative of healthy stock abundance. Extended protection of the area (over 20 years) by the community has worked to preserve green snail at Wiawi. A thorough assessment of the area must be undertaken as soon as possible. Other visits on Malekula in 2013 found signs of juvenile green snails at Uripiv Island and Rano Island. A summary of these sightings is provided in Table 6.

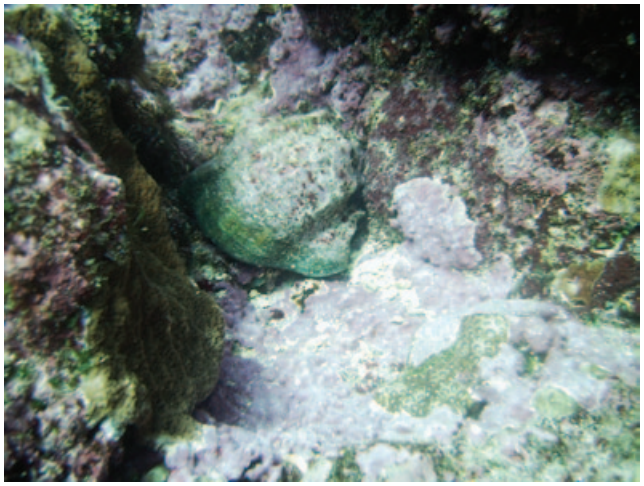

Figure 22. Young green snail specimens recorded in 2011 at Vulai Island, Maskelyne, Malekula (Photos: Kalo Pakoa).

Table 6. Sightings and reports of green snails in other sites.

Date	Descriptions of sightings	Record of sightings	Comments
June 2011	MOP transect survey exercise at Vulai Island, Maskelyne	2 specimens: 130 and 150 mm	Need for dedicated assessment
September 2011	Sea cucumber surveys at Uliveo Island, Maskelyne	3 specimens recorded south of Lutes Village	Need for dedicated assessment
September 2013	Uripiv Island, released juvenile recapture surveys by JICA project	Some adults and tagged juveniles recorded (no data provided)	Need for dedicated assessment
September 2013	Rano Island, Malekula dead shells found on the beach	Picture of dead shells of juveniles with burnt mark, broken shell and operculum	Need for dedicated assessment
November 2013	Malekula-Wiawi Conservation Area search survey by villagers with Fisheries Officer advice	Swim search by three villagers in 115 green snails recorded in a Morning at a section of the reef, data forwarded to Pita Neihapi	Need for dedicated assessment
December 2013	Malekula — Crab Bay, Tisman, Aulua	Suitable places for green snail	Need for dedicated assessment
December 2013	Cooks Bay and Port Narvin, Erromango information from a village member	Sightings of many green snail shells, a fisher seeking market for the shell in September 2013	Need for dedicated assessment

4.5 Green snail mariculture and reseeding trials

Green snail mariculture and reseeding studies have been undertaken through the assistance of the Grace of the Sea project. Some of the adult green snails from Aneityum have been used for hatchery breeding since 2007 and in 2008 trial reseeding studies were conducted at Mangaliliu on Efate (Fig. 23) (Jimmy et al. 2009). Further reseeding trials were undertaken at Uripiv Island on Malekula from 2012 to 2013. The results so far have indicated high mortality of reseeded juveniles. Hatchery-produced juveniles were not adapted to the natural reef environment and did not hide from predators and so were easy prey. Released juveniles were eaten by carnivorous invertebrates such as hermit crabs (*Aniculus aniculus, A. sibogae*), reef crabs (*Thalamita pelsarti* and *Carpilius smaculatus*), mantis shrimp (*Ordontodactylus scyllarus*) and spiny lobster (*Panulirus penicillatus*), parrot fish (*Scarus microrhinus*), wrasse (*Choerodon azurio*) and pufferfish (*Diodon holocanthus*).

While trials continue to be conducted, reseeding with hatchery-reared juveniles for stock enhancement is inconclusive. The main challenges for green snail mariculture are the difficulty of sourcing broodstock and the high cost of financing the hatchery and reseeding studies. Similar studies have been conducted in Tonga (Niumeitolu et al. 1999) and in Japan (Kikutani et al. 2002) but have faced the same problem of high mortality and inconclusive results with regard to reseeding as a management tool.

Figure 23. Hatchery reared green snail juveniles ready for release (left) and release site at Mangaliliu, Efate (Photos: Kenichi Kikutani).

5. Discussion

Green snail stock recovery on Efate: Green snail is a declining resource in Vanuatu but through the enforcement of the 15-year moratorium on commercial harvesting and export of the shell, the resource is beginning to recover. The species has become rare on Efate but has reappeared on reefs at Takara in the north, and Moso, Mangaliliu, Hat Island and Tukutuk Bay on the west of the island. Additional fishing activities reported at the reefs along the south coast of the islands at Devils Point, Bukura, Pango, Erakor, Eratap, Teouma, Whitesands and Erueti are indications of stock presence. Further resource assessments in these areas should be undertaken as a matter of priority. Green snail shells transplanted to Mangaliliu and Lelepa Island are in relatively good condition and are contributing to the recruitment of young green snail in the area. Green snail adults released at Sunae Reef have not been recovered and are likely to have been lost. The reef habitat condition of north Moso (Sunae) is unsuitable for green snail (low reef complexity and impacted by high siltation), although the lack of recovery of dead shells raises a question of fishing impact.

Fishing of green snail on Efate for subsistence use and for the shell, which is sold as souvenirs, has increased over the last three years. Polished green snail shells are sold at VAT 3,000–5,000 per piece and VAT 100–300 per piece for the shell operculum, while the meat is used as food. Shells confiscated at the market comprised mainly young green snails, indicating that young recruited shells are being fished. Fisheries Enforcement officers began to confiscate shells at the market in 2012, which has helped to deter and reduce sale activities in 2013. It seems, however, that fishers and market vendors are unaware of the existing ban on the sale of green snail. Fishers on the other hand are unaware of the ban and the need to leave green snails on the reef to allow faster recovery of this resource. While some communities on Efate are making an effort to protect their green snails, poaching by fishers from Port Vila is a serious problem. Raising awareness is important in order to educate the public on the need to protect the resources, and that fishing for green snail meat or the shell should be discouraged throughout Vanuatu.

Green snail recovery on Aneityum: Overall, green snail stocks at Aneityum are intact, and are present and abundant on the reefs around the island. High abundance of green snail was recorded at Anelgouhat and Anejo in relation to the larger habitat area present. But there are signs of impact on shells less than 180 mm, which could be caused by subsistence fishing activities, or the recruitment of shells in shallow waters has yet to reach its full capacity. The green snail population size structure at Aneityum is skewed towards older shells (i.e. larger than 180 mm in shell height), and these older stocks are sustaining populations of younger green snails. Green snails larger than 180 mm are overgrown with calcareous algae and micro-invertebrates on their outer layer and the inner shell is infected by shell-boring parasites. These larger shells have a high reproductive capacity and should be reserved as breeding stock to support stock reproduction. A maximum size limit for fishing for the shell should be set at 180 mm to minimise the take of larger fecund green snail that are generally of lower economic value due to shell-boring parasites.

Fishing controls enforced by the community five years prior to the national ban have helped to preserve the stock from further harvests. Stocks in shallow waters are now recovering but their distribution and abundance on different reefs are uneven due to various habitat conditions. Areas of habitable reef systems at the north, west and southwest support the main stocks of green snail, while the reef-limited coasts on the south and east support few stocks. The green snail stock at the Mystery Island marine protected area was concentrated on the western reef edges and reef slope due to the presence of complex reef systems well covered with feed algae in these areas. Along the southern reefs of Mystery Island, the reef complexity and topography is moderate to low and lacks cervices, holes and overhangs which are preferable habitats for green snail. On the east side of the marine protected area, the reef habitat is good for green snail but high wave action may limit recruitment flow to the east. The presence and abundance of green snail is determined largely by the suitability of the reef habitat; a marine protected area that has been established in an unsuitable green snail reef habitat will not increase stock abundance.

Green snail translocation and reseeding: The introduction of adult green snails on west Efate is contributing to the recovery of green snail in the surrounding areas of Moso, Lelepa, Hat Island, Mangaliliu and Tukutuku Bay. However, recruitment from this stock to reefs of south Efate (from Devils Point and eastward to Erueti) is questionable and may be limited. From experience, the recruitment of green snail along the southeast, east to the northern reefs of Tahiti Island, French Polynesia was successful because the original stock was released on the southeastern part of the island (Tautira Reef). Incoming currents generated by the southeasterly trade winds was responsible for the dispersal of larvae in the direction of the current flow to the west and north and south coast (Yen 1991).

Similarly, the recruitment of trochus on the western reefs of Tongatapu lagoon in Tonga was due to recruitment originating from stock introduced at the eastern reefs of Euaiki Island (Pakoa et al. 2010). Larval flow to the southern and northern reefs of Efate goes against current understanding. Recruitment originating from existing wild green snail stocks at Efate has not been ruled out as an explanation of recruitment seen in the north and south of the island. Information on current flow for Efate Island would help provide information on potential recruitment patterns and potential re-stocking sites on Efate.

The current lack of green snail stocks in Vanuatu is a challenge for resupplying stocks within Vanuatu and abroad. Aneityum is the only site that has a healthy stock but caution must be taken to leave enough breeding stock to replenish that population. Community leaders on Aneityum have indicated the need to protect their green snail stock and use existing stocks for restocking reefs on the island first to rebuild stocks in areas of low stock abundance. Reseeding with hatchery-produced green snail has yet to produce positive results with regard to recovery. Despite ongoing studies, the high cost of hatchery breeding and reseeding means that a decision must be made about whether future trials should continue or be abandoned, and instead focus efforts on wild stock transplantation, public awareness, and monitoring and effectively managing existing stocks.

Green snail recovery in other areas: Signs of green snail recovery have been observed at Malekula. Green snail specimens observed at the Maskelyne Islands in 2011 and recently at Wiawi Conservation Area are encouraging signs. Dedicated resource assessment surveys are needed in these areas to document the state of the recoveries in these areas and including other areas of northeast Malekula where harvesting activities has been reported. Similar monitoring surveys are needed in major fishing grounds of Emae, Erromango, Santo and the Banks Group in the next six years of the moratoria to assist decision making at the end of the moratoria. General education and outreach on green snail protection should be conducted in communities and current harvesting practiced discouraged.

6. Management recommendations

1. ***Effectiveness of the 15-year ban:*** The 15-year ban on the harvesting and sale of green snail shell or meat is working to protect the resource from further depletion and is allowing recovery of the resource. Signs of successful recruitment are being seen at Aneityum and Efate and sightings have been reported in Malekula. While these are good news for the species, it is too soon yet to see full recovery of stocks to harvestable levels. More monitoring assessments are needed in other areas in the next six years to locate existing stocks. This and other information gathered should be used to decide about the future management of the resource after 2020.
2. ***Effectiveness of enforcing the ban:*** The enforcement of the ban on the sale of green snail shells in Port Vila markets has been effective. Polished shells that were being sold illegally are no longer offered for sale at the markets and many handicraft sellers are now aware that selling green snail shell is prohibited. However, some sellers are still selling shell operculum commonly known as "cats eye". The ban covers all parts of the green snail, including the meat, shell and operculum, and therefore sale of shell operculum should not be allowed.
3. ***Knowledge about the regulation of the ban:*** Awareness and education about the regulation banning green snail are important. The production of posters, pamphlets and signs posted at potential fishing grounds are options to increase public awareness about the ban. On the other hand, the lack of knowledge about the existing ban or other regulation on green snail should not be used as an excuse not to enforce the current regulation.
4. ***Is harvesting for subsistence use exempted from the ban:*** Under the current Fisheries Regulation, the harvesting of green snail is outlawed. The regulation says it is prohibited to take, harm, have in possession, sell or purchase green snail until October 1st 2020. Therefore, the harvesting of green snail at Aneityum, Efate, and Malekula for food is illegal and anyone found doing so including subsistence use violates the current law and should be prosecuted.
5. ***Use of green snail shells must be discouraged:*** The Vanuatu Fisheries Department should not promote any activities that could be seen to encourage the harvesting of green snail. Activities such as green snail shell polishing, collection and keeping of dead green snail shells, tasting of green snail meat by visitors, or an estimation of harvestable stock of green snail in an area during the moratoria period whereby such information can be used by fishers for illegal fishing activities; these activities are or can be seen as encouraging the harvesting of green snail and therefore should not be encouraged.
6. ***Green snail fishery management plan:*** A national fishery management plan for green snail should be developed during the current moratorium. The management plan should provide national policy on the green snail fishery and the measures needed to control fishing activities (e.g. licenses, quotas, price information, product quality, procedures for conducting resource assessments etc), as well as the requirements for green snail translocation and mariculture and reseeding activities. The plan should outline the domestication of the commercial green snail fishery when the fishery reopens to promote shell value adding opportunities for local small scale handicraft stores or in other words a ban on the commercial export of raw or processed green snail shell products.
7. ***Protecting green snail products for growing handicraft market:*** Vanuatu has learned a lesson: the collapse of the fishery means the resource is naturally limited to support the commercial export of large quantities of green snail shells. The local marketing of polished green snail shells by local Ni-Vanuatu owned handicraft shops in Port Vila points to the need for domesticating green snail shell marketing in the future. Increasing tourism provides potential markets for handicrafts and souvenirs, and green snail shell makes an excellent product for this local market. Commercial harvesting of green snail in future should be allowed only for the domestic market, and the export of raw or partly processed shells should be prohibited.

8. ***Minimum and maximum size limit:*** When the resource recovers and prior to lifting the moratorium, a new green snail regulation should include minimum and maximum harvestable size limits. Large green snail shells are poor in shell quality from parasitic invertebrates clinging on the shell and coralline algae growth and internal shell damages by shell-boring worms. These large shells have high spawning capacity and should be protected as breeding stock. A size limit range of 150–180 mm shell height is proposed based on the former minimum size limit regulation of 150 mm and a 30 mm harvest size window allowance. Noting that shell quality and sizes can vary by sites, shell quality grading should be undertaken on a site by site basis during stock assessment surveys for use in estimating the stock of high quality shells.
9. ***Green snail shell size measurement:*** Shell height and widest shell diameter have been used in size measurements of green snail in Vanuatu which have not been useful in aggregating or comparing the data. Measuring widest shell diameter can vary depending on the formation of the shell or the placing of the measuring instruments as compared to measuring shell height. Shell height provide a more consistent size measure and have been used mostly in recent size recordings (Jimmy et al. 2009) and therefore should be maintained and standardized in all surveys as the formal green snail size measurement method in Vanuatu.
10. ***Shell operculum:*** Shell operculum products have been offered for sale as handicraft and it is currently impossible to tell an undersized green snail shell from an operculum. The definition of minimum shell size should also include operculum or "cats eye". A study on operculum diameter and shell height relationship is needed to determine minimum and maximum operculum size limits in relation to overall shell size limits.
11. ***More resource assessment surveys to locate stocks:*** Surveys of green snail are recommended on Efate from Devils Point, Bukura, Pango, Erakor, Eratap, Teouma, and Erueti to locate existing stocks. These areas should be monitored over time to assess overall recovery. At Malekula, surveys should target Wiawi, Rano and Uripiv to assess the status of stocks. Other areas of interest for assessments are Emae and Cooks Reef, Tutuba Island and Port Narvin on Erromango. Other sightings across the country should be followed up with assessments to properly document the distribution of green snail across the country. Effort should be made to standardised survey methodologies.
12. ***Community ecotourism opportunities:*** Green snail is a rare species in Vanuatu and the Pacific Islands. The communities of Aneityum and Efate should promote protection of their green snail sites and promote ecotourism tours to raise more awareness about this species. Vanuatu Fisheries Department, Non-government organisations and tourist operators should assist communities in the area.
13. ***Shell translocation and introduction:*** The community of Aneityum would like to see their green snail stock being used to restock reefs around their island as priority. Once the stock recovers on all reefs of the island only then would they be in a position to donate adult green snail stock to assist other islands and or countries in the region with introduction of green snail. It is recommended that the removal of live green snail stock from an area for translocation or for introduction purposes should be based on sound stock assessment surveys to ensure removal of stock does not affect the sustainability of the remaining population.
14. ***Management of introduced green snail at Mangaliliu and Lelepa:*** The communities of Mangaliliu and Lelepa are encouraged to aggregate newly recruited green snails from other reefs to the original transplantation sites to increase spawning biomass and to supplement the current spawners group which are getting too old.

15. ***Mariculture and reseeding:*** Reseeding studies currently being conducted should report on the final result at the end of the current trial and recommend ways forward. If the trial is not producing positive outcomes then a decision should be made on the continuation of such trials for cost effectiveness. A focus on adult transplantation, monitoring and effective enforcement of the current ban seems to be a more effective management approach. More efforts should be put into monitoring of wild stocks, awareness and enforcement.
16. ***Community-based management:*** Community management is important and should continue to be promoted. However, pressure to harvest the resource for money can drive fishers to ignor community management rules. The current regulation banning green snail harvest need to be well explained to the communities if illegal green snail harvesting is to be controlled at the community level.

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Appendix 1.

Historical green snail export production from Vanuatu, 1950–2004

Year	Quantity (t)	Reference	Year	Quantity (t)	Reference
1950	6	Van Pel 1956	1984	46	McElroy 1992 from Tim Adams
1951	10	Van Pel 1956	1985	22	McElroy 1992 from Tim Adams
1952	9	Van Pel 1956	1986	30	McElroy 1992 from Tim Adams
1953	27	Van Pel 1956	1987	24	McElroy 1992 from Tim Adams
1954	18	Van Pel 1956	1988	20	McElroy 1992 from Tim Adams
1955	52	Van Pel 1956	1989	23	McElroy 1992 from Tim Adams
1956	40	Van Pel 1956	1990	10	Vanuatu Fisheries Department
1957	35	Vanuatu Bureau of Statistics	1991	44	McElroy 1992 from Tim Adams
1958	8	Vanuatu Bureau of Statistics	1992	7	Vanuatu Fisheries Department
1959	-	Data not available	1993	51	Vanuatu Fisheries Department
1960	-	Data not available	1994	11	Vanuatu Fisheries Department
1961	-	Data not available	1995	1	Vanuatu Fisheries Department
1962	-	Data not available	1996	2	Vanuatu Fisheries Department
1963	-	Data not available	1997	2	Vanuatu Fisheries Department
1964	-	Data not available	1998	1	Vanuatu Fisheries Department
1965	-	Data not available	1999	1	Vanuatu Fisheries Department
1966	-	Data not available	2000	0	Vanuatu Fisheries Department
1967	-	Data not available	2001	0	Vanuatu Fisheries Department
1968	-	Data not available	2002	0	Vanuatu Fisheries Department
1969	14	Grandperrin and Brouard 1983	2003	1	Vanuatu Fisheries Department
1970	-	Grandperrin and Brouard 1983	2004	0	Vanuatu Fisheries Department
1971	7	Grandperrin and Brouard 1983	2005–2020	-	Moratorium
1972	17	Grandperrin and Brouard 1983			
1973	20	Grandperrin and Brouard 1983			
1974	50	Grandperrin and Brouard 1983			
1975	51	Grandperrin and Brouard 1983			
1976	65	Grandperrin and Brouard 1983			
1977	22	Grandperrin and Brouard 1983			
1978	20	Grandperrin and Brouard 1983			
1979	23	Grandperrin and Brouard 1983			
1980	16	Grandperrin and Brouard 1983			
1981	36	McElroy 1992 from Tim Adams			
1982	49	Grandperrin and Brouard 1983			
1983	25	McElroy 1992 from Tim Adams			

Note: Vanuatu Fisheries Department are the Departmental Annual reports for 1997, 1998 and for 2004.

Appendix 2.

Reef habitat area for Aneityum Island

Habitat type	Total reef area (m^2)	Total reef area (ha)
Barrier reef pinnacle / patch reef	62,100	6.2
Deep terrace	965,700	96.6
Forereef	12,196,800	1,219.7
Pass	2,183,400	2,18.3
Pinnacle	43,200	4.3
Reef flat	17,246,700	1,724.7
Shallow terrace	3,602,700	360.3
Shelf slope	44,126,999	4,412.7
Subtidal reef flat	1,183,500	118.4
Total reef area	**81,611,099**	**8,161.1**

Appendix 3.

Sites surveyed and coverage area at Efate and Aneityum islands

Sites	Survey type	Number of stations	Reef area (m^2)	Reef area (ha)
Efate — Undine Bay	RBt	10	2,400	0.30
Efate — Lelema	RBt	9	2,160	0.20
	SWSs	1	480	0.05
Aneityum — Analgauhat	RBt	8	1,920	0.20
	SWSs	6	9,504	0.90
Aneityum — Anejo	RBt	12	2,880	0.90
	SWSs	8	12,672	1.30
Aneityum — Anawonsei	RBt	5	1,200	0.10
	SWSs	3	4,752	0.50
Aneityum — Mystery Island	RBt	13	3,120	0.30
	SWSs	7	11,088	1.10
Aneityum — Anawonjei	RBt	4	960	0.10
	SWSs	3	4,752	0.50
Aneityum — Umej	RBt	4	960	0.10
	SWSs	2	3,168	0.30

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