The status of sea cucumber fisheries resources and management for Palau

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by

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Summary

Palau has recently experienced one of the highest levels of income ever realised from the sale of sea cucumber. Over USD 1.3 million was received by fishers in 48 days of harvesting in 2011 — the benefit of investing nearly 20 years of waiting for resources to fully recover. The 2011 harvest produced the largest catch of sea cucumber ever seen in Palau, at 1,160 tonnes of raw sea cucumbers. This production was made up mainly of hairy greyfish, a type of sea cucumber endemic to Palau, Yap and Pohnpei, and brown sandfish.

The low price of hairy greyfish at the beginning of the season (USD 0.04 cents per piece) contributed to loss of income in Palau. This was remedied somewhat when the price rose to USD 0.15 later in the season. The price of USD 0.33 per piece for brown sandfish was too low for an animal that weighs nearly a kilo wet weight, and also too low compared to the price in Fiji of USD 2.00 per kg wet weight. The price per piece in Palau should have been set at around USD 1.50 per piece. Despite good data collected during the open season in 2011, there is a need for improvements.

Beche-de-mer exported during the official open season in 2011 totalled 72 tonnes at a total declared value of over USD 1.1 million. The beche-de-mer export operators are all foreign-owned companies in joint venture arrangements with local interests. The declared export value of USD 1.1 million is lower than the total purchase value USD 1.3 million declared based on landing data confirms under-reporting of the export value. The unauthorised export of over 27 tonnes of beche-de-mer as cultured sea cucumber led to loss of income for the people of Palau. These are hard lessons for authorities responsible, who must ensure that this is prevented from happening again in future.

Hairy greyfish (*Actinopyga* sp.) is the most important resource and comprised the majority of exports (70%). The capacity of this species to aggregate in relatively high densities in a small area, its medium value (USD 20.00 per kg dry weight) and its seagrass habitat preference makes it a highly fragile resource but an attractive candidate for strong community-based management. Recent harvesting in 2011 at Ngarchelong, Ngatpang and Ngardmau reduced stocks of hairy greyfish by 80% to 90%. Stock protected inside the Marine Protected Area at Ngardmau State can contribute to the recovery in fished areas.

Harvesting of the non-permissible species — including some of the banned species — has occurred. Effective enforcement of the regulations on permissible species in recent seasons has been challenging due to the lack of an established mechanism to effectively monitor landings, flow of products and exporting activities. The draft national sea cucumber management plan provides a framework for an improved monitoring system and finalising it should be a priority before more fishing occurs.

The fisheries management authority in Palau should be mindful of investors in mariculture of sea cucumbers. While mariculture could provide an opportunity, it has not been proven as yet as a successful economic activity for species present in the Pacific Islands region. An aquaculture licensing system with a license application appraisal procedure is required to ensure that only genuine developers are allowed to conduct sea cucumber mariculture research and that results are provided to the government of Palau.

The improved harvesting strategy adopted in 2011 is a step in the right direction. The new sea cucumber management arrangement and resource assessment and stock estimation procedure provided ways forward for preparing future harvests. As opening harvesting in many States at the same time can be a challenge, implementing rotating open harvests by State is a better strategy. The high population of certain stocks of sea cucumber in Palau is the result of the long resting period; a system based on long periods of rest and short open seasons and by State based on prescribed harvestable species is thus the way forward for Palau for a sustainable sea cucumber fishery.

1. Introduction

1.1 Background

Located in the western Pacific within the "Coral Triangle", Palau's rich and varied marine ecosystems support a number of valuable marine species, including sea cucumbers, which are used in the commercial beche-de-mer trade. Palau's coastal marine habitats consist of lagoons (with a combined estimated area of 1,034 km^2), outer reefs (area = 265 km^2), inner reef (area = 187 km^2) and mangroves (area = 45 km^2). (Friedman et al. 2009). Coastal reef fisheries are important for subsistence food security and domestic economy. Sea cucumber resources are an important source of protein and livelihood for the people of Palau. Commercial fishing for sea cucumbers began in the 1700s, and is thought to have actively occurred in Palau and the rest of Micronesia in the 1800s. Commercial fishing and the export of beche-de-mer (dried and processed sea cucumbers) were banned in Palau in 1994 after the resource had been overfished.

Eight species of sea cucumbers are consumed by the native people of Palau (Pakoa et al. 2008). Subsistence harvesting of sea cucumbers is practiced for home use, sale at the local market, and for export to relatives living abroad. In 2007, traders were interested in exporting sea cucumbers from Palau and sought to obtain export licenses. A trial open season was permitted in 2011 for seven months, however harvest of non-prescribed species and difficulty in effectively monitoring fishing activities resulted in decision to reinstate the ban while new management arrangement is put in place. The Bureau of Marine Resources (BMR) was tasked to come up with an improved national sea cucumber fisheries management arrangement and monitoring mechanism, regulatory measures and a standard resources assessment process.

1.2 Objectives of this report

Since March 2012, the Palau International Coral Reef Center (PICRC) has conducted assessment surveys for sea cucumbers in Ngardmau State at the request of the State Governor after the massive harvesting that occurred in 2011. The Bureau of Marine Resources conducted assessments in the same area and both institutions conducted further sea cucumber surveys at Peleliu State the same year. However, the results obtained from differing sampling methods resulted in disagreements. SPC was requested to assist with resources survey training for better understanding of the state of the resource. At the same time the survey training provides an opportunity to gather sea cucumber stock information at Ngarchelong, Ngardmau, Ngatpang and Peleliu to advise on resource statuses. Resource information is cross-checked with catch and export data for the 2011 season to assess the impact of fishing activities. Specifically the objectives of this report are to:

- provide up to date sea cucumber species list for Palau and their abundances at sites assessed;
- provide the results of the quantity and value of landed sea cucumbers and exported beche-de-mer from Palau; and
- recommend measures for improved management and monitoring to be incorporated in the Palau national sea cucumber fisheries management plan.

1.3 Sea cucumber resources

Of the 1,200 species of sea cucumbers distributed throughout the world's oceans, 28 species are present in Palau and 26 of these species are important in the beche-de-mer trade. Table 1 provides an up to date list of common, local Palauan names and scientific names of sea cucumbers found in Palau. One species of interest is the hairy greyfish or eremrum (its local Palauan name), which has been exploited both traditionally and commercially in Palau for many years both for the production of beche-de-mer and for subsistence and domestic sale. To date, however, this species has not been correctly described in the scientific literature. Taxonomic study is currently being carried out on this species.

Sea cucumbers are filter feeders that feed by ingesting sand grains and detritus on the sea floor. In doing so, they help recycle nutrients that are locked into the lagoon floor, and making them available to other organisms and ensuring a healthy lagoon ecosystem. Sea cucumbers breed by both sexual and asexual means by natural regeneration of body parts. Spawning typically occurs in summer when seawater temperatures are warm (Chao et al. 1994), however some species have been observed to spawn in winter, such as black teatfish (Conand 1993) and year-round, such as sandfish (Ramofafia et al. 2003), particularly in the Pacific. Most sea cucumbers have separate sexes and some species, especially soft-bodied species, undergo asexual reproduction.

Table 1. Commercial sea cucumber species in Palau.

Common name	Abbreviation	Palauan name	Scientific name
Amberfish	AF		*Thelenota anax*
Black teatfish	BTF	Bakelungal	*Holothuria whitmaei*
Brown curryfish	BCF	Ngimes	*Stichopus vastus*
Brown sandfish	BSF	Mermarch	*Bohadschia vitiensis*
Chalkfish	CHF	Mermarch	*Bohadschia marmoratus*
Curryfish	CF	Ngimes	*Stichopus herrmanni*
Deepwater blackfish	DWBF	Ewas	*Actinopyga palauensis*
Deepwater redfish	DWRF		*Actinopyga echinites*
Dragonfish	DF	Ngimes	*Stichopus horrens*
Elephant trunkfish	ETF	Delal a molech	*Holothuria fuscopunctata*
Flowerfish	FF		*Pearsonothuria graeffei*
Golden sandfish	GSF	Molech	*Holothuria lessoni*
Greenfish	GF	Ngimes	*Stichopus chloronotus*
Hairy blackfish	HBF	Eremrum	*Actinopyga miliaris*
Hairy greyfish	HGF	Eremrum	*Actinopyga* sp.
Impatient sea cucumber	ISC	Sekesakel	*Holothuria impatiens*
Kingfish	KF		*Holothuria maculata*
Lollyfish	LF	Ewas	*Holothuria atra*
Pinkfish	PF	Ewas	*Holothuria edulis*
Prickly redfish	PRF	Temtaml	*Thelenota ananas*
Red snakefish	RSF	Usekerel a daob	*Holothuria flavomaculata*
Sandfish	SF	Molech	*Holothuria scabra*
Snakefish	SNF	Usekerel a daob	*Holothuria coluber*
Stonefish	STF	Eremrum	*Actinopyga lecanora*
Surf redfish	SRF	Eremrum	*Actinopyga mauritiana*
Tigerfish	TF	Mermarch	*Bohadchia argus*
Tiger tail	TTF		*Holothuria hilla*
White teatfish	WTF	Bakelungal	*Holothuria fuscogilva*

1.4 Sea cucumber fishery

1.4.1 Subsistence fishing and processing

The subsistence harvest and use of sea cucumbers in Palau occurred long before they were harvested commercially. Of the 26 species of sea cucumbers present in Palau, eight species are harvested by the subsistence fishery: sandfish, hairy greyfish, brown curryfish, impatient sea cucumber, prickly redfish, dragonfish, chalkfish, and brown sandfish. The most important sea cucumbers are sandfish, hairy greyfish, dragonfish and impatient sea cucumber (Pakoa et al. 2009). The intestine of brown sandfish and hairy greyfish is edible, whereas both the intestine and body wall of sandfish are edible as pickled food. The intestine of impatient sea cucumber is prepared mainly by the people of Ngarchelong State, and is highly sought after at the local market (Harvey Renguul, Aquaculture Specialist, Palau Bureau of Marine Resources, pers. comm. 2008). It takes about 20 animals to make a pack of pickled impatient sea cucumber, which is sold at the local market at USD 5.00 pack^{-1}, while the meat (body wall) of sandfish (molech) and hairy greyfish (eremrum) is sold at USD 1.50 pack^{-1} of 0.5 kg, and USD 2.50 pack^{-1} of 1 kg (Pakoa et al. 2009).

Collecting and processing sea cucumbers is primarily done by women, although men sometimes participate. Most of the sea cucumbers that are important for the subsistence fishery are shallow water, inshore species found in soft bottom seagrass beds that are associated with mangroves. Collecting is done in groups of two or more fisherwomen at low tide by both wading and by snorkelling. A canoe, dinghy or raft is used to load the catch and bring it ashore. The technique for processing the body wall is slightly different for each species. For the hairy greyfish, the body wall is softened by hanging it out overnight in a wire mesh basket, and letting the contents slowly pass through the mesh, collecting it in a basin for use the next day.

Over the years, the subsistence sector has developed into an important semi-commercial fishery that has supplied the local and overseas market for home consumption by Palauan nationals living abroad in Guam, Hawaii and the US mainland. Production information is rare, but the available landing data for raw sea cucumbers from 1989 to 1998 reveals an average of 20 t year^{-1}. Much of this production (40%) is exported for home use, 30% is for local market sales, and another 30% is for domestic consumption within Palau. Local sales continue to be an important activity for women. A fisherwoman from Ngatpang State sells over 120 packs of processed sea cucumber body wall and intestine to shops and restaurants in Koror each week. Based on an average price of USD 2.07 pack^{-1}, this fisherwoman makes around USD 248.00 week^{-1} from selling sea cucumbers.

1.4.2 Commercial fishing and processing

In the past, the collection of sea cucumbers for processing into beche-de-mer was done mostly by exporters operating in the main fishing areas of Palau. A few local fishers who knew how to process some sea cucumber products in the village sold their produce to exporters at USD 0.20 kg^{-1}. In 1983, the Palau Federation of Fishing Associations (PFFA) bought dried sea cucumber products from local fishermen for export. The main products were black teatfish, white teatfish and prickly redfish at a standard price of USD 4.44 kg^{-1}; however, when the price fell to USD 3.33 kg^{-1} and even further to USD 1.11 kg^{-1} (Lewis Filibert, former exporter, pers. comm. 2008) in later years, local suppliers stopped supplying the market.

From 1986 to 1988, the two exporters based in Peleliu State exported 808 kg of black teatfish, white teatfish, prickly redfish and surf redfish to Singapore (Kokichi Ingas, pers. comm. 2008). More recently, three local exporters were active in Koror between 1986 and 1992. Each was active for only a year or two and each exported approximately 3 t of dried cucumbers (or ~9 t in total) to an agent in the Philippines at a standard export price of USD 5.00 kg^{-1}. Black teatfish, white teatfish and prickly redfish were the dominant export products in the 1980s and 1990s because of their thick body wall, with black teatfish being the most sought after.

Processing was done by the exporter (or exporters) with some assistance provided by the Division of Marine Resources, which later became BMR. Processing of good quality products requires certain skills that were not available at that time. Foreign workers, mainly from the Philippines, were brought in to do the diving and

processing. Some locals already knew how to process products but these people have either passed away or are quite elderly.

Commercial fishing and the export of beche-de-mer were stopped in 1994. In 2011, a six-month trial fishing period was allowed for Ngardmau State for a single species — hairy greyfish (*Actinopyga* sp.). During the six-month period, fishing was permitted only two days per week and during daytime hours only, for a total of 48 fishing days. All catches were landed at a designated spot at Ngardmau jetty where BMR officers and Ngardmau State Rangers (State officials in charge of providing surveillance of the State maritime area) were present to conduct inspections and sample catches. Catches were sold by bucket units (i.e. an 18-litre bucket) (Fig. 1) to an intermediary based in Ngardmau State for processing. Fuelwood was not permitted for cooking sea cucumbers so the processors used diesel cookers (Fig. 1, right) instead and dried sea cucumbers using a sun-drying rack. Dried sea cucumbers were transferred to the export company's storehouse at Koror where they were packed properly for export.

Five companies were licensed to export beche-de-mer in the 2011 open season. Some of these exporters set up their processing operations in Koror and bought sea cucumbers from fishers from other States, including Koror, Ngaraard, Ngiwal, Ngarchelong, Ngatpang, Airai, and Ameliik. Sea cucumber harvest season was granted only for Ngardmau State; however, fishers from other States also went fishing and supplied their produce to buyers in Ngardmau and Koror. It proved difficult for the State Governments and the Bureau of Marine Resources to effectively control harvesting activities. A Cabinet decision in December 2012 resulted in the reinstatement of the moratoria on commercial fishing and exports to allow time to come up with a national sea cucumber fisheries arrangement plan and monitoring mechanism.

Figure 1. 18-litre buckets (left) used for pricing catches, and diesel boilers (right) used to boil sea cucumbers. (Photos: Kalo Pakoa)

1.4.3 Sea cucumber export production

Since the 1920s, the islands of Micronesia produced an average of 189 t of dried sea cucumber per year for export to Hong Kong and China. Palau alone was a major producer of sea cucumbers in the region, supplying on average 84 t (or 44%) of dried weight from the 1922 to 1938. Species of importance that were traded in the 1920s and 1930s in Palau were sandfish, black teatfish, white teatfish, surf redfish, hairy blackfish and prickly redfish (Ilek 1991). Exports from 1922 to 1938 indicated a general decline in sea cucumber production in the 1930s (Fig. 2).

Fishing records after the Japanese occupation of Micronesia — from the 1940s up to the 1960s — are patchy although some trading activities are known to have occurred in the 1950s. Trade resumed in 1970 with a local

Palauan with assistance from the Division of Marine Resources. Two container loads of dried cucumbers were shipped out of Palau in 1970, each containing approximately 700–1,000 sacks of dried sea cucumber (Teruo Remoket, former DMR staff member, pers. comm. 2008). The main species targeted were sandfish, black teatfish, white teatfish, prickly redfish and surf redfish, which were sold at the export price of USD 7.00 kg^{-1}. Export information was not available up to 1990 and it was speculated to be due to the low catch rates of the six main commercial species.

Subsistence use of sea cucumber was not affected by the ban — especially for sandfish and hairy blackfish, which are consumed locally. Slowly the subsistence use of the local delicacy developed into a small-scale domestic market for the Koror based consumers and for Palauan consumers abroad in Guam, Saipan and the United States mainland (Pakoa et al. 2009). Landings data for raw sea cucumbers at domestic markets and exported to families living abroad are not being collected. Average annual landing for 1989 to 1998 were 11.3 t $year^{-1}$ of raw sea cucumber. Of this, 6.0 t (52%) were directly consumed, 5.3 t (48%) were sold at local markets, and 0.5 t were exported for home use overseas (The Environment, Inc 1999). Sea cucumber landing is known to have increased although there is little data evidence.

A further analysis of landing and exports for the 1990s and the recent landing and exports from 2009 to 2011 is covered in detail in the results subsection 4.1.

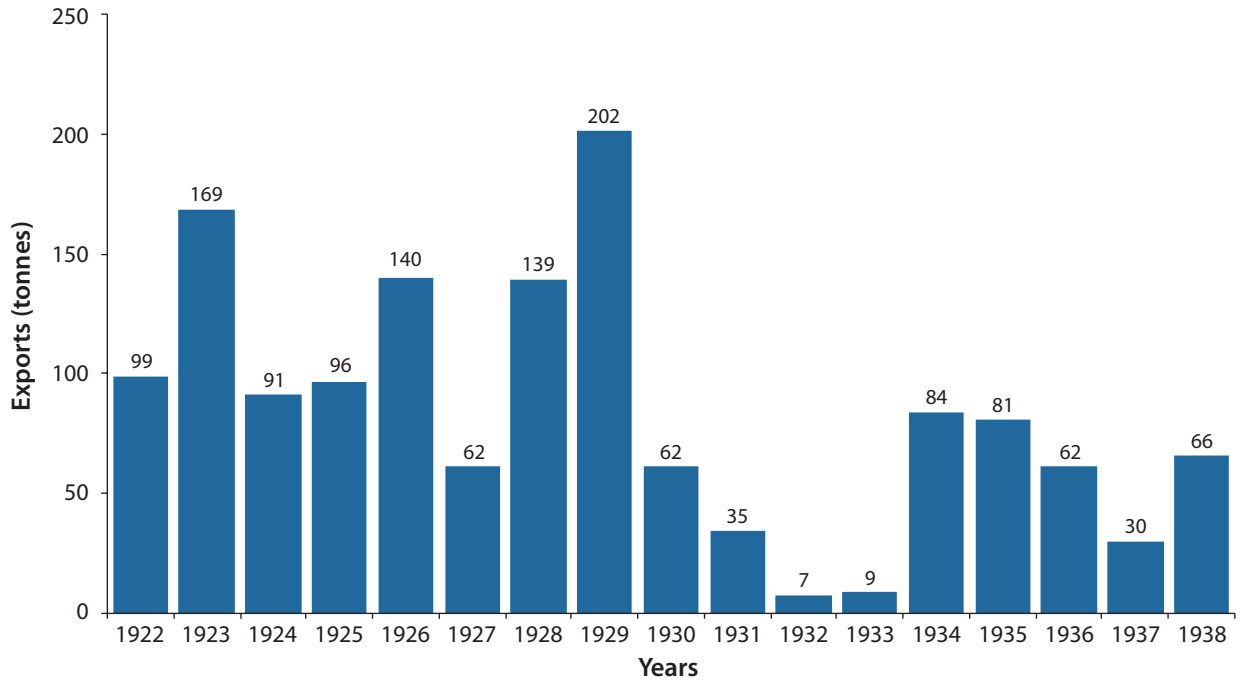

Figure 2. Sea cucumber export production from Palau from 1922 to 1938 (Ilek1991).

1.5 Sea cucumber management

Palau's commercial sea cucumber fishery is managed under State and national control. The low numbers of sea cucumbers revealed in resource surveys in Koror and Airai in 1991 (Ilek 1991) resulted in the formulation of regulations to ban commercial exports of sea cucumbers from Palau. The Palau Marine Protection Act (1994) legislates against the commercial export of six sea cucumber species: black teatfish, white teatfish sandfish, prickly redfish, surf redfish and hairy blackfish. These species were the main commercial species targeted by beche-de-mer traders in the past. The Palau Marine Protection Act (1994) bans the use of any underwater breathing apparatus for collecting sea cucumbers and other reef fish and invertebrate species. The Act authorises fisheries officers to inspect consignments leaving the country and legal power

to seize and condemn vessels violating the export laws. The Act also empowers the Minister of Fisheries to promulgate regulations pertaining to the protection of resources from overharvesting. A draft national sea cucumber management plan was developed in 2008 and submitted to BMR for consultation, but it was incomplete and lacks the measures to effectively control the fishery. A new management plan is going through consultation in Palau.

Subsistence fishing for locally edible sea cucumbers was restricted by the ban. Airport inspection was set up to monitor consignments of seafood leaving the country including sea cucumber. While these inspections have been effective, information on quantities was not accurately captured. In addition, exports for personal consumption was allowed to go ahead for sandfish and hairy blackfish, leaving a loophole for illegal exporting practices. In 2007, for instance, a sea cucumber trader in Palau obtained a license to cultivate and export brown curryfish but was later caught exporting dried sandfish under the name of dried brown curryfish. Likewise the commercial sale of sandfish and hairy greyfish at local shops and restaurants in Koror are not controlled.

Traditional management practices known as buls are still used in Palau and come under the authority of traditional chiefs (Ridep-Morris 2004). The traditional leaders from each State are responsible for implementing a local management system and are recognised by Palau's Constitution. All marine and terrestrial resources in each State are owned, managed and controlled by the State, and include areas such as lagoons, inshore areas and reef areas extending out to 12 nautical miles. Each State operates on its respective laws and enforcement program but seeks advice from the national government on technical matters relating to the Palau Marine Protection Act. National laws are well respected by the States and perceived as the supreme law of the land; however, enforcement is the sole responsibility of the national government despite the interest from State governments for national authorities to delegate the enforcement powers to the State level. Implementing the measures of the national sea cucumber management plan at the State level would require that respective State laws pertaining to marine resources are in agreement with the Palau Marine Protection Act.

1.6 Mariculture and sea ranching

Sea cucumber aquaculture and sea ranching activities have been trialled in Palau with mixed results. From 2000 to 2003, a joint venture company trialled sea ranching of brown curryfish by artificial cuttings and ranching in sea pens. Sea cucumbers harvested from the sea pen a few months later were exported as cultured products. The company's first export of wild caught sea cucumbers was worth around USD 7,000 (Jerome Temengil, former export company worker, pers. comm.). The company license was terminated for illegally exporting species that were not prescribed for harvest. A similar trial was undertaken from 2009 to February 2011 and involved a total export of over 27 tonnes of beche-de-mer. The lack of standard procedures for mariculture and ranching of sea cucumbers are a weakness, as investors are used to having access to wild stocks.

2. Past resource assessment surveys

As with other Pacific Island fisheries, resource assessment surveys of sea cucumbers have adopted various sampling strategies. Ilek (1991) used an unknown transect length to assess sea cucumber in Airai State, and Birkeland (1992) conducted 30-minute visual surveys at 47 sites in Palau to assess invertebrate resources. Kitalong (2003) used 100 m x 5 m transects to assess invertebrate resources in Airai State, and Maragos et al. 1994) carried out 30-minute timed scuba searches and transects to record marine species, including invertebrates. Miller (1995) surveyed 100 m x 4 m transects for sea cucumbers, and Bailey (2001) used 50 m x 5 m transects for sea cucumber surveys. In recent surveys conducted by BMR, a 250 m x 2 m transect was used to assess sea cucumber resources in Ngardmau State and 50 m x 2 m transects and 100 m x 2 m transects were used in Peleliu State to assess sea cucumbers. Palau International Coral Reef Center used 25 m x 2 m transects to assess sea cucumbers in Ngardmau State (Golbuu et al. 2012). Sampling strategies for assessing sea cucumber numbers have varied considerably, depending on the needs of different researchers and their project objectives.

The varying assessment protocols and results fail to ensure a unified understanding of the status of sea cucumber resources in Palau. SPC surveys conducted in 2007 (Friedman et al. 2009; Pakoa et al. 2009) provided comprehensive information on species, abundances and populations for the Palauan States of Ngatpang, Koror, Airai and Ngarchelong, and estimated annual landings by the subsistence sector. The flexibility in replication based on area of interest, habitat present, and timing have enabled a greater coverage and increased information about sea cucumber resources in these sites. The main results from the 2007 study (Friedman et al. 2009) indicated improvement in the abundance of most species as a result of the moratorium. In addition, there are signs that the continued harvesting for subsistence use, especially in Airai State, has dropped as result of continued harvesting to supply the local market of raw sea cucumbers in Koror.

3. Resources surveys and fishery data collection methods

3.1 Fishery data collection

Past sea cucumber catch and export data were extracted from the Palau Bureau of Marine Resources Annual Report (1992), Ilek (1991) and Pakoa et al. (2009). Recent catch and export data were provided by the BMR, and the export data for the period December 2009 to May 2011 were provided to SPC at the Regional Sea Cucumber Management Workshop in Nadi in 2011 as aquacultured sea cucumber production data. Beche-de-mer exports from these harvests are referred to in this report as the unofficial beche-de-mer exports, which are from harvests made without an official declaration of an open season — in other words illegal harvests.

The official sea cucumber open season was declared from 1 June to 29 December 2011 for the State of Ngardmau as a trial for a new harvest strategy. Catch landing data were collected by officers from the BMR and the State Officers from Ngardmau State (Fig. 3). Harvests were conducted for two days per week in the seven-month season, which amounts to 48 fishing days. Harvest was permitted during daytime hours — from 6 a.m. to 6 p.m. As fishers from other surrounding States also harvested and brought their catch to buyers based at Ngardmau, landing sites were set up at Ngarchelong, Airai and Koror (Fig. 3, top pictures) and respective State officers were asked to assist with the catch data collection. The sale of sea cucumber catch by fishers to processors was in 22-litre buckets (Fig. 3, bottom left), and the sale of raw sea cucumber meat at the local market in packets (Fig. 3, bottom right).

Beche-de-mer export data were provided by the BMR in Excel spreadsheets. Other information on fishing activities was obtained from discussions with community leaders, fishers, State officers and officers from BMR who were involved in the monitoring. Other experiences were shared by stakeholders at a sea cucumber management meeting in Koror and attended by representatives from the State Rangers, Environment Protection Authority, The Nature Conservancy, Palau International Coral Reef Center and the BMR.

Figure 3. Catch of brown sandfish in the 2011 open season from Koror and Airai States in Palau (left) (Photos: Eyos Rudimch); catch of hairy greyfish and processed meat sold at a local market (Photos: Kalo Pakoa).

3.2 Resource assessment surveys

3.2.1 Survey sites and planning

Ngardmau State on Babeldaob Island was the site of interest for this assessment, but because harvesting had spread to two other northern States, Ngatpang and Ngarchelong; they, too, were included in the surveys as additional sites (Fig. 4). Ngatpang and Ngarchelong were previously surveyed in 2007 (Friedman et al. 2009), so this follow-up provides a useful comparison of the impact of fishing activities. The third site, in Peleliu State, was assessed by trained officers from the BMR. The Peleliu State government had requested an assessment of sea cucumber stocks and advice on harvest quotas for future harvests. Boats and drivers used for conducting assessments were provided by the respective State Rangers, while SPC provided the fuel. Figure 4 indicates the locations of study sites.

Figure 4. Map of Baboldaob Island in Palau indicating the States where sea cucumber fishing occurred (red triangles) and where resource surveys were conducted (blue circles).

3.2.2 Resource survey methods and data analysis

The survey was based on maximum coverage of shallow reef habitat (0–10 metres) within the time allocated and resources available for assessment at each site. Assessments at Ngatpang and Ngarchelong States were a follow-up to the 2007 surveys (Friedman et al. 2009) to assess the impact of fishing in areas outside of Ngardmau. A mix of broad-scale survey methods (using manta tows) and fine-scale survey methods (using shallow water reef transects) were used in a range of habitats at each site. Details of the survey methods are outlined below.

Manta tow. Manta tow surveys are conducted over back reefs, shallow lagoons and lagoon slopes where coral and hard bottom substrates predominate (Fig. 5). These areas are representative of habitats suitable for tigerfish, black teatfish, prickly redfish and brown sandfish. Manta surveys are conducted at depths of

1–10 m, depending on visibility, but mostly around 1.5–4.0 m over coral and sand substrates. Manta tow surveys could not be conducted in areas that were too shallow for an outboard powered boat (< 1 m), in murky waters where visibility was poor, adjacent to wave-impacted reefs (reef top), or over dangerous swells. Manta tow transects cover a swath 300 m long and 2 m wide, an area of 600 m^2 per transect and 3,600 m^2 sample area per station (Pakoa et al. 2014).

Reef-benthos and soft-benthos transects. Reef-benthos and soft-benthos transects follow the same methodology but are differentiated by their respective habitat types (Fig. 5). Both methods are conducted in shallow waters (0–3 m) by snorkelling or wading at low tide over reef crests, back reefs, reef flats and sea grass beds. Six 40 m x 1 m transects are examined per station by two observers snorkelling on either side of the transect line and recording benthic invertebrates within each transect. Soft-benthos transects were conducted over soft-bottom seagrass and seaweed beds for hairy blackfish, chalkfish, dragonfish, golden sandfish, brown sandfish, red snakefish and sandfish.

Figure 5. Illustrations of the two assessment methods used for sea cucumber surveys in Palau: reef-benthos and soft-benthos transects (top) and manta tow surveys (bottom). (Illustrations: Youngmi Choi, SPC)

Information recorded during these surveys includes species counts, sizes, site name, date and environmental parameters, including descriptors such as relief and complexity, depth and substrate composition. Substrate composition is recorded as a percentage of coverage type, including fleshy algae, crustose coralline algae, seagrass, soft corals and hard corals. Location of transect stations and manta tow replicates were taken using a global positioning system (GPS) for geographic information system (GIS) use and for future monitoring purposes. Resource survey data were entered into a database (Reef Fisheries Integrated Database) in Noumea by trainees from BMR and the Palau International Coral Reef Center. After data entry and checking were completed, summaries on species presence, densities, size frequency, mean sizes were extracted and organised into tables and graphics for reporting purposes.

4. Results and interpretations

4.1 Fishery information

4.1.1 Subsistence, local market sales and personal consignment

Sea cucumbers are an important food resource in Palau and although landing information are not adequate enough to understand production trends, subsistence catches in general for all fisheries have increased with increase population size (Lingard et al. 2011). The total sea cucumber landings by the subsistence and commercial sector combined for the years 1989–1998 was averaged at 11.3 t per year (The Environment, Inc. 2000). Of this, 50% was for subsistence consumption, 48% was sold at the local market, and less than 2% was exported. Total productions in wet weight (Fig. 6 and Fig. 7) indicated subsistence, local market sales and commercial exports. The high productions from 1990 to 1992 include the dried beche-de-mer exports in wet weight. The corresponding dry weights are 2.2, 1.6 and 0.2 for the three years respectively. These were converted to wet weight using 6% wet-dry conversion (Palau Conservation Society 2000). In 1991, black teatfish, prickly redfish and white teatfish accounted for the bulk of the exports (87%), with black teatfish making up 61% of the exports.

The fall in commercial exports since 1993 (Fig. 6) was confirmed by the scarcity of these commercial species from a resource survey undertaken in 1991 (Ilek 1991). This prompted the decision taken in 1993 to close commercial harvest and export for the six main commercial species (black teatfish, white teatfish, hairy blackfish, surf redfish and prickly redfish) in 1994. Subsistence and local market sales continued to occur and were unaffected by the ban (Fig. 7).

Annual subsistence production of sea cucumbers (household use, local market and export for personal use) from 1993 to 1998 was averaged at 11.3 t at 52% for domestic household use, 48% sold locally and the rest was exported for home consumption (Fig. 6) (The Environment, Inc. 2000; Pakoa et al. 2009; Lingard et al. 2011). Excluding the beche-de-mer exports in 1990, 1991 and 1992, the subsistence production increased from 10.7 t in 1989 to 13.1 in 1998 (Fig. 6 and Fig. 7). While export data were being collected at the airport, it is not being analysed to monitoring trends. Increase in the frequency and size of containers being shipped out on nearly every flight leaving Palau has been noted by BMR staff (Harvey Rengul, BMR Officer, pers. comm. 2012).

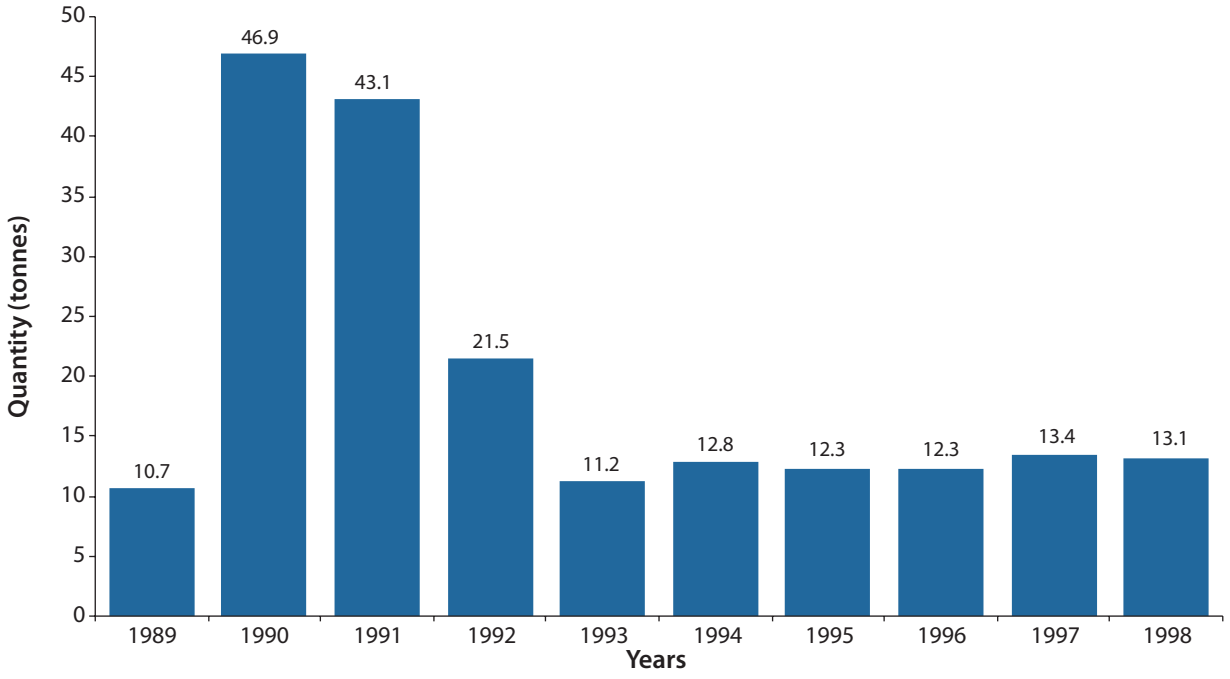

Figure 6. Total sea cucumber production quantity from Palau (data for 1990–1992 include beche-de-mer exports).

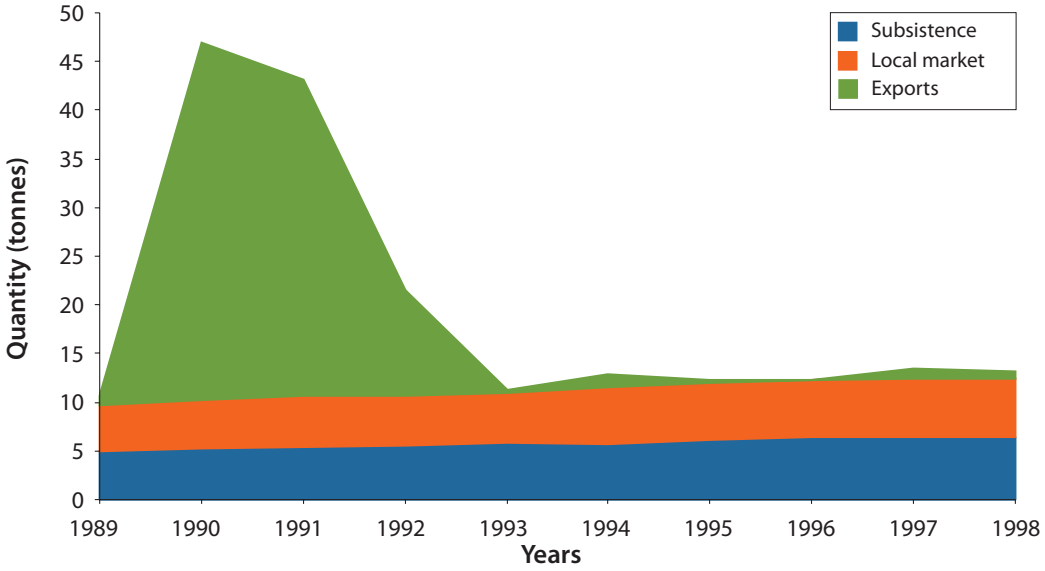

Figure 7. Total sea cucumbers production composition (data for 1990–1992 include beche-de-mer exports).

4.1.2 Recent commercial harvests

During the 48 days of fishing, an average of 1,074 buckets (18 litres in size or 22.5 kg when full) of wet sea cucumbers was landed each day from eight Palau States, for a total of 51,573 buckets during the entire fishing season (Table 2 and Fig. 8). These amounts to 1,160,392 kg of raw sea cucumbers landed and sold to the five licensed processors at a total value of USD 1,303,540. The highest production was from the State of Ngardmau with 47% of the catch and 48% of the landed value of over USD 623,000. The high production at Ngardmau could also reflect catches from other States that were sold to processors based at Ngardmau. Airai and Aimeliik were the second and third biggest producers, representing 26% and 11% of catch landings and 18% and 17% of landed value respectively (Fig. 8).

The buying, processing and export of sea cucumbers during the 2011 open season was permitted under the normal business license issued by the Department of Treasury for operating a business within Palau. The export license is no specific to beche-de-mer exports and it is unclear as to the types of license condition used if any. Five export companies were active in 2011 season, these companies have agents based in Ngardmau, Airai and Koror who purchase raw products and process them to beche-de-mer. Diesel fuel cookers and driers were used to process sea cucumbers. In total 4,892 fishers harvested sea cucumbers during the 48 days of fishing.

Table 2. Sea cucumber catches (by number of 18-litre buckets) landed at eight sites in Palau, and their total value.

State	No. of buckets	Pieces landed	Weight per bucket (kg)	Total wet weight (kg)	Total wet weight (t)	Value (USD)
Aimeliik	5,683		22.5	127,878	128	220,754
Airai	13,266	1,067	22.5	298,501	300	238,710
Koror	4,560		22.5	102,600	103	134,908
Ngardmau	24,357		22.5	548,043	548	623,195
Ngatpang	558		22.5	12,566	13	19,332
Ngarchelong	875		22.5	19,698	20	38,535
Ngaraard	27.		22.5	45	0	1,237
Ngiwal	2,244		22.5	50,490	50	27,933
Total	**51,573**			**1,159,824**	**1,160**	**1,303,540**

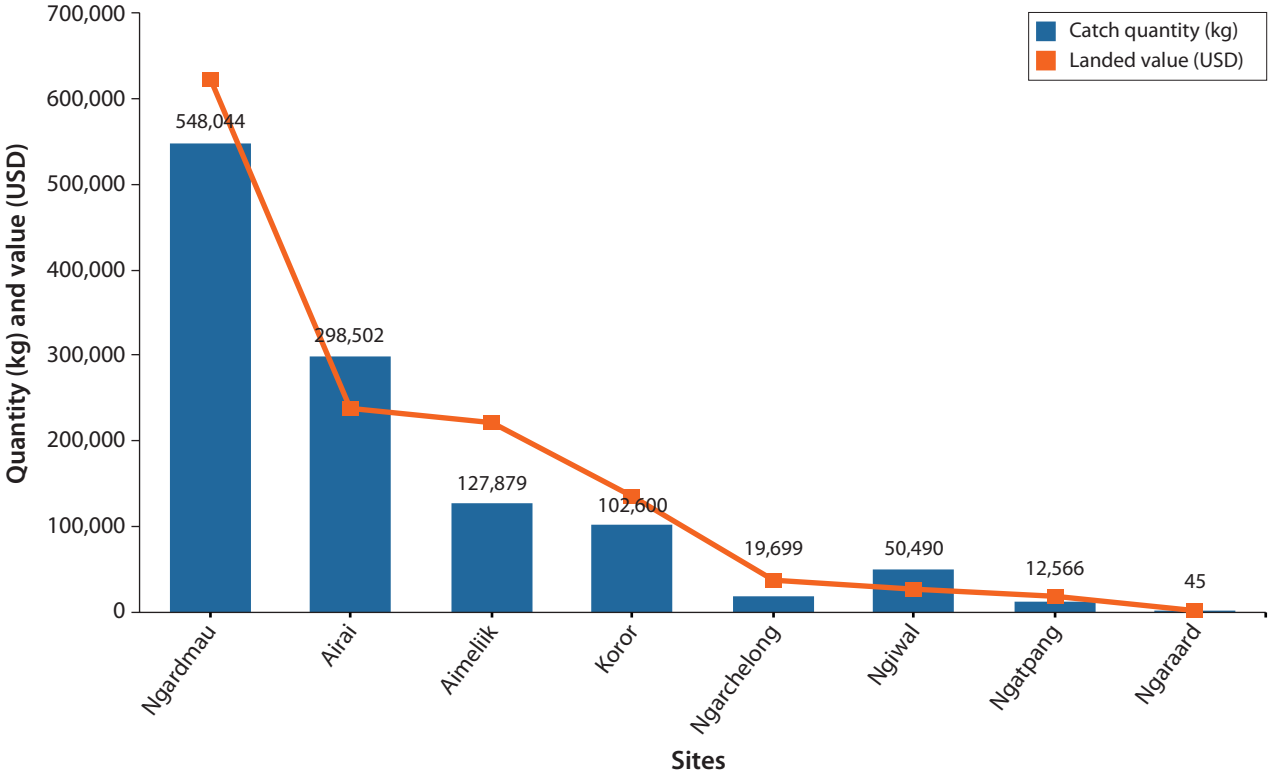

Figure 8. Sea cucumber catch and purchase value for the 2011 official open season.

4.2 Recent catch valuation and potential

Hairy greyfish and brown sandfish were the prescribed species declared for harvest during the fishing season. Catches of all sea cucumbers were sold by bucket units (22.5 kg in wet weight) by species. A bucket full of brown sandfish, hairy greyfish and greenfish were purchased at prices ranging from USD 12.00–46.00 bucket^{-1}. Non-prescribed species that were also harvested include greenfish, lollyfish, deepwater blackfish and tigerfish; these species were purchased at USD 1.00 piece^{-1}. The price of brown sandfish was USD 10.00 bucket^{-1} through the season and only slight increase to USD 12.00 bucket^{-1} at the end of the season while prices for greenfish were maintained at USD 10.00 bucket^{-1} and lollyfish at USD 1.00 piece^{-1}.

A larger increase in price was seen for hairy greyfish from USD 12.00 bucket^{-1} at the start of the season to USD 46.00 bucket^{-1} at the end of the season (Fig. 9). A full bucket of hairy greyfish is equivalent to about 300 pieces (this is after much of the water in the animal body has been excreted prior to landing). This increase in price per bucket is equivalent to an increase from USD 0.04 piece^{-1} to USD 0.15 piece^{-1} or a 3.8 fold increase in price. Comparing this to lollyfish — which is a low-value species but was purchased at USD 1.00 piece^{-1} — the price per piece for hairy greyfish which is a medium-value species is low (15% of the value of lollyfish). The price of hairy greyfish at USD 0.15 piece^{-1} is most likely close to optimal purchase price of the product. Local fishers would have earned an additional USD 472,596 from their produce if this price was used at the start of the season.

Considering that hairy greyfish is a medium-value species, if the unit price had been set at USD 0.20 piece^{-1} or USD 0.50 piece^{-1} wet weight, the potential value to be gained by fishers would have increased by USD 1,004,530 and USD 4,196,132, respectively (Table 3). For brown sandfish, the unit price of USD 10.00 bucket^{-1} or USD 0.33 piece^{-1} is also too low for a fairly large animal of over 1 kg (wet weight). Tigerfish, a species similar to brown sandfish, was purchased at USD 1.00 piece^{-1}. If brown sandfish had been sold for USD 1.00 piece^{-1} or around USD 30.00 bucket^{-1} (30 pieces per bucket), fishers would have made an additional USD 298,081 in income (Table 4). In another comparison, the recent purchase price of brown sandfish in a site in Fiji in 2012 was

FJD 4.00 or USD 2.14 per kilo wet; this would amount to USD 48.00 bucket^{-1} for the 22.5 kg bucket^{-1} of brown sandfish used in Palau. Fishers in Palau have not gotten a faire price for their sea cucumber produce. Effort must be made to improve product prices in Palau to enable fishers get optimum value for their produce.

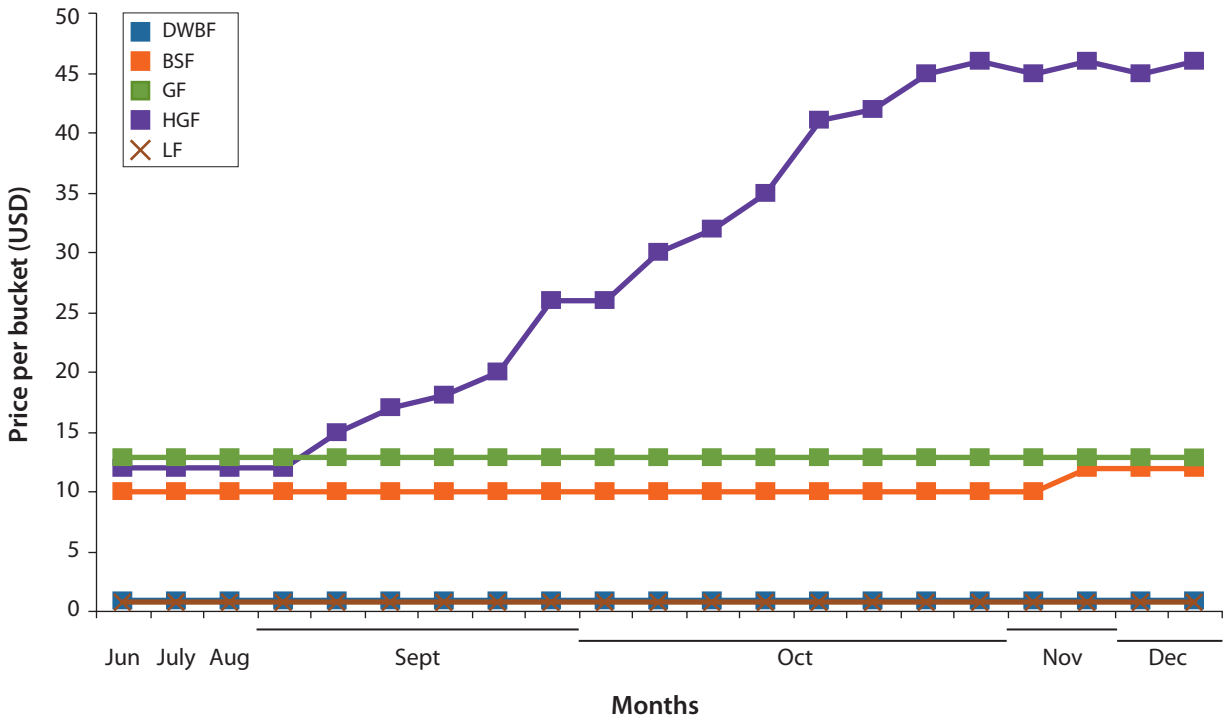

Figure 9. Sea cucumber prices by bucket in Palau in 2011
(DWBF = deepwater blackfish; BSF = brown sandfish; GF = greenfish; HGF = hairy greyfish; LF = lollyfish).

Table 3. Landed quantity and value of hairy greyfish for the 2011 harvest season in Palau, and the potential value.

State	Total bucket	Total pieces	Total value (USD)	2011 price USD 0.15	Price at USD 0.20	Price at USD 0.50	Price at USD 1.00
Ngardmau	23,467	7,039,950	614,193	1,055,993	1,407,990	3,519,975	7,039,950
Airai	3,123	936,825	123,279	140,524	187,365	468,413	936,825
Aimeliik	4,889	1,466,550	211,356	219,983	293,310	733,275	1,466,550
Koror	2,538	761,400	111,060	114,210	152,280	380,700	761,400
Ngarchelong	808	242,250	36,206	36,338	48,450	121,125	242,250
Ngiwal	175	52,350	7,853	7,853	10,470	26,175	52,350
Ngatpang	437	131,100	18,023	19,665	26,220	65,550	131,100
Ngaraard	28	8,250	1,238	1,238	1,650	4,125	8,250
Total	**35,465**	**10,638,675**	**1,123,208**	**1,595,804**	**2,127,735**	**5,319,338**	**10,638,675**
Potential value lost and projections				**472,596**	**1,004,530**	**4,196,132**	**9,515,469**

Table 4. Landed quantity and value of brown sandfish during the 2011 harvest season in Palau, and potential values.

Site	Total bucket	Total pieces	Total value USD 0.30	2011 price USD 0.50	Price at USD 1.00	Price at USD 2.00
Ngardmau	887	26,610	8,951	13,305	26,610	53,220
Airai	10,144	304,320	113,292	152,160	304,320	608,640
Aimeliik	795	23,850	9,398	11,925	23,850	47,700
Koror	2,006	60,180	23,383	30,090	60,180	120,360
Ngarchelong	22	660	260	330	660	1,320
Ngiwal	1,771	53,115	17,705	26,558	53,115	106,230
Ngatpang	122	3,645	1,310	1,823	3,645	7,290
Total	**15,747**	**472,380**	**174,299**	**236,191**	**472,380**	**944,760**
Potential value projections				**61,891**	**298,081**	**708,570**

4.3 Recent export quantity and value

Recent beche-de-mer exports in Palau were divided into two categories: exports in 2009, 2010 and 2011 prior to the open season (unauthorised harvest and exports)[1] and sea cucumber exports during the official open harvest season from June to December 2011.

Beche-de-mer exports before the official open season (unauthorised harvest and exports)

Exports of beche-de-mer undertaken prior to the open season in 2011 were classed as aquacultured sea cucumbers. The company — Palau Sea Cucumber Hatchery Farm — was a joint venture arrangement between a foreigner and local interests. Artificial propagation by cuttings and hatchery breeding and ranching trials were conducted on five sea cucumber species (hairy greyfish, hairy blackfish, black teatfish, golden sandfish and prickly redfish), and using the BMR hatchery facility at Koror. It appears that this venture was harvesting, processing and exporting wild sea cucumbers starting when the company began operating its mariculture activities in December 2009. Sea cucumber exports continued through 2010 and the first half of 2011. Beche-de-mer exported during this period was categorised as aquacultured sea cucumbers, although there was no evidence to suggest these products were cultured.

Eight species were traded between December 2009 and May 2011. In total, 27.3 t of beche-de-mer were exported, with hairy greyfish making up 59% of the exports, brown sandfish 21%, surf redfish 14% and other species 6% (Fig. 10). Product purchase price information for export value was not available. Included with the exported products were the four banned species: black teatfish, prickly redfish, surf redfish and hairy blackfish. Details of the aquaculture venture were unclear, although it seems that a new company appeared in the 2011 official harvest season, suggesting that the same company may have changed its name to apply for a new export license.

Exports during the official open season, June–December 2011 (authorised harvest and exports)

Fully dried products are packed in bags and exported mainly to Hong Kong. The bag weights for export are not standardised; some exporters use 20-kg bag while others use bags of varying weights from 27 kg to 37 kg. In total, 2,526.5 bags of beche-de-mer were exported from Palau during the 2011 harvest season, amounting to 72.5 t (72,518 kg in total). Beche-de-mer exports were dominated by hairy greyfish during both unauthorised and authorised harvest seasons (comprising 70% and 59% respectively) (Fig. 10). Brown sandfish was the second most important product exported, comprising 28% of total exports. Average export price of USD 23.48 kg^{-1} was used to estimate total export value of hairy greyfish by States for the authorised open season in 2011 (Fig. 11).

[1] Here we mean the harvest of wild stock which were declared as aquacultured sea cucumber.

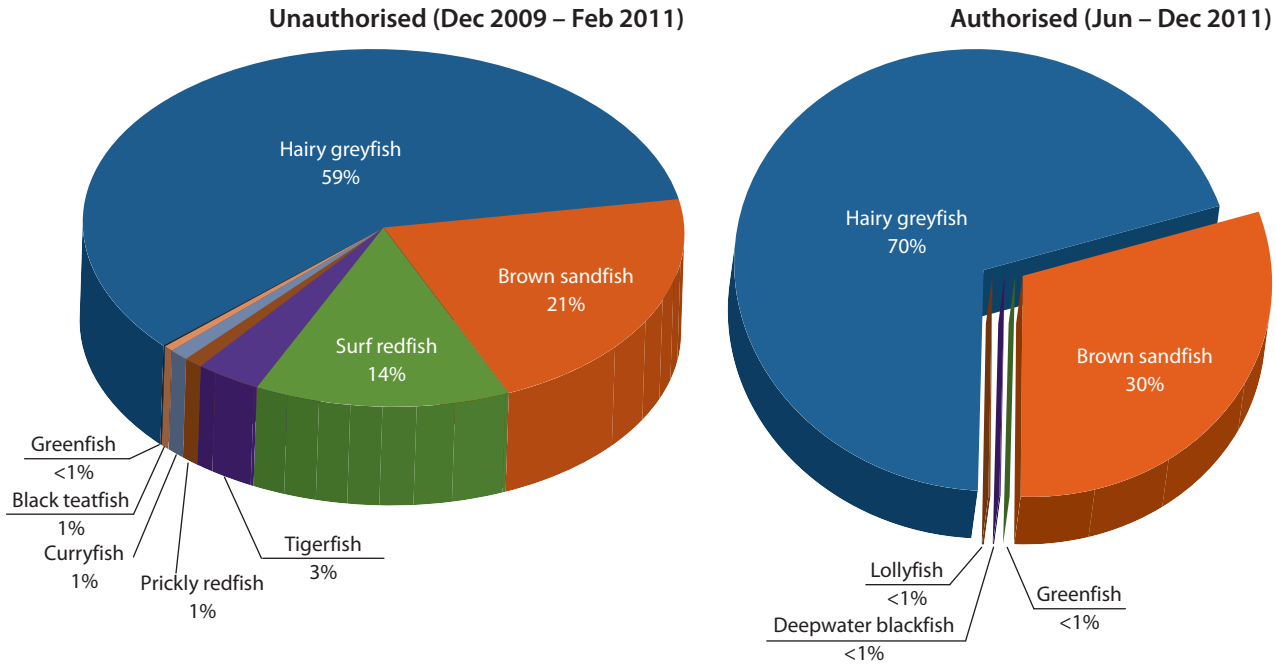

Figure 10. Beche-de-mer exports from Palau for unauthorised harvest in 2009–2011 (left) and authorised harvest (right) in 2011.

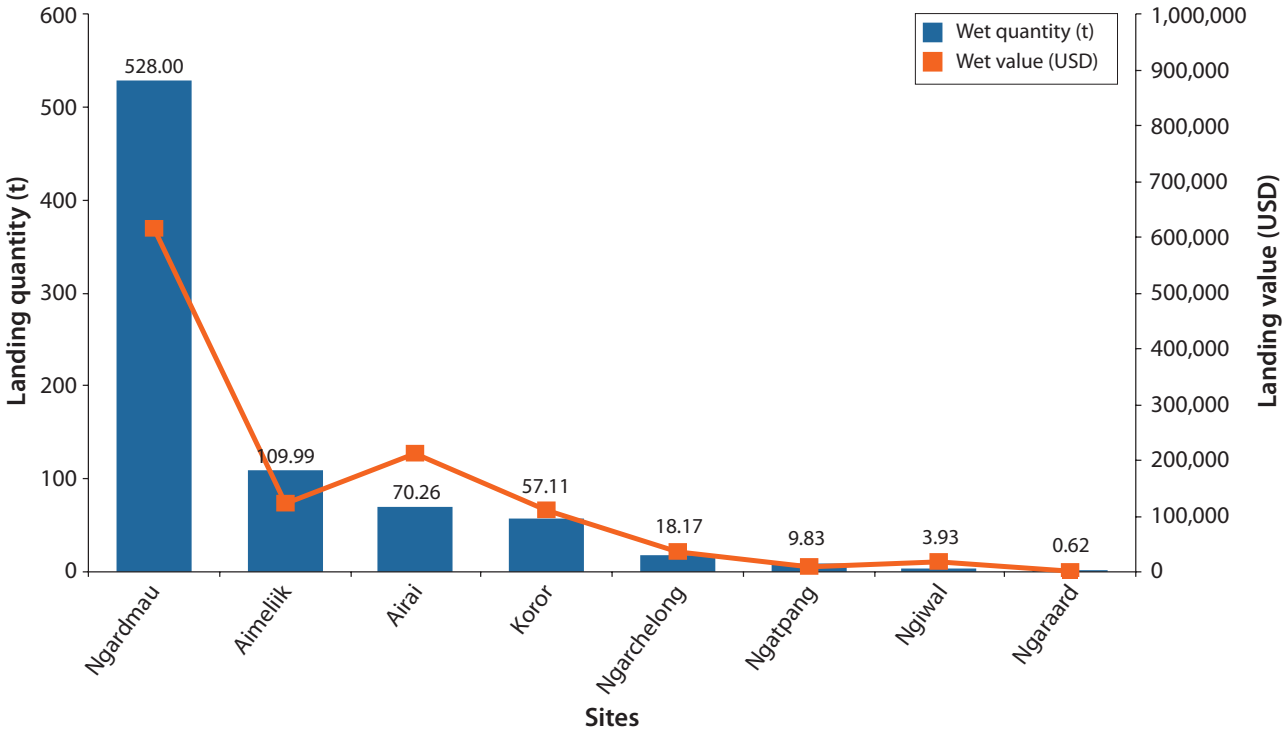

Figure 11. Hairy greyfish (*Actinopyga* sp.) landing by States of Palau during authorised harvest season in 2011.

Beche-de-mer exports from 2009 to 2011 totalled 99.8 t (27.3 t plus 72.5 t). The total value of beche-de-mer exports during the authorised open season in 2011 was USD 1,138,459 based on receipts submitted to BMR. With the value of unauthorised exports added, the real export value is higher. When comparing this to the total purchase value of sea cucumbers landed during the authorised season at USD 1,302,302, the total export value is lower. The export value of beche-de-mer is much higher than the landed value; however, the export values for hairy greyfish by site are not much different from the landed quantity (Fig. 12). More harvests

and exports may have taken place during the unauthorised harvest, but these were not reported as BMR was unaware of the harvest and export of wild products. Aquaculture and sea ranching has been used as a disguise for wild stock harvests which was not correclty reported. Capturing the value lost would have increase the total economic value of the fishery higher than the reported USD 1.3 million.

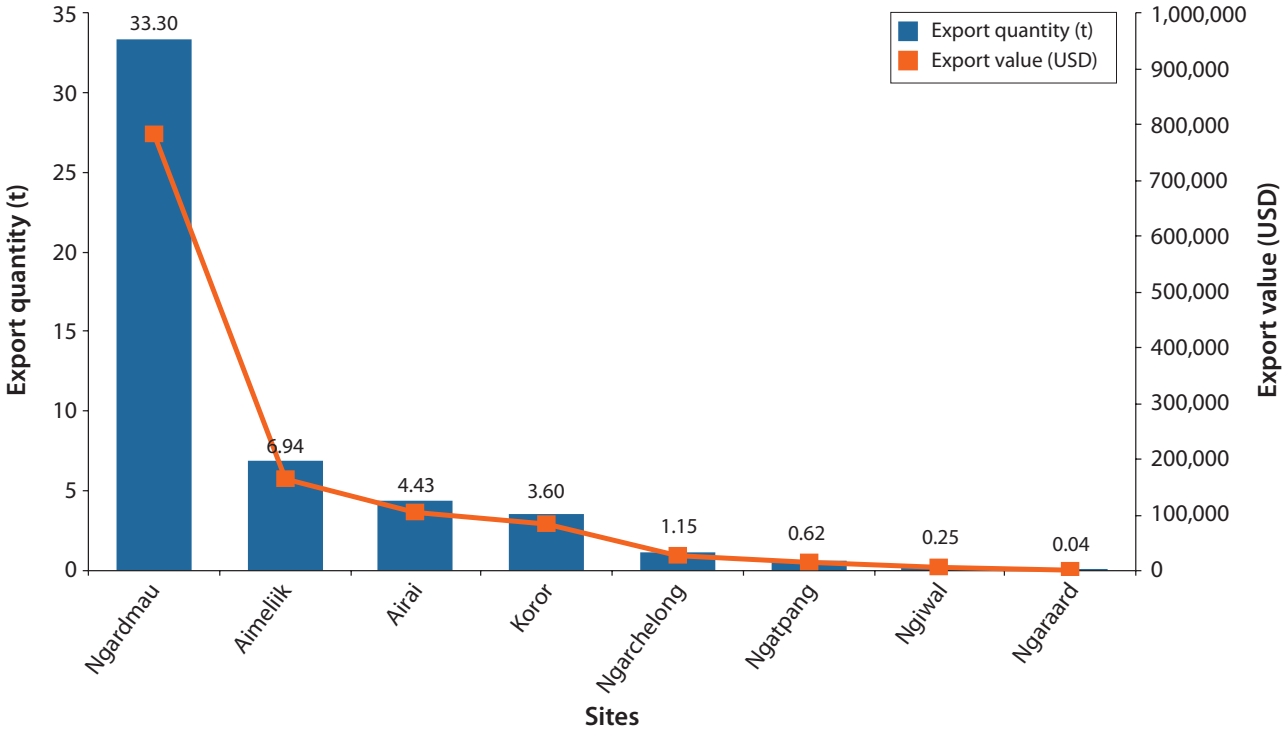

Figure 12. Hairy greyfish (*Actinopyga* sp.) exports by States of Palau during authorised harvest season in 2011.

4.4 Resource survey results

4.4.1 Survey coverage

In total, 129 stations were surveyed in Palau's three northern States of Ngarchelong, Ngardmau and Ngatpang. The surveys covered 8.8 hectares (ha) of reef area, with 5.4 ha surveyed by manta tows, and 3.4 ha surveyed by reef- and soft-benthos transects (Table 5). Back reefs and mangrove-influenced seagrass areas were surveyed by reef-benthos transects and soft-benthos transects, while manta tows were conducted in shallow lagoons and on reef slopes along the sides of deep lagoons. Surveys of soft-benthos areas were important for capturing information on the two targeted species — hairy greyfish and brown sandfish — which were permitted in the 2011 season. This was the third time that surveys had been conducted at Peleliu; results of the previous two surveys by BMR (prior to the SPC training) were disputed by researches from the Palau International Coral Reef Center.

Table 5. Summary of stations and survey areas in Palau.

Site	Methods	Stations	Area (in m^2)	Area (in ha)
Ngarchelong	Manta tow	11	39,600	3.960
Ngarchelong	Soft-benthos transects	23	5,520	0.552
Ngarchelong	Reef-benthos transects	12	2,880	0.288
Ngardmau	Manta tow	4	14,400	1.440
Ngardmau	Soft-benthos transects	43	10,320	1.032
Ngardmau	Reef-benthos transects	8	1,920	0.192
Ngatpang	Manta tow	0		0
Ngatpang	Soft-benthos transects	22	5,280	0.528
Ngatpang	Reef-benthos transects	14	3,360	0.336
Peleliu	Manta tow	0		0
Peleliu	Soft-benthos transects	11	2,640	0.264
Peleliu	Reef-benthos transects	10	2,400	0.240
Total		**158**	**88,320**	**8.832**

4.5 Species diversity

Palau has a rich diversity of sea cucumber species. However, studies of invertebrate resources in the past have failed to properly document the correct number of species present. SPC-sponsored surveys in 2007 in the States of Ngarchelong, Ngatpang, Airai and Koror (Friedman et al. 2009) provide a more accurate list of species that are present. The current surveys complement the previous surveys by revisiting two sites previously assessed, and by gathering information at two new sites (Fig. 13). In total, 28 species of sea cucumbers are found in Palau, and 26 of these are important for subsistence use and for commercial exploitation (Table 6). A good baseline of species diversity is important for continuous monitoring recovery and extinction. The survey in Peleliu targeted only seagrass habitats in order to provide information on brown sandfish, which is of interest. Therefore, the results show low species diversity although including other habitats would likely increase the number of species present in this area.

The population of sea cucumbers sampled in recent assessments are presented in Table 6. Comparisons with the 2007 study are presented for Ngarchelong and Ngatpang. The sampled population of each species present is the first information on abundance prior to density analysis. The four most abundant species recorded are hairy greyfish, lollyfish, brown sandfish and brown curryfish. Local residents have specialised methods of preparing certain species of sea cucumbers (Pakoa et al. 2009). Eight sea cucumber species — sandfish, impatient sea cucumber, hairy greyfish, brown curryfish, dragonfish, prickly redfish, chalkfish and brown sandfish — are harvested for subsistence use (Pakoa et al. 2009).

Table 6. Total number of sea cucumbers observed at sites in Palau.

English name	Palauan name	Scientific name	Ngarchelong 2007	Ngarchelong 2012	Ngatpang 2007	Ngatpang 2012	Peleliu 2013	Ngardmau 2012
Hairy greyfish	Eremrum	*Actinopyga* sp.	1,420	274	1,618	62	2,013	4,734
Lollyfish	Cheuas	*Holothuria atra*	478	3,711	1,305	483	2,668	3,113
Brown sandfish	Meremarech	*Bohadschia vitiensis*	481	71	165	396	1,610	397
Brown curryfish	Ngimes	*Stichopus vastus*	5,774	1,983	283	57		244
Pinkfish	Cheuas	*Holothuria edulis*	133	10	152	7		164
Snakefish	Cheuas	*Holothuria coluber*	27	61	29	103		121
Red snakefish	Cheuas	*Holothuria flavomaculata*						62
Black teatfish	Bakelungal	*Holothuria whitmaei*	32	221	62	15	38	36
Hairy blackfish	Eremrum	*Actinopyga miliaris*	4	1	45	4	8	24
Chalkfish	Meremarech	*Bohadschia similis*	172	162	6	24	102	22
Sandfish	Molech	*Holothuria scabra*	142	84	214	43	3	22
Impatient sea cucumber	Sekesakel	*Holothuria impatiens*						19
Tigerfish	Meremarech	*Bohadschia argus*	142	18	128	42	2	11
Curryfish	Ngimes	*Stichopus herrmanni*	33		72	1		6
Greenfish	Ngimes	*Stichopus chloronotus*	173	71	66	3		5
Elephant trunkfish	Delalamolech	*Holothuria fuscopunctata*				3		2
Prickly redfish	Temetamel	*Thelenota ananas*	48	10	88	13	5	2
White teatfish	Bakelungal	*Holothuria fuscogilva*	13	1	21	2		2
Deepwater redfish	Eremrum	*Actinopyga echinites*	5	3	1		6	1
Amberfish	Ngimes	*Thelenota anax*	59		43			
Deepwater blackfish	Eremrum	*Actinopyga palauensis*		1		31	12	
Dragonfish	Irimd	*Stichopus horrens*	7	4	1			
Flowerfish	Meremarech	*Pearsonothuria graeffei*	29			1		
Golden sandfish	Delalamolech	*Holothuria lessoni*				1		
Stonefish	Eremrum	*Actinopyga lecanora*	2	1	2			
Surf redfish	Bad el chelid	*Actinopyga mauritiana*	14		21		1	
Tiger tail*		*Holothuria hilla*	14		8			
Kingfish*		*Synapta maculata*		2		1		
Total species			**23**	**19**	**24**	**20**	**12**	**19**

* = non-commercial species.

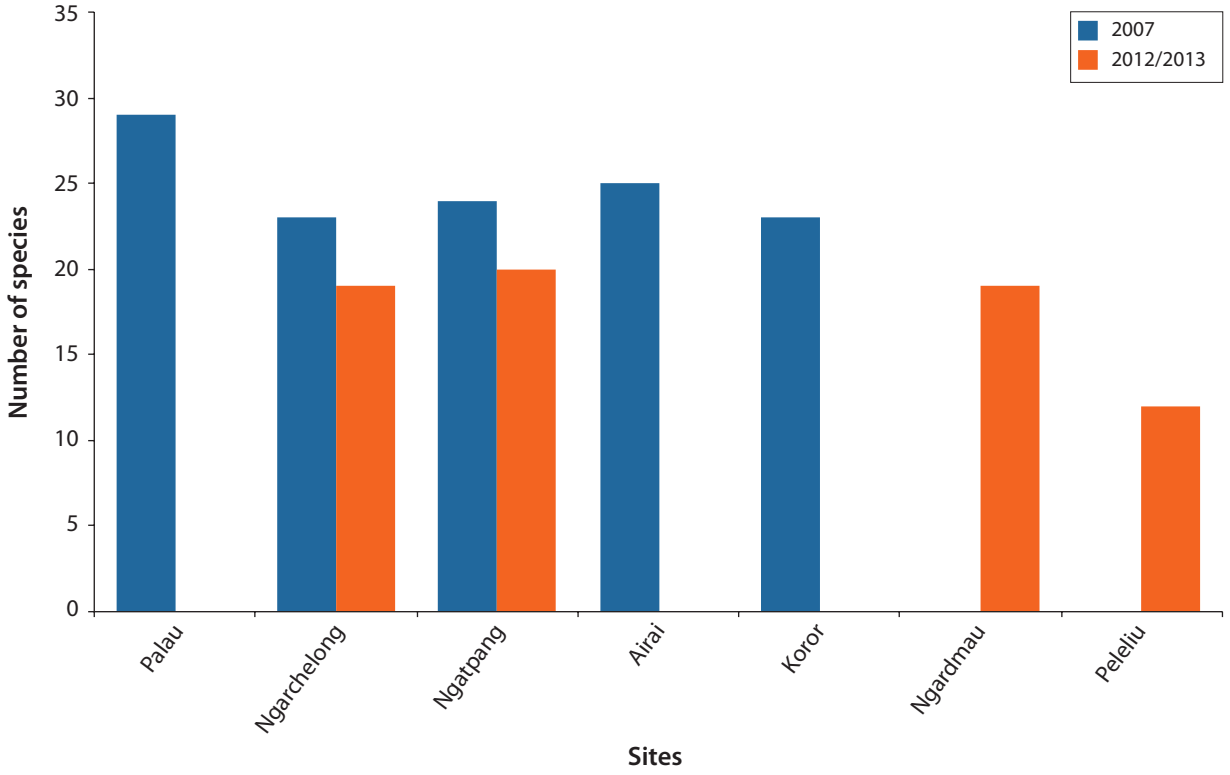

Figure 13. Sea cucumber species present in Palau and by sites assessed in 2007, 2012 and 2013.

4.5.1 Important and rare sea cucumbers

Hairy greyfish, brown curryfish and sandfish are the most important sea cucumbers in Palau, for both subsistence use and for commercial exports. Two other species, golden sandfish and deepwater blackfish were rare species in Palau. Detail information about these species are assessed and provided below.

Hairy greyfish* (Actinopyga *sp.)

Hairy greyfish is a new common name given to this important sea cucumber. Eremrum is used widely to refer to this species but the name eremrum covers all species of the *Actinopyga* genus. Despite its importance in Palau for subsistence use, local domestic sales, and the production of beche-de-mer (dominant product in the 2011 export production in Palau), hairy greyfish was only discovered by scientists in 2004 and is currently being studied by taxonomists.

Several trade names have been used (stonefish, hairy blackfish and eremrum) to refer to this species in Palau; however, these common names are incorrect. Stonefish and hairy blackfish are two different species of the genus *Actinopyga*. The name hairy greyfish best describes its dominant grey colour and its hairlike podia similar to hairy blackfish and was agreed on by participants at a consultation meeting in Koror in December 2012. The name hairy greyfish also rhymed with "Harry Fritz" the name of the former Minister for Fisheries and Marine Resources of Palau. Mr Harry Fritz remarked that the new sea cucumber should bear a local Palauan name because of its importance to the Palauan people.

Hairy greyfish is present in four colour morphs: full grey, grey with thin black stripes, grey with large black stripes, and dark grey to black (Fig. 14, top pictures). The dark grey to black morph is indistinguishable from hairy blackfish. It inhabits seagrass beds (mainly *Enhalus acoroides* and *Thalassia hemprichii*) and has been observed to shelter under patches of coralline algae (*Alimeda* sp.) during the day (Pakoa et al. 2009). During the day when it is inactive, it contracts to a round ball, and many individuals may aggregate beneath the seagrass bed and coralline algae. At night, hairy greyfish becomes active, and as it comes out, its body stretches out, and the animal feeds on algae and detritus matter on the bottom and on the leaves of seagrasses.

Brown curryfish **(Stichopus vastus)**

Brown curryfish or ngimes (local Palauan name) (Fig. 14, bottom right), is quite common in Palau, inhabiting the same habitat as hairy greyfish. Both species tend to be widely distributed, with larger specimens occupying deeper soft coral rubble areas outside of seagrass beds. Confusion over the identity of this species is apparent. For instance, Lambeth (1999) reported it as curryfish previously called *Stichopus variagatus* by scientific names and sometimes confused as dragonfish. The presence of the depressed harlequin pattern on the body's surface and the ease with which specimens disintegrate has ruled out the possibility that the species in question were juvenile curryfish or brown curryfish. Brown curryfish is harvested for its intestine, which is eaten raw as pickled food by Palauans, who consider it to be a delicacy (Pakoa et al. 2009). After extracting the intestine, the carcass is return back to the sea to regenerate back into a complete animal.

Sandfish **(Holothuria scabra)**

Sandfish is the most valuable species in the beche-de-mer trade currently valued at USD 90.00 per kg for high-grade product (Carleton et al. 2013). Likewise sandfish is an important resource in Palau for both its meat and its intestine, which are consumed locally. Sale of intestine and the flesh of sandfish at the local market generate higher unit income per animal and are sought after by fishers. As a result, stocks have been overfished in Koror and Airai States, which are close to the market in Koror (Pakoa et al. 2009). Harvesting for the local market continues to put pressure on the stock despite the existing ban on commercial harvesting.

Figure 14. Important sea cucumbers in Palau: hairy greyfish colour morphs and aggregation (top photos); brown sandfish (bottom, left); brown curryfish morphs (bottom, right) (Photos: Kalo Pakoa).

Golden sandfish **(Holothuria lessoni)** *and deepwater blackfish* **(Actinopyga palauensis)**

Golden sandfish and deepwater blackfish (also called Palauan blackfish) are rare sea cucumbers in Palau (Fig. 15). Local fisheries officers and State Officers observed these two species for the first time during the survey training in December 2012. Both species were present at the same area inhabiting sandy bottom in shallow lagoon at 2 meters depth) at Ngatpang State. Golden sandfish is a high-value species (USD 60.00 kg^{-1}) (Carleton et al. 2013), and, like sandfish, it is of interest for aquaculture development. Deepwater blackfish is a medium-value species and their presence in shallow habitats (i.e. are easily accessible) make them vulnerable to overfishing. Both species were not reported in the 2007 assessment by SPC (Friedman et al. 2009), and deepwater blackfish appeared in 2011 catches and sold at USD 1.00 $piece^{-1}$. Considering the size of deepwater blackfish (length 40 mm), this price is too low for such a rare species. Stocks in other areas need to be identified and protective measures put in place to protect them.

Figure 15. IUCN Red Listed sea cucumber species present in Palau.
Golden sandfish (GSF) (photo: Kalo Pakoa), sandfish (SF) (Photo: Kim Friedman), black teatfish (BTF) (Photo: Emmanuel Tardy), prickly redfish (PRF) (Photo: Emmanuel Tardy) are endangered with extinction. Curryfish (CF) (Photo: Kim Friedman), white teatfish (WTF) (Photo: Kalo Pakoa), deepwater redfish (DWRF) (Photo: Kalo Pakoa), surf redfish (SRF) (Photo: Kalo Pakoa) and hairy blackfish (HBF) (Photo: Kim Friedman) are vulnerable to extinction.

4.5.2 *IUCN Red List for threatened and endangered species*

The International Union of Conservation of Nature (IUCN) has placed 16 species of sea cucumbers under the IUCN Red List of Threatened Species (Conand et al. 2014). Nine of these species are present in the Pacific Islands region. In this listing, four species — sandfish, golden sandfish, black teatfish and prickly redfish — are listed as endangered with extinction or are considered to be species facing a very high risk of extinction. The other five species — deepwater redfish, surf redfish, hairy blackfish, white teatfish and curryfish — are considered to be vulnerable to extinction, or are species that are likely to become endangered if no management measures are taken in the short to medium term (Fig. 15). All nine are shallow- to mid-water species. Golden sandfish, sandfish, hairy blackfish and deepwater redfish are restricted to very shallow mangrove-influenced and seagrass habitats. Use of these threatened species for aquaculture development must take into consideration this listing, and ensure the use of wild stocks for breeding purposes does not affect the breeding capacity of the natural stock. Any introduction or translocation of these threatened sea cucumbers should be accompanied by proper risk assessment protocols.

4.6 Species densities

Sea cucumber densities presented in Table 7 are derived from different assessments and by merging stations of the same transect size to assess the abundance of certain species in certain habitats. Species inhabiting exclusively soft-bottom sea grass beds — such as sandfish, hairy greyfish, hairy blackfish, chalkfish and brown curryfish — are best surveyed using soft-benthos transects, while tigerfish, black teatfish and prickly redfish are best assessed using manta tow surveys. The remaining species are less aggregated and their general densities are best assessed using soft-benthos and reef-benthos surveys. Reference densities for selected species (Table 7) should be used as guide for setting healthy densities for sites in Palau.

The high density of hairy greyfish in Ngardmau State includes the densities within the permanent no-take area. As indicated (Fig. 16), the relatively large area assessed in open access areas (n = 29 stations in open access compared to n = 14 stations in marine protected areas — MPA) held lower densities (2,139.4 ± 3,631.0 ind ha^{-1}) of hairy greyfish. Strict surveillance by the Ngardmau State Rangers during the harvest season ensured no harvesting within the Ngermasech marine protected area, which currently holds the majority of the existing hairy greyfish stock. The result is consistent with results of permanent monitoring stations set up in the area by the Palau International Coral Reef Center which indicated an 88% decline in hairy greyfish densities between 2009 and 2012 (Golbuu et al. 2012).

Densities for hairy greyfish in recent assessments were significantly reduced at Ngarchelong and Ngatpang by 87% and 97% for the two sites respectively between 2007 and 2012 (Fig. 17). Similarly, the density of brown curryfish in Ngarchelong dropped from 17,445 ± 6,071 ind ha^{-1} in 2007 to 3,592 ± 1,619 ind ha^{-1} in 2012. Brown curryfish is targeted for its intestine by the subsistence fishery in Palau and the low density could reflect the impact of the subsistence harvest.

Table 7. Densities for commercial sea cucumber (ind ha^{-1}) by sites in Palau, from 2012–2013 surveys.

Species	Ngarchelong		Ngardmau		Peleliu		Ngatpang		Reference
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Lollyfish	2,675	1,507	2,505	602	5,294	3,022	1,482	662	5,600
Greenfish	7	4	4	4			11	7	3,500
Chalkfish	293	280	21	10	386	371	43	20	1,400
Snakefish	73	31	99	44			31	18	1,100
Sandfish	152	99	21	10	11	11	78	67	700
Pinkfish	11	9	134	54			60	34	260
Surf redfish					2	2	1	1	200
Hairy blackfish	1	1	20	8	16	10	48	42	150
Tigerfish	2	2	8	4	4	3	48	16	120
Flowerfish							10	6	100
Brown sandfish	56	27	324	136	3,194	1,792	7	4	100
Curryfish	1	1	5	4			4	3	100
Black teatfish	326	117	52	141	21	14	48	23	50
Prickly redfish	10	5			10	7	42	32	30
White teatfish			0.4	0.4			17	15	20
Elephant trunkfish			2	1			1	1	10
Stonefish	1	1					1	1	10
Hairy greyfish	496	181	4,587	1,291	19	7	112	50	n/a
Brown curryfish	3,592	1,169	235	167			98	31	n/a
Red snakefish			51	24			9	7	n/a
Golden sandfish							2	2	n/a
Amberfish							1	1	n/a
Dragonfish	4	4					1	1	n/a
Deepwater blackfish					24	13	1	1	n/a
Deepwater redfish	2	2	4	3	12	12	1	1	n/a
Impatient sea cucumber			11	8					n/a

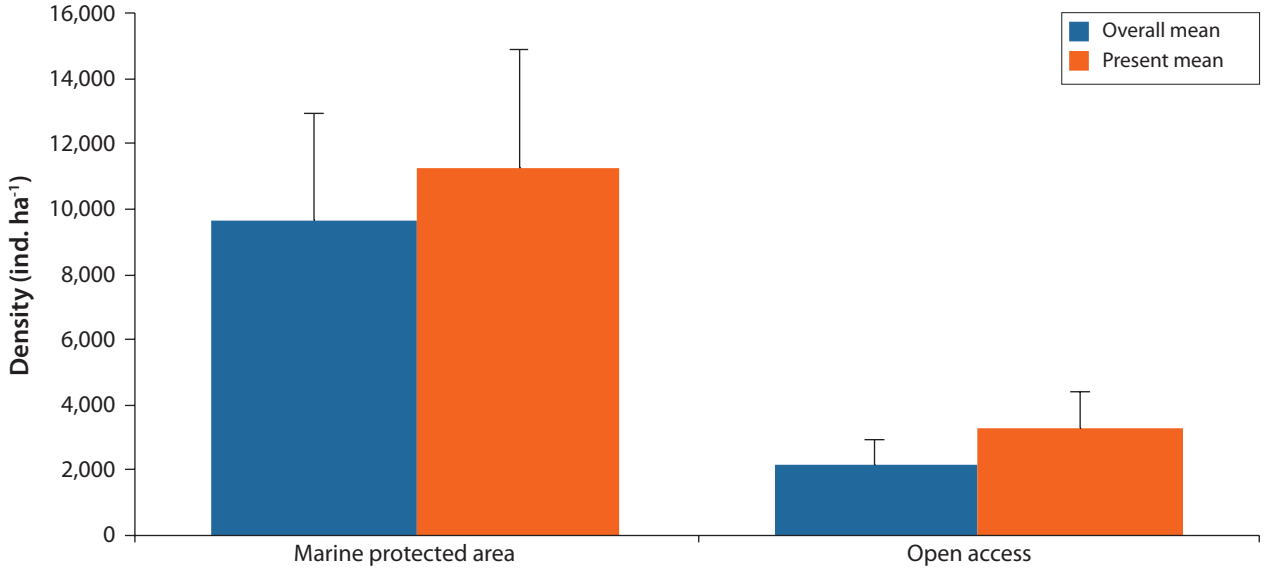

Figure 16. Density of hairy greyfish (*Actinopyga* sp.) at open access areas and marine protected area at Ngardmau State.

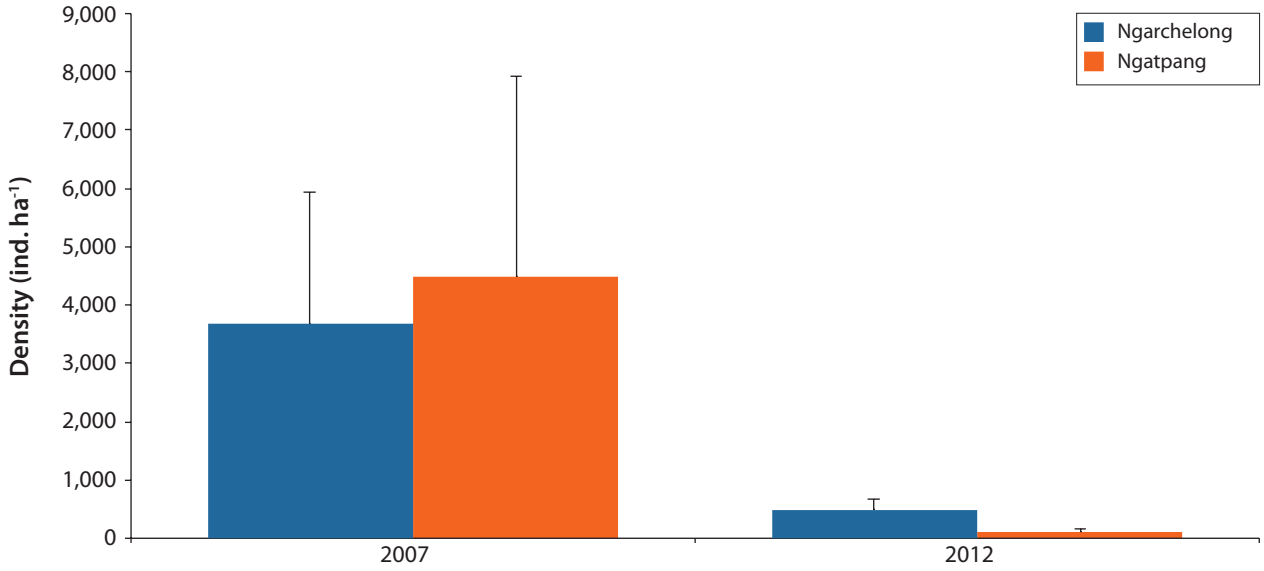

Figure 17. Density of hairy greyfish (*Actinopyga* sp.) for Ngarchelong and Ngatpang for 2007 and 2012.

4.7 Size distribution

Size distribution is analysed for five main sea cucumbers: hairy greyfish, brown sandfish, brown curryfish, black teatfish and sandfish.

Hairy greyfish. The sample size for length measure was large at Ngardmau MPA (n = 452) and open access areas (n = 596) in contrast to small sample size at Ngatpang (n = 61). The mean sizes of 117 mm and 113 mm at Ngatpang and Ngarchelong were not different in 2012 (Fig. 18). This is indicative of the relative plasticity of hairy greyfish (stretched when active and shrunk to a round ball when disturbed).

Brown sandfish. The mean sizes of brown sandfish at sites in Ngatpang and Ngarchelong were 269 mm and 167 mm respectively (Fig. 19), and the overall mean size was 237 mm for the two sites combined. Mean sizes recorded in 2007 were 195 mm and 174 mm at the two sites respectively.

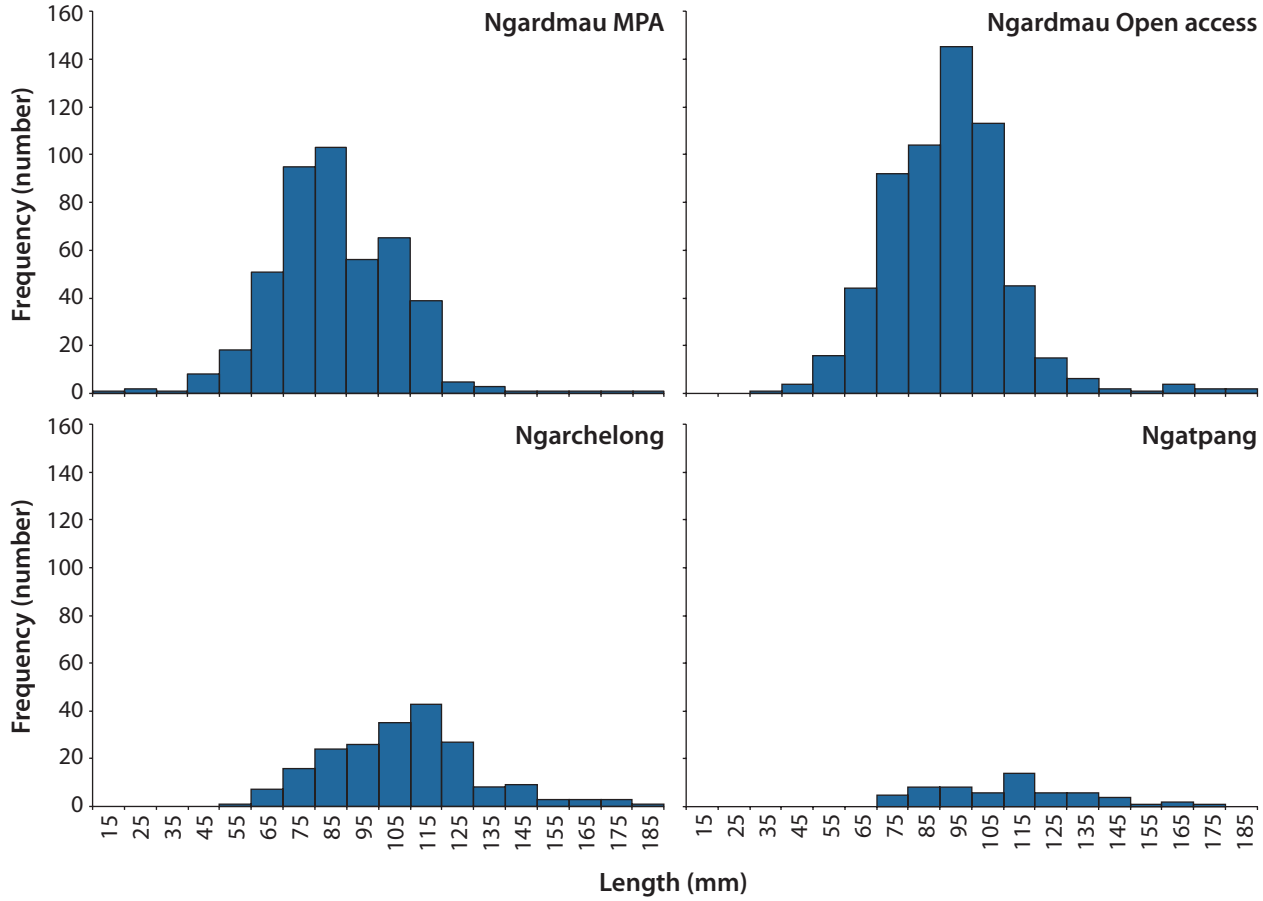

Figure 18. Size distribution for hairy greyfish (*Actinopyga* sp.) at sites surveyed in Palau (2012).

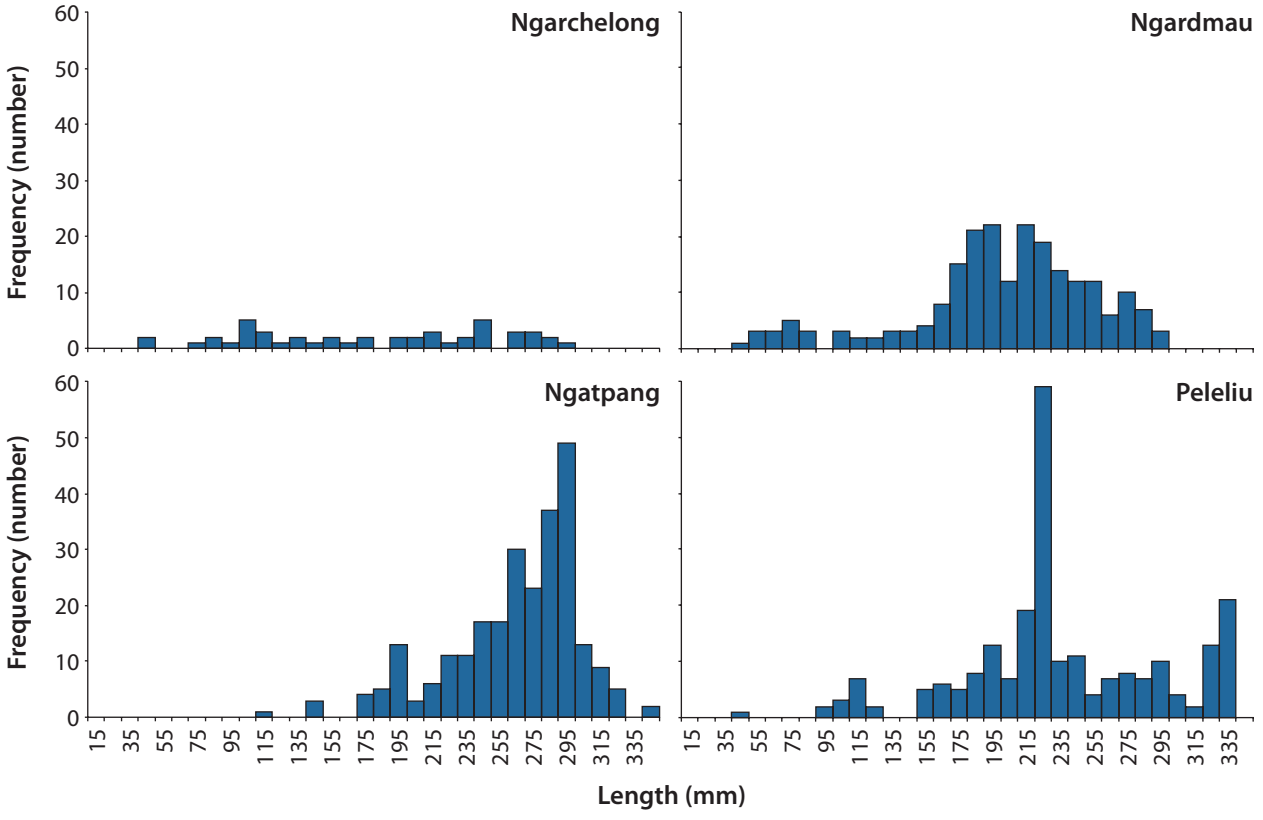

Figure 19. Size distribution for brown sandfish (*Bohadschia vitiensis)* at sites surveyed in Palau (2012).

Sandfish. Sandfish is one of the six species of sea cucumbers that have been banned for commercial export since 1994, and it was not a prescribed harvested species in the 2011 commercial harvest. However, as the existing population structure indicates, stocks of sandfish at Ngarchelong and Ngatpang appear to be more impacted than in 2007 (Fig. 20). Overall, fewer specimens were recorded in 2012 at the two sites (n = 100) compared with a high number (n = 320) in 2007. Sandfish was absent in the recorded catch landings in 2011, but the fact that other species besides the prescribed species were also harvested — greenfish, lollyfish, deepwater blackfish and tigerfish — points to possible harvesting of sandfish. Furthermore, sandfish has been illegally harvested in the past and packed at the bottom of the bags for export by an exporter in 2007 (Pakoa et al. 2009). The same activity could have occurred in 2011.

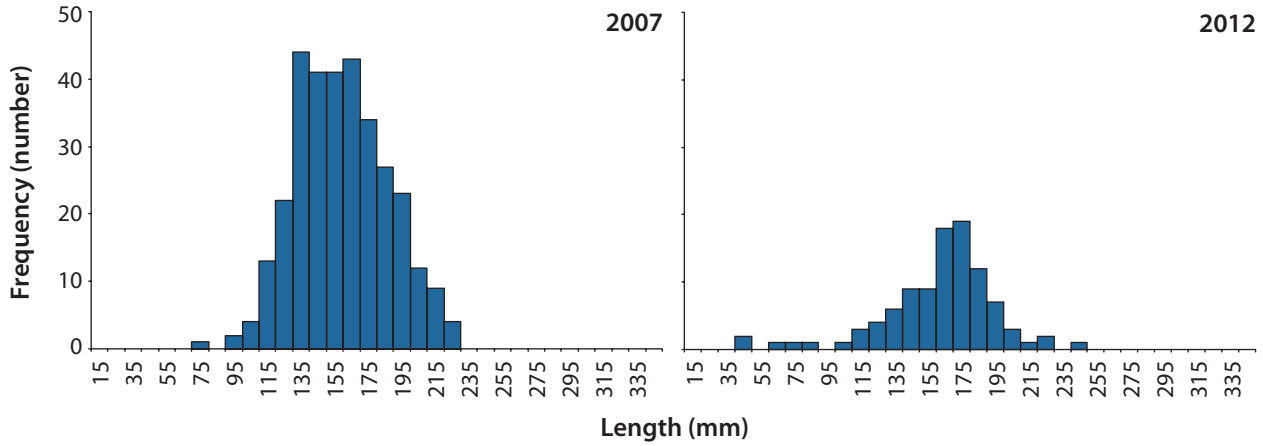

Figure 20. Overall size distribution for sandfish (*Holothuria scabra*) at Ngarchelong and Ngatpang in 2007 and 2012.

Brown curryfish. Brown curryfish was not a target species in the 2011 fishing season but it is an important species in the subsistence sector. Its intestine ,which is consumed locally, is removed at sea and the body is placed back in the water to regenerate. The mean size of brown curryfish at Ngatpang and Ngarchelong from this survey was 155 mm and 131 mm, respectively, with 2007 mean sizes of 152 mm for Ngatpang and 128 mm for Ngarchelong (Friedman et al. 2009; Pakoa et al. 2009).

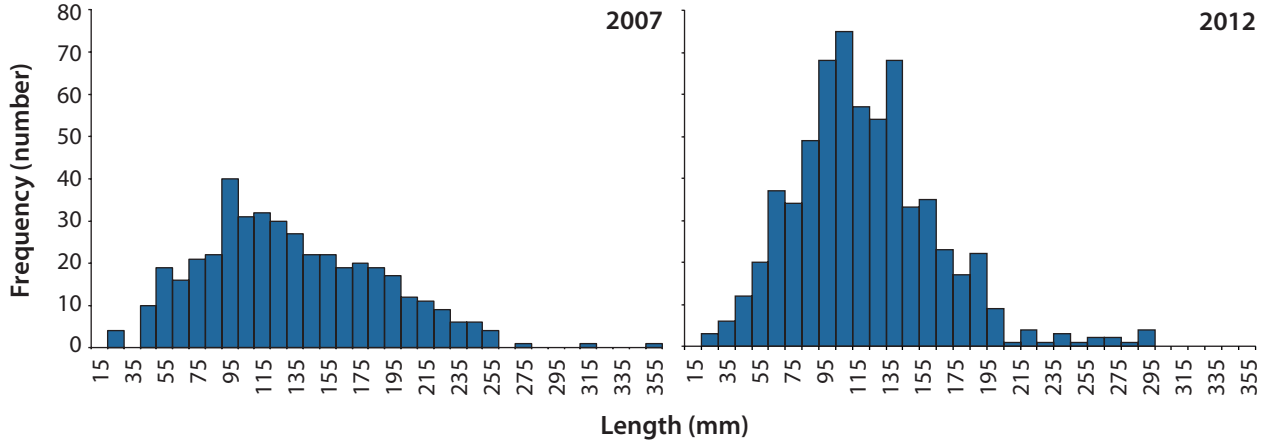

Figure 21. Overall size distribution of brown curryfish (*Stichopus vastus*) at Ngarchelong and Ngatpang in 2007 and 2012.

Black teatfish. Black teatfish is banned from commercial exports under the Marine Protection Act 1994. Most black teatfish recorded were at Ngatpang and Ngarchelong, with the highest count observed at Ngarchelong (n = 82). The overall mean size of black teatfish in the recent surveys was 272 mm (Fig. 22) and this is relatively similar to the the mean size recorded previously (Friedman et al. 2009).

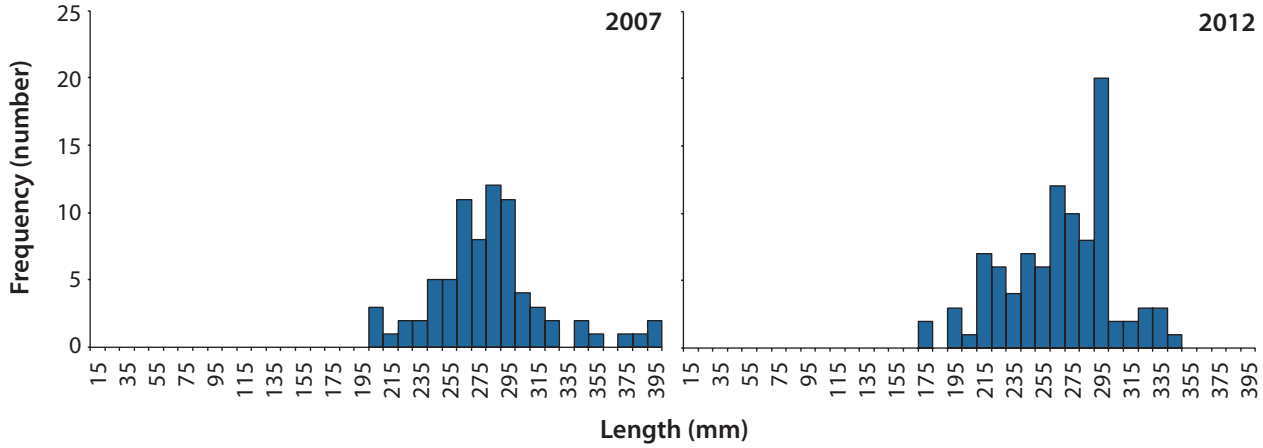

Figure 22. Overall size distribution for black teatfish (*Holothuria whitmaei*) at Ngarchelong and Ngatpang in 2007 and 2012.

4.8 Estimating standing stocks and harvest quantity

Estimating standing and fishable stocks is the ultimate aim of stock assessment; this analysis is best performed prior to a fishing season. Palau has been able to control its sea cucumber fishery and is in a better position to move into adopting area-based harvest quotas or total allowable catch system. The trial harvest of two permissible species allowed for one State and the adoption of 100% monitoring coverage are positive indications for this improved sea cucumber harvest strategy. While hairy greyfish stock may have been overfished, other stocks such as brown sandfish in Peleliu may present an opportunity for development consideration. To assist with stock estimation processes, this report presents the reef habitat areas by State (Appendix 1). These can be used to calculate the stock of each species based on its preferred habitat. The following steps can be followed to estimate species fishable quota for a site in future.

1. Use the same survey protocols to produce density estimates before open seasons are decided in future. Assessments should target the main habitat of the species of interest in each State.
2. Enter data into a database (if available), or enter into an Excel spreadsheet and perform the analysis following the procedure provided in the Invertebrate Survey Manual (Pakoa et al. 2014). SPC can provide advice on data processing procedures.
3. The reef habitat areas for the States of Palau are provided in Appendix 1. These areas are based on GIS mapping and standard reef habitat (or geomorphological) types based on Andrefaut et al. (2005).
4. Extrapolations of densities to produce total population estimates for a habitat area are performed by multiplying densities by the total suitable habitat area.
5. The final harvestable quota is determined by taking a proportion (<30%) of the population that are above an agreed minimum size. The total harvestable stock (in number), is then converted to quantity (kilograms and/or tonnes). Conversion of wet weight to dry weight can be performed using standard conversion ratios provided in Appendix 2.
6. Once a harvestable quantity is produced for the species of interest, the next step is to determine the selling price or purchase price of the product. This can be negotiated with interested buyers; however, traders always compete on prices, and at times undercut each other's prices. Setting minimum reference price for each species is recommended to prevent unnecessary price fluctuation.
7. SPC is available to provide advice on regional price ideas to help with decisions on prices at the local level.

Detail procedure for estimating standing and fishable stock is provided in Appendix 7 of the Assessing Tropical Marine Invertebrates: a Manual for Pacific Islands Resource Managers (Pakoa et al. 2014).

5. Discussions

While sea cucumber fisheries in most Pacific Islands have not been well managed, Palau is among a few island countries that have managed their sea cucumber fisheries relatively well. The ban on the six high-value sea cucumbers — which has been enforced since 1994 — has helped to protect these resources from being overexploited. These six species have been overharvested in other tropical regions of the world and are now listed on the IUCN Red List of endangered and threatened species. However, there are gaps in existing regulations that have weakened management. Subsistence and artisanal harvests of sandfish and hairy blackfish have increased with limited control, creating an avenue for illegal trade of the two species through exports as personal consignments.

The people of Palau, especially those from the eight States that allowed harvesting of sea cucumbers, have received the highest income from their sea cucumber resources at over USD 1.3 million. However, the prices received by fishers for two of their main products (hairy greyfish at USD 0.04 piece^{-1} and brown sandfish at USD 0.33 piece^{-1}) were too low, resulting in lost income. More income could have been realised had the price been set a little higher. The new sea cucumber harvesting strategy trialled in 2011, which prescribed the harvesting of two non-protected species from one State (Ngardmau), and 100% coverage of the landed catches, was a step in the right direction. Valuable information generated from the trial was useful in assessing the economic value and the potential lost income from the fishery.

The lack of a national sea cucumber fishery management plan with associated measures and monitoring mechanisms has been a challenge. As harvesting spreads to other States, it becomes difficult to effectively monitor activities. As an example, the reported total export value for the recent open season was lower than the landed value. Accurate species-disaggregated export information and a catch and export data verification system would have helped prevent under-reporting. To allow transparency in monitoring of catches and exports, the export license must be separated from the processing license so that each license has separate enforceable conditions on the operators. Finalising the improved plan and implementing the measures in the plan are the first steps to improved product pricing.

The licensing system for exporters buying, processing and exporting sea cucumber is not transparent and therefore does not provide an effective mechanism for monitoring fishing and exporting activities. In addition, the five licensed beche-de-mer exporters were too many, and it was unclear how much was charged for the license fees and what the conditions of the licenses were. An improved licensing system should provide a transparent mechanism for effectively monitoring fishing activities and the movement of products within the country.

The use of aquaculture and sea ranching as a disguise for wild stock harvesting is a concern for Palau. The export of over 27 tonnes of wild-caught beche-de-mer between December 2009 and May 2011 by a private company permitted to conduct aquaculture research is an example of this. The value of this illegal production is known and it could be the cause of a considerable loss for fishers and the country as a whole. Aquaculture is a new technology, and while proper studies are being conducted, some traders are using the new knowledge to obtain a license to harvest wild sea cucumbers (Pakoa et al. 2012). The grow-out and ranching of sea cucumber is still in the research phase and yet to produce a successful result. Leaders and decision makers in Palau are advised to be cautious and to seek expertise advice (from SPC or independant advice) to avoid the possibility of falling into such a scam.

Information generated by these surveys indicates that sea cucumber species diversity was intact, but that the abundance of some species in Ngatpang, Ngarchelong and Ngardmau was negatively impacted by recent fishing events. Sandfish and hairy greyfish stocks were more impacted in Ngatpang and Ngarchelong because of the relatively smaller stock sizes in the two areas. In Ngardmau, hairy greyfish stocks were more important, and although they were impacted in fished areas, sufficient breeding population is held at Ngermasch MPA to support the recovery of the resource. Both Ngarchelong and Ngatpang experienced significant drops in the population of hairy greyfish — by 87% and 97%, respectively. Stocks will need to be

better managed if they are to remain sustainable. The unequal distribution and abundance of species across habitats and sites requires specific surveys in each State to yield a more realistic harvestable quota.

Palau made the right decision in reinstating the ban in January 2012 and calling for an improved sea cucumber management system. A draft sea cucumber fisheries management plan developed by SPC and BMR has been submitted to Palau for consultation. Efforts must be made to finalise the plan and its implementation.

6. Recommendations for improved management

Below are recommended measures and actions to effectively control: sea cucumber fisheries in Palau; fishing activities; and the buying, processing and exporting of sea cucumbers. In addition, recommendations are provided on improving the value of products and ensuring the sustainability of the resource.

1. ***Permanent moratoria and short open season.*** Enforcing a permanent moratorium and short open season when stocks have recovered is proving to be the way forward for Palau to control the commercial sea cucumber fishery and ensure optimum return from the resources. The harvesting strategy trialled in 2011 has proven to work but improvements via a national sea cucumber management arrangement are required for the strategy to be applied more effectively in the country.
2. ***Sea cucumbers are lucrative commodities in Palau.*** Sea cucumber harvested in 48 days of fishing in 2011 landed 51,573 buckets of raw sea cucumbers at a total quantity of 1,160 tonnes and generated over USD 1.3 million in direct income to the people of the 8 States of Palau. But the income from these resources are seriously underestimated as a result of (a) inaccurate reporting of catch from other States and (b) harvesting and exporting of some 27 tonnes of beche-de-mer prior to official open season in 2011. Effort must be made to develop an improved licensing system and stricter monitoring mechanism to effectively control supply and price.
3. ***Unauthorised wild stock harvest and export.*** A large quantity of beche-de-mer (around 27 t) was exported out of Palau as cultured beche-de-mer. Sea cucumber harvesting, processing and exporting went on from December 2009 to May 2011. A company licensed in 2009 to undertake sea cucumber farming was harvesting wild sea cucumbers during the period. It is unclear if these catches were purchased from local fishers or freely harvested and it is unknown if the company operated through an exporter license. Some of the products exported — black teatfish, surf redfish, hairy blackfish, prickly redfish, sandfish and white teatfish — were banned from commercial exports. Strict measures should be put in place to prevent this from happening again in future.
4. ***Aquaculture and sea ranching of sea cucumbers.*** Investors interested in breeding and sea ranching of sea cucumbers should seek advice from the BMR and apply for an aquaculture license to operate a hatchery and farm. As part of the licensing criteria, strict conditions should be established to evaluate applicants and monitor activities of operators. BMR should liaise with SPC for assistance to develop the licensing system and procedures.
5. ***Aquacultured sea cucumber products.*** As part of recommendation 4, cultured sea cucumbers should be accompanied by a certification issued by an independent body verifying the farm, the farmer responsible, farming sites, and livestock information such as species, sizes, weights and farming treatment and product quality and price. Size limit regulations should apply to all sea cucumbers, including those that are cultured. The procedure should ensure transparency in sea cucumber mariculture development.
6. ***Beche-de-mer export license and sea cucumber processing license.*** The existing licensing system should be reviewed and split into two licenses: one for exporting beche-de-mer and the other for processing products. Each of the licenses should be accompanied by specific conditions to ensure efficient monitoring and compliance, and to allow collection of reliable data at landings points, from processors and from export operators.
7. ***Localisation of the sea cucumber industry.*** The participation of local Palauan citizens in sea cucumber export businesses must be encouraged. Efforts must be made to encourage locally owned businesses (100% Palauan-owned or majority Palauan-owned partnerships) over joint venture arrangements where foreign partners are majority owners. Relevant authorities should work together to assess opportunities to fully localise the beche-de-mer industry in Palau. One method that can be considered is to restrict the ownership of processing licenses to resident Palauan nationals.

8. ***Monitoring and compliance.*** The 100% landing coverage undertaken in 2011 at Ngardmau State was effective to some extent; however, widespread fishing in other States and transhipment of catches to Ngardmau has been the challenge. Efficient monitoring should be implemented by States as part of the conditions of licenses issued to operators, and this should include requiring shipment certificates, landing logsheets, and monthly processor logsheets. The cost of monitoring and compliance should be billed to operators.
9. ***National sea cucumber fisheries management plan.*** The draft national sea cucumber fishery management plan for Palau, developed by SPC and BMR, contains measures to improve the sea cucumber fishery. The plan should be finalised and necessary measures developed into regulations ready for implementation in future open seasons.
10. ***Product quality and packaging.*** Harvest and sale of wet sea cucumbers to processors is recommended for Palau to maintain production of good-quality beche-de-mer. Other forms of product packaging need to be assessed, such as vacuum packs, packs with a set number of pieces, and standardised bag weights (10 kg for example).
11. ***Product prices must be improved.*** Fishers in Palau earned one of their highest overall annual incomes from sea cucumbers harvest in 2011. However, the buying prices used were generally low. The price increase of 375% for hairy greyfish at the end of the season (from USD 12.00 to USD 46.00 per bucket) indicates that it is time to set lower price limits for these products. Fishers in Palau have been denied an additional USD 770,677 because of the low prices for hairy greyfish and brown sandfish (USD 0.04 $piece^{-1}$ and USD 0.33 $piece^{-1}$ respectively). A higher purchase price per piece by species is recommended in future harvests.
12. ***IUCN Red Listing.*** Nine species of sea cucumber — golden sandfish, sandfish, black teatfish, curryfish, hairy blackfish, prickly redfish, surf redfish, deepwater redfish and white teatfish — are listed under the IUCN Red List of threatened and endangered species. These species are currently banned from commercial exports and need to be properly assessed first before deciding whether they can be harvested. These species are threatened and should continue to be protected in Palau; commercial harvest of these species can only be permitted when stocks are healthy.
13. ***Community-based management.*** Management of coastal fisheries resources by State Governments in Palau has been effective in controlling fishing activities. State-managed marine protected areas as in Ngardmau have been effective in preserving the stock of hairy greyfish; management of these no-take areas should continue to be maintained to protect fragile stocks. Other States that do not have MPAs for sea cucumbers should make an effort to establish such areas in the near future.
14. ***Resource assessment surveys.*** Assessment protocols for sea cucumbers should be standardised to the protocols used by SPC surveys which have so far covered six states. BMR and the Palau International Coral Reef Center should continue to use the improved assessment methods to gather resource data from other States. BMR should also make use of the Reef Fisheries Integrated Database installed by SPC to facilitate data flow to SPC headquarters in Noumea for back-up and safekeeping. Harvestable quotas should be set by species and by State, and these quotas should be developed before an open season starts.
15. ***Local sale and exports for personal consumption.*** Considerable quantities of sea cucumbers have been produced to supply the local market and as exports for personal use. While the BMR have been collecting information on market landing and exports at the airport, these data are not being analysed and used effectively. To improve gathering of landing and export information, shops selling sea cucumbers should be licensed and required to submit their purchase and selling information as part of the licensing condition. Exportation of raw sea cucumber meat for personal consumption is likely to be avenue where illegal exporting of dried beche-de-mer. BMR should consider allocating a limited quota for raw sea cucumbers per travelling passenger. Dried beche-de-mer is not consumed by Palauans and should not be permitted to be exported for personal consumption.

16. ***Data management and database.*** Current catch data have not been well managed. BMR should seek support from SPC to set up necessary databases for recording sea cucumber harvests and exports. The database should be used for entering landings and shipment data, product types, export inspection data, and export permit information.

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Appendix 1.

Reef and lagoon habitat area by States of Palau

State	Habitat	Area (m^2)	Area (ha)
Aimeliik	Deep lagoon	45,204,253	4,520
Aimeliik	Reef flat	19,152,070	1,915
Aimeliik	Shallow terrace	15,190,642	1,519
Aimeliik	Shallow terrace with constructions	6,836,906	684
Aimeliik	Forereef	1,980,322	198
Aimeliik	Deep terrace	269,312	27
Aimeliik	Channel	244,600	24
Airai	Deep lagoon	95,957,572	9,596
Airai	Reef flat	27,795,939	2,780
Airai	Shallow terrace	6,400,017	640
Airai	Deep terrace	4,927,657	493
Airai	Forereef	4,403,188	440
Airai	Channel	3,089,588	309
Airai	Diffuse fringing reef	2,781,285	278
Airai	Subtidal reef flat	2,441,674	244
Airai	Enclosed lagoon or basin	1,320,300	132
Airai	Pass	195,300	20
Airai	Shallow terrace with constructions	8,021	1
Angaur	Forereef	3,699,000	370
Angaur	Reef flat	858,600	86
Hatobohei	Deep lagoon	75,276,000	7,528
Hatobohei	Reef flat	62,217,000	6,222
Hatobohei	Inner slope	16,927,200	1,693
Hatobohei	Forereef	9,250,200	925
Hatobohei	Pass	5,413,500	541
Hatobohei	Enclosed lagoon or basin	2,578,500	258
Hatobohei	Pass reef flat	1,344,600	134
Hatobohei	Lagoon pinnacle	698,400	70
Kayangel	Deep lagoon	160,327,800	16,033
Kayangel	Subtidal reef flat	88,864,200	8,886
Kayangel	Inner slope	74,709,900	7,471
Kayangel	Forereef	29,656,800	2,966
Kayangel	Reef flat	18,380,700	1,838

Appendix 1. *(cont.)*

State	Habitat	Area (m^2)	Area (ha)
Kayangel	Shallow lagoon	6,947,100	695
Kayangel	Shallow terrace	6,664,500	666
Kayangel	Enclosed lagoon or basin	4,490,100	449
Kayangel	Pass	1,895,400	190
Kayangel	Lagoon pinnacle	340,200	34
Koror	Deep lagoon	520,541,966	52,054
Koror	Reef flat	99,085,290	9,909
Koror	Shallow terrace	78,437,388	7,844
Koror	Deep terrace	67,399,168	6,740
Koror	Forereef	17,211,070	1,721
Koror	Subtidal reef flat	15,237,000	1,524
Koror	Channel	4,508,612	451
Koror	Pass	3,640,500	364
Koror	Enclosed basin	538,200	54
Koror	Enclosed lagoon or basin	413,100	41
Koror	Forereef or terrace	32,400	3
Melekeok	Reef flat	4,401,801	440
Melekeok	Shallow terrace	1,538,915	154
Melekeok	Diffuse fringing reef	1,092,725	109
Melekeok	Forereef	1,079,634	108
Melekeok	Subtidal reef flat	830,700	83
Melekeok	Pass	486,606	49
Ngaeaard	Deep lagoon	30,796,020	3,080
Ngaeaard	Reef flat	18,415,971	1,842
Ngaeaard	Reticulated fringing reef	14,803,200	1,480
Ngaeaard	Shallow terrace	10,496,559	1,050
Ngaeaard	Shallow terrace with constructions	6,352,641	635
Ngaeaard	Forereef	5,745,131	575
Ngaeaard	Diffuse fringing reef	3,007,543	301
Ngaeaard	Enclosed lagoon or basin	1,106,100	111
Ngaeaard	Pass	455,825	46
Ngaeaard	Enclosed basin	154,786	15
Ngaeaard	Channel	27,900	3
Ngarchelong	Deep lagoon	296,441,498	29,644
Ngarchelong	Shallow terrace	68,762,427	6,876
Ngarchelong	Reef flat	60,440,303	6,044

Appendix 1. *(cont.)*

State	Habitat	Area (m^2)	Area (ha)
Ngarchelong	Forereef	39,585,090	3,959
Ngarchelong	Shallow terrace with constructions	26,343,278	2,634
Ngarchelong	Subtidal reef flat	20,392,200	2,039
Ngarchelong	Deep terrace	9,433,800	943
Ngarchelong	Diffuse fringing	9,086,011	909
Ngarchelong	Enclosed basin	3,298,031	330
Ngarchelong	Pass	2,593,800	259
Ngarchelong	Channel	17,100	2
Ngarchelong	Enclosed lagoon or basin	14,400	1
Ngardmau	Reef flat	19,938,253	1,994
Ngardmau	Deep lagoon	19,453,844	1,945
Ngardmau	Shallow terrace	3,972,551	397
Ngardmau	Forereef	2,430,726	243
Ngardmau	Subtidal reef flat	234,000	23
Ngardmau	Channel	48,600	5
Ngardmau	Pass	25,134	3
Ngardmau	Enclosed lagoon or basin	11,700	1
Ngatpang	Deep lagoon	11,610,588	1,161
Ngatpang	Reef flat	6,087,014	609
Ngatpang	Shallow terrace	5,436,341	544
Ngatpang	Aquatic land features	4,000,500	400
Ngatpang	Forereef	930,206	93
Ngchesar	Deep lagoon	16,946,108	1,695
Ngchesar	Reef flat	12,237,615	1,224
Ngchesar	Forereef	2,760,256	276
Ngchesar	Diffuse fringing reef	932,046	93
Ngchesar	Shallow terrace	844,463	84
Ngchesar	Subtidal reef flat	758,748	76
Ngchesar	Pass	434,348	43
Ngchesar	Enclosed basin	33,300	3
Ngeremlengui	Deep lagoon	18,496,391	1,850
Ngeremlengui	Reef flat	15,576,893	1,558
Ngeremlengui	Shallow terrace	8,494,724	849
Ngeremlengui	Forereef	2,763,625	276
Ngeremlengui	Pass	1,082,700	108
Ngiwal	Reef flat	2,147,163	215

Appendix 1. *(cont.)*

State	Habitat	Area (m^2)	Area (ha)
Ngiwal	Shallow terrace	1,962,457	196
Ngiwal	Forereef	1,031,969	103
Ngiwal	Diffuse fringing reef	1,018,609	102
Ngiwal	Pass	110,379	11
Peleliu	Shallow terrace	37,242,065	3,724
Peleliu	Reef flat	15,332,306	1,533
Peleliu	Forereef	7,792,549	779
Peleliu	Deep terrace	7,088,251	709
Peleliu	Deep lagoon	3,538,982	354
Peleliu	Land on reef	3,409,200	341
Peleliu	Drowned bank	2,555,100	256
Peleliu	Diffuse fringing reef	595,800	60
Peleliu	Channel	579,600	58
Sonosorol	Reef flat	4,166,100	417
Sonosorol	Forereef	3,699,000	370

Appendix 2.

Standard conversion ratio for wet and dry sea cucumber species

Common name	Unprocessed weight 1 piece (g)	Semi-processed weight (gutted/salted)	Dried weight (beche-de-mer)
Amberfish	3,500	0.5	0.05
Black teatfish	2,400	0.5	0.10
Blackfish	500	0.5	0.10
Brown curryfish	650	0.5	0.04
Brown sandfish	1,000	0.5	0.04
Chalkfish	750	0.5	0.06
Curryfish	2,100	0.5	0.04
Deepwater blackfish	400	0.5	0.12
Elephant trunkfish	2,000	0.5	0.13
Flowerfish	1,000	0.5	0.04
Golden sandfish	1,400	0.5	0.08
Greenfish	300	0.5	0.03
Lollyfish	300	0.5	0.05
Peanutfish	100	0.5	0.04
Pinkfish	300	0.5	0.04
Prickly redfish	3,500	0.5	0.07
Red snakefish	300	0.5	0.04
Sandfish	750	0.5	0.05
Snakefish	300	0.5	0.04
Stonefish	650	0.5	0.05
Surf redfish	850	0.5	0.06
Tigerfish	1,000	0.5	0.04
White teatfish	2,500	0.5	0.09

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